for Information Technology Companies

MEMORIES WORLDWIDE

Dataquest's Memories Worldwide program provides quantitative and qualitative market information and analysis vital to the marketing and procurement efforts of both semiconductor memory manufacturers and electronic equipment producers.

Partnering to Provide Solutions

As a client, you have direct access to experienced analysts who can provide insights and advice on market dynamics, industry events, and competitive issues.

Inquiry Support

Personalized inquiry support is a primary component of your Dataquest annual subscription program.

Through an interactive approach, Dataquest analysts work with you to tailor the program to meet the unique needs of your organization.

Electronic Delivery

Dataquest offers a variety of tools, known collectively as *Dataquest On The Desktop*, that have the power to deliver Dataquest insights directly to you, whether you are on the road or in the office.

Information Resource Centers

Clients have unlimited access to Dataquest's extensive print and online resource libraries worldwide.

Optional Custom Research

Should your needs exceed the scope of this program, Dataquest offers extensive primary research and consulting services.

Market Coverage

Dataquest's market statistics and growth projections have been indispensable tools for product managers and strategic planners for more than two decades.

This program provides a cross-regional perspective of the forces and issues affecting global memory markets.

Market Statistics

Dataquest provides market estimates and forecasts by density for DRAMs, SRAMs, EPROMs, EEPROMs, flash memories, and ROMs.

Statistics include:

- Units shipped
- Average selling price
- Factory revenue
- Trillions of bits
- Price per bit

Product Coverage

Dataquest covers the following memory product segments:

- DRAMs
- SRAMs
- VRAMs
- EPROMs
- EEPROMs
- Flash memories
- ROMs
- Other MOS memories

Dataquest

Worldwide Semiconductor Group

WHAT YOU WILL RECEIVE AS A CLIENT

MEMORIES WORLDWIDE

Market Analysis

Market Trends Report: A comprehensive report analyzing key factors driving the growth of major segments of the MOS memory market. The report includes market share estimates of major players and five-year forecasts for each product segment.

Published in the Third Quarter

Worldwide MOS Memory Forecast: Five-year forecasts by density for total MOS memory, DRAMs, SRAMs, EPROMs, EEPROMs, flash memories, ROMs, and other MOS memories. Forecasts are provided for total revenue, units, average selling prices, trillions of bits, and price per bit. Regional forecasts are provided for the summary categories (such as DRAM).

Published in the Second and Fourth Quarters

Worldwide MOS Memory Market Share: Worldwide and regional market share by company for total MOS memory, DRAMs, SRAMs, nonvolatile memories, EPROMs, EEPROMs, flash memories, ROMs, and other MOS memories.

Published in the First Quarter

Worldwide MOS Memory Unit Shipments—Annual Summary: Quarterly shipments by company for DRAMs, fast SRAMs, EPROMs, EEPROMs, flash memories, and ROMs.

Published in the Second Quarter

Worldwide Semiconductor Consumption Forecast: Five-year revenue forecasts for the global semiconductor market by region: Asia/Pacific, North America, Japan, and Europe.

Published in the Second and Fourth Quarters

Perspectives

Timely analysis and commentary published in an easy-to-read newsletter format. These reports chart industry events, evolving technologies, changing user requirements, emerging standards, and new products.

Six Issues per Year

Market Analysis—Quarterly Memory Shipments: Each report provides an update on unit demand and pricing trends for leading memory products.

Published Quarterly

Dataquest Predicts—Memory Forecast: In these hard-hitting reports, Dataquest takes a bold, opinionated, often controversial look at key issues, products, and trends shaping worldwide memory markets. The reports make predictions about why, when, and how events will happen.

Published in the Second and Fourth Quarters

Dataquest Alerts

News and analysis, delivered by fax, giving a concise overview of significant events or announcements in the industry and markets.

Published on an Event-Driven Basis

The DQ Monday Report

Weekly news and commentary on semiconductor industry events and issues with a monthly snapshot of semiconductor pricing for 25 key semiconductors from six regions. Clients may wish to subscribe to this valuable newsletter for a broad view of this dynamic industry.

Weekly via Internet

Conferences

Dataquest hosts the industry's preeminent semiconductor conferences in the United States, Europe, Japan, Taiwan, and Korea. For more information contact Dataquest's Conference Desk or your local Dataquest office. Clients receive a special discount on conference fees.

Dataquest

a company of The Dun & Bradstreet Corporation

Corporate Headquarters
1290 Ridder Park Drive
San Jose, CA 95131-2398
United States
Phone: (1) 408-437-8000
Fax (1) 408-437-0292

Boston Area
550 Cochituate Road
Framingham, MA 01701-9324
United States
Phone: (1) 508-370-5555
Fax (1) 508-370-6262

London Area
Holmers Farm Way
High Wycombe, Buckinghamshire
HP12 4XH
United Kingdom
Phone: (44) 1494-422722
Fax (44) 1494-422742

Munich
Kronstadter Strasse 9
81677 Munich 80
Germany
Phone: (49) 89-930-9090
Fax (49) 89-930-3277

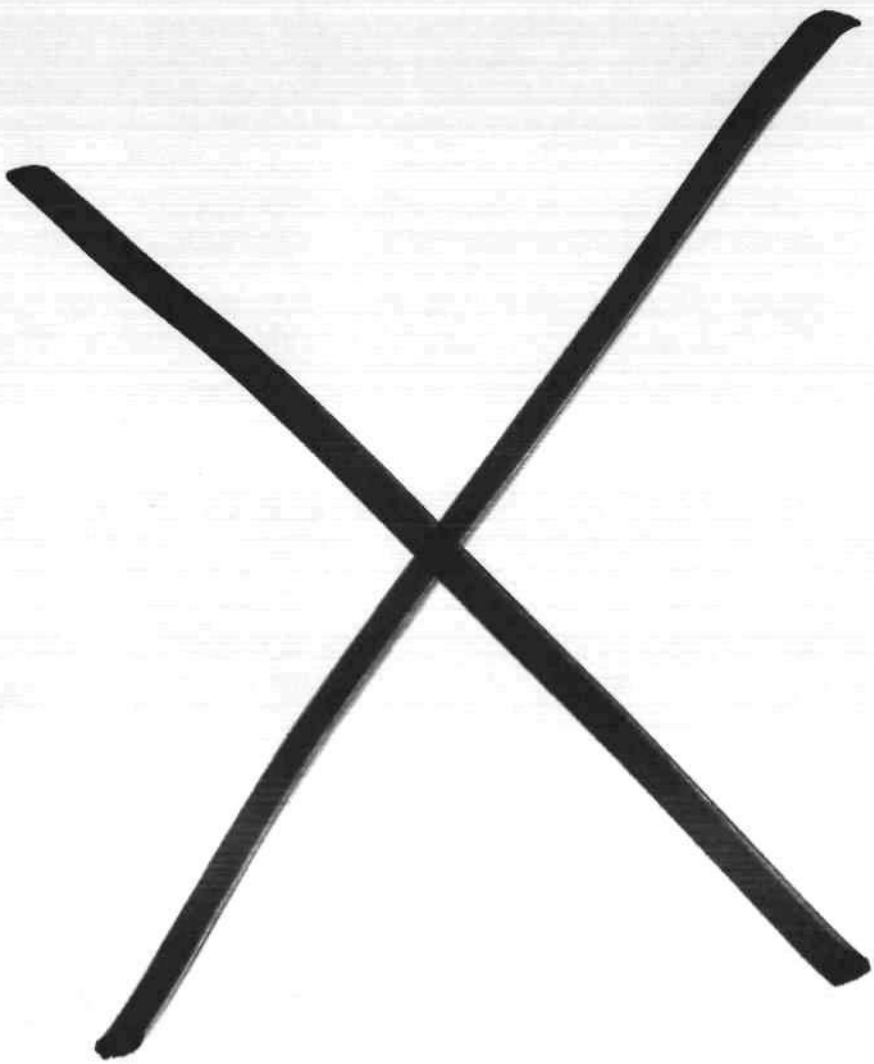
Paris
Tour Franklin, Cedex 11
94042 La Défense, Paris
France
Phone: (33) 1-41-25-18-00
Fax (33) 1-41-25-18-18

Tokyo
Shinkawa Sanko Building
6th Floor
1-3-17, Shinkawa
Chuo-ku, Tokyo 104
Japan
Phone: (81) 3-5566-0411
Fax (81) 3-5566-0425

Taiwan
3/F, No. 87 Sung Chiang Road
Taipei
Taiwan, R.O.C.
Phone: (886) 2-509-5390
Fax (886) 2-509-5660

Korea
Trade Tower, Suite 3605
159 Samsung-dong
Kangnam-gu, Seoul 135-729
Korea
Phone: (82) 2-551-1331
Fax (82) 2-551-1330

MKTG 9/94 (AKL 168)



Dataquest

Dataquest ALERT

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

"The 1995-1996 DRAM Fab Outlook--Can PCs Absorb That Much DRAM Capacity?"

Dataquest's Semiconductor Group held the above-entitled telebriefing on March 23, 1995. This *Dataquest Alert* presents the key figures and opening statement from the telebriefing.

Introduction

This is Jim Handy of Dataquest's Memories Worldwide service. First, let me introduce the speakers, then I'll give an overview of the subject and structure of the telebriefing. In the room here at Dataquest we have Clark Fuhs, Näder Pakdaman, and Calvin Chang of the Semiconductor Equipment, Manufacturing, and Materials Worldwide service (SEMM); Mark Giudici and Scott Hudson from the Semiconductor Procurement Worldwide service; and Mario Morales from our Research Operations Group. Ron Bohn and I represent the Memories Worldwide service.

What is this telebriefing about?

- Dataquest performs an analysis of DRAM supply and demand, and publishes the result in a report updated quarterly.
- There has been a big increase in capital spending for semiconductor processing equipment. Despite all the new equipment coming online, the DRAM shortage will persist through 1996.
- This teleconference will describe the reasons that the DRAM shortage will continue, despite the installation of so much semiconductor processing equipment.

First, Clark Fuhs will speak about semiconductor wafer fabrication plant capacity, then I will return with a statement about the DRAM market. After these statements, we will open the phones to questions from the participants.

DRAM Supply-Side

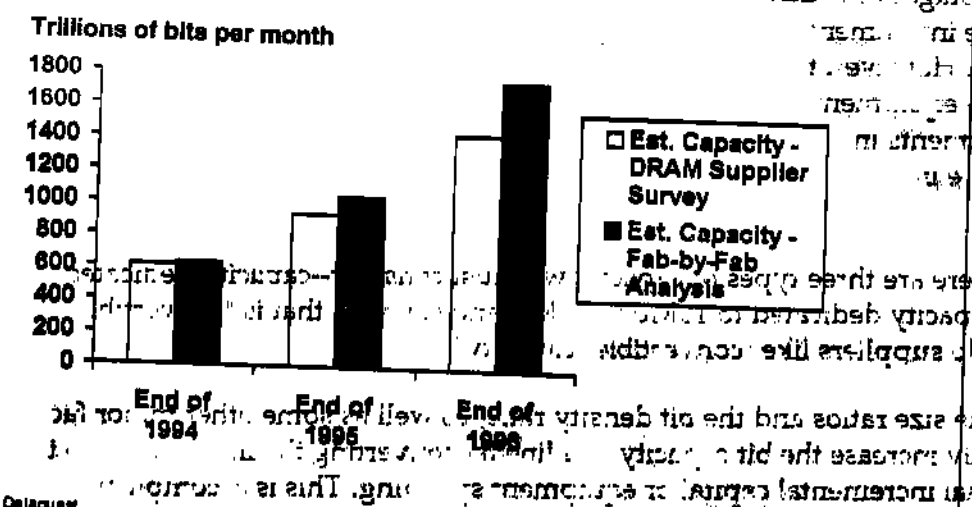
I am Clark Fuhs, a senior analyst from the SEMM group... We track most aspects of the actual manufacturing of semiconductors worldwide... Today we will briefly review the dynamic arena of DRAM capacity and supply.

The key source for our analysis today is a report Dataquest has just issued on 4Mb and 16Mb DRAM supply and demand. We entitled it "DRAM Supply and Demand Report."

Supply-Side Analytical Methodologies

There are two supply-side methodologies, and their differences are outlined in Figure 1. Shown are three snapshots in time--at the ends of 1994, 1995, and 1996. The left bar in each year represents results of a survey of DRAM suppliers, which will be referred to by Jim Handy later... The right bar represents an estimate based on a fab-by-fab analysis of capacity and committed plans.

Figure 1: Estimated Fab Monthly Run Rates for 4 Mbit and 16 Mbit DRAMs



The capacity estimate through the fab analysis includes the following assumptions: die size estimates, the effects of shrinks, and a gradual yield increase from today through the end of 1996 factored in on a company-by-company basis.

We have not included any capacity associated with unannounced capital spending increases or commitments over the next two years such as the recently announced acceleration of NEC's new U.S. facility--nor 6- to 8-inch wafer conversions.

As seen in Figure 1, these two methodologies have produced results within 3 percent of each other for the year just completed. But as we go into the future, the figure shows an increasing divergence. The conclusion here is that suppliers are not optimistic in the near term regarding their ability to increase yields on the 1x16 configuration for the 16Mb DRAM, and their outlook is conservatively hedged.

This leads to a question we get fairly often: What is the capacity of the market in 4Mb "equivalent units"? Unfortunately, from a fab perspective, this is not a very useful way to view capacity—and is a metric that we at Dataquest view may not provide an adequate picture of bit capacity. Why not? In a fab, capital spending and equipment purchases are driven by the requirement for wafers, or better yet, square inches of silicon.

Three Stages of Capital Spending

Let me highlight here the dynamics of how capital spending and bit supply are related. There are three identifiable parts to this cycle, and as you will see, we are in the later stages of part 2.

In the early to middle stages of a unit ramp in a specific DRAM density generation, square-inch requirements and equipment purchases are generally driven by bit demand. This is part 1 of the investment cycle, and it occurred in 1993 for the 4Mb generation.

In the later stages of ramp, as the next density generation starts to become available, we enter part 2 of the investment cycle. During this state, capital investment is still primarily driven by bit demand. However, the style of investment changes to install "convertible" capacity--in today's case equipment earmarked for 16Mb DRAM capacity, but initially running 4Mb parts. Most investments in 1994 into the present have been of this nature. The later stages of part 2, which we are in today, will also tend to include dedicated capacity for the next density generation.

So today there are three types of capacity we must consider--capacity dedicated to 4Mb DRAMs, capacity dedicated to 16Mb DRAMs, and capacity that is "convertible" between the two. Why do suppliers like "convertible" capacity?

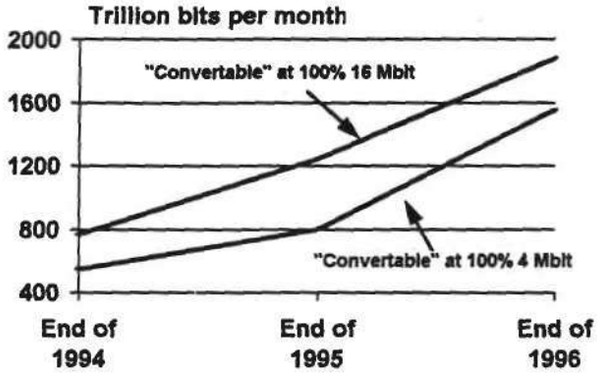
Based on die size ratios and the bit density ratio, as well as some other minor factors, a supplier can generally increase the bit capacity of a line by converting the line from 4Mb to 16Mb parts, with minimal incremental capital or equipment spending. This is accomplished because the bits per square inch are increased on the order of two or three times, meaning a supplier can double or triple the bit capacity of a line by conversion. Thus part 3 of the investment cycle, typically lasting two years, creates bit capacity primarily by conversion rather than new equipment purchases. Thus a "pause" in the equipment market ensues. When all the capacity is converted, we begin part 1 of the cycle all over again.

Industry's DRAM Capacity

Back to the original question: What is the DRAM capacity of the industry? The answer is--it depends. It depends on how the "convertible" capacity is employed. The most useful way to view capacity is by a "window" and this is shown in Figure 2, using a fab-by-fab analysis. What

I mean by "window" here is the area between the two lines that represent the possible capacity measured in terms of bits. Let's first relate this to Figure 1.

Figure 2: Monthly DRAM Bit Capacity "Window" for 4 Mbit and 16 Mbit



Source: Dataquest

At the end of 1994, Figure 1 shows that the monthly run rate of the industry was slightly more than 600 trillion bits. If all the "convertible" capacity were running 4Mb DRAMs at the end of 1994, the run rate would calculate to about 550 trillion bits per month, shown as the lower limit line in Figure 2. Likewise, if all of this convertible capacity were running 16Mb parts at today's yields, the capacity would calculate to slightly less than 800 trillion bits per month. Employing this methodology into the future, we have produced Figure 2 as a range of capacity over time.

I would like to emphasize that the width of the window increases in 1995 and shrinks in 1996. Because of the low yield and slow ramp issues of the 1x16 configuration part, suppliers are being forced to add more 4Mb capacity of a "convertible" nature today. This will increase the growth for the front-end equipment market during 1995 well beyond our current published forecast of 16 percent--probably not far away from 30 percent growth. Momentum factors will establish 1996 as a small growth year as well (originally we indicated a slight decline).

Our model indicates that the "pause" in the equipment market that we have been forecasting is unavoidable, however, because installing "convertible" capacity today by definition installs future "hidden" bit capacity and will likely cause a slight decline for wafer fab equipment in 1997. This conversion stage will also reduce the growth in the consumption of silicon in a like manner.

The trigger for the pause will be the availability and subsequent pull of the 1x16 configuration part into the end-use market. Until this happens, silicon square inch demand will continue to be driven by bit demand closely. The severity and length of the ultimate "pause" will be

determined by how long the current boom lasts, basically building pent-up bit supply as well as the demand for bits during the conversion stage.

Now I'd like to turn it back over to Jim Handy for a review of demand.

DRAM Demand-Side

This is Jim Handy. Today's DRAM market is phenomenal. There has been an undersupply for two-and-a-half years, and in our recent analysis, the February 1995 version of the quarterly "DRAM Supply and Demand Report," we have found little reason to expect the current shortage to ease through the end of the report's forecast window, the end of 1996.

4Mb DRAM prices have slowly risen since the third quarter of 1992, yet DRAM use in megabytes per PC has gone up.

DRAM Pricing Alert

In the face of a strengthening yen against the dollar, Japanese suppliers of DRAMs have been able to raise average selling prices measured in dollars to stabilize the yen value of their worldwide DRAM sales. By all appearances, this trend will continue through the end of next year.

Our current North American contract-volume DRAM price forecast calls for firm pricing. We are aware that some Japan-based DRAM suppliers right now are considering an increase in the contract pricing for DRAMs. Korean and North American DRAM suppliers are waiting in the wings to see what happens. Should these changes materialize during second-quarter price negotiations, we will make appropriate changes in our price forecast.

Let's go over some of the background causes of the current DRAM shortage:

- PC demand is strong and shows no signs of letting up.
- Japanese DRAM suppliers, which accounted for nearly 50 percent of worldwide sales, were slow to react to the market and didn't increase capital spending until the fourth quarter of 1993.
- PCs have increased their per-system consumption of DRAM despite these stable/rising prices both in response to the requirements of advanced software as well as to decreases in the prices of CPUs, chipsets, and other system components.
- The 16Mb DRAM has met with limited acceptance in the traditional x1 and x4 organizations. A new x16 organization is the product of preference, and is late to market, forcing an increase in the consumption of 4Mb DRAMs unlike that seen in any other DRAM generation.

The PC market has stayed in a strong growth phase for some time now. However, the cause of this strength has varied over time. Two years ago growth was fueled by a rebound in PC

shipments to the office. More recently, a big growth in home computer purchases including multimedia systems has driven the market. Now the business channel once again stands poised for important growth.

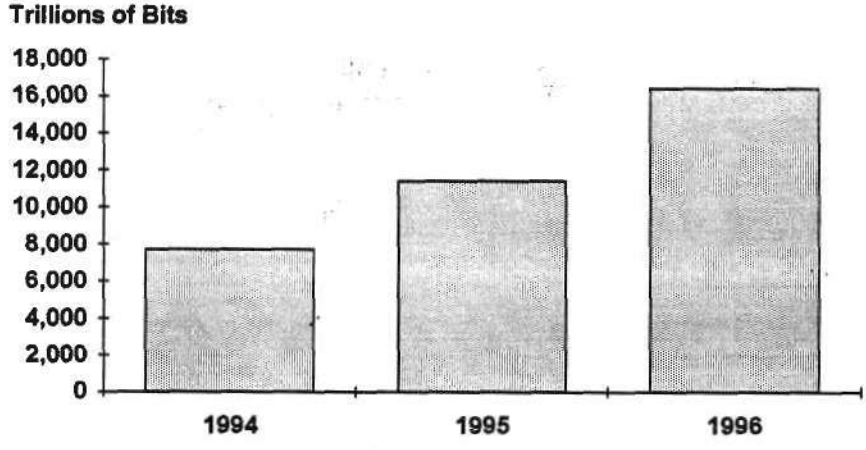
PC Forecast Revised Upward

We want to highlight today that Dataquest has just revised its worldwide PC unit-shipment forecast upward. Dataquest's PC shipment forecast calls for 57 million units to ship in 1995, and in excess of 65 million units in 1996. This means a strong 19 percent growth in worldwide PC unit shipments this year and equally impressive 18 percent growth for 1996.

Within each of these PCs we see another jump in the amount of DRAM consumed. The minimum DRAM size will increase from the 4MB per PC that shipped in 486-based PCs in 1994 up to 6MB when the 8MB Pentium minimum is averaged with the 4MB 486 this year.

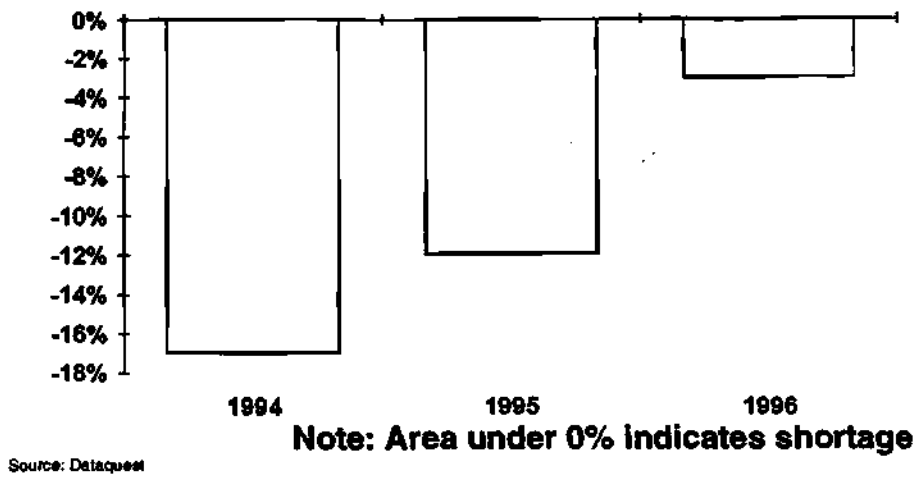
Now let's look at Figures 3 and 4. Figure 3 shows the annual bit demand of the total data processing market and other DRAM markets. We derive this number from our electronic equipment forecast, which includes PC and other data processing forecasts as well as forecasts for other DRAM applications such as printers, fax machines, video games, hard disk drives, and even digital set-top boxes. This is the demand side of our supply demand analysis, and is driven to a great extent by the health of the PC market.

Figure 3: DRAM Demand in Bits



Source: Dataquest

Figure 4: 1995-1996 DRAM Supply-Demand Scenario (Supply as % of Demand)



DRAM Shortage Will Continue

In Figure 4 we see the difference between the *supply* of DRAMs and the *demand* based on the electronic equipment production forecasts used to generate Figure 3. This undersupply is expressed in percentage of bits, where a number less than zero indicates an undersupply of bits shipped into the market.

As long as there exists an undersupply, DRAM prices will either hold or go up. Despite a recent increase in our estimates for 4Mb DRAM production in 1995, Dataquest expects the shortage to continue through 1996, mostly because of the late start of the 1Mx16 ramp-up. Although the shortage will lessen, from nearly 20 percent in 1994 to less than 5 percent in 1996, it will still be a shortage, and prices cannot be expected to fall dramatically.

So what about all that added capacity, and, more importantly, why do some forecasters predict DRAM price plunges while Dataquest holds that the undersupply will continue? This misunderstanding stems from a commonly held belief that all convertible capacity will immediately be put into volume production of 16Mb DRAMs. This alone would at least satisfy DRAM demand, if not overwhelm it. Instead, a large portion of the convertible capacity is still being used to produce 4Mb DRAMs.

This begs the question: "Why don't DRAM suppliers convert all convertible capacity quickly to 16Mb devices?" The following is our explanation.

PCs account for more than two-thirds of all DRAM consumption. There is a phenomenon called "granularity," which forces PCs to diverge from using traditional organizations of DRAMs of x1 and x4. Instead, today the great majority of 16Mb density DRAM demand is for

a 16-bit-wide organization. There are two reasons that the x16 version of the 16Mb DRAM is not available today in the volumes needed by the PC market:

- First: DRAM manufacturers waited to introduce the x16 version of the 16Mb DRAM until they had met reasonable production yields on the more traditionally accepted x1 and x4 versions.
- Second: Design, debug, and test of the x16 organization present challenges never before encountered by DRAM designers and manufacturers.

The result of this is that, despite the timely ramp-up of the 16Mb DRAM, the ramp-up of the 1Mx16 version is about 18 months behind the market. The need for this particular part has had to be filled by the 1Mx4 version of the 4Mb density, and four times as many of these parts are required to make up the difference.

The result is that, until the x16 organization of the 16Mb DRAM ramps into high-volume production, there will be a severe shortage, and an overwhelming consumption of 4Mb DRAMs to account for the difference.

We see strong price-ups in the spot market. However, this has not been the case in the contract market, mostly owing to the close business relationships most DRAM manufacturers try to maintain with their clients. Japanese DRAM manufacturers have pointed out to us that, while they have held the ASP for a 4Mb DRAM at 1,200 yen since mid-1992, they had every opportunity to raise prices. Their reluctance to raise the price to "what the market will bear" shows restraint in an effort to continue to satisfy their customers' needs. As I noted at the outset, we continue to carefully watch for any change in DRAM contract pricing, especially in North America.

Conclusions

In conclusion, although Dataquest has observed a very strong response to the current DRAM shortage in the form of plant expansions, we do not expect this new and existing capacity to be able to match demand through 1996. The result should be continued allocation, high spot-market prices, and the continuance of DRAM contract-volume prices to be keyed to a fixed yen value.

(This concluded the opening statement.)

Clark Fuhs, Näder Pakdaman, and Calvin Chang of the Semiconductor Equipment, Manufacturing, and Materials Worldwide service (SEMM)
Mark Giudici and Scott Hudson of the Semiconductor Procurement Worldwide service (SPSG)
Jim Handy and Ron Bohn of the Memories Worldwide service

Dataquest ALERT

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

The Worldwide DRAM Market--Two Weeks After the Kobe Quake

This Dataquest Alert assesses the worldwide DRAM supply-demand situation two weeks after the earthquake in Kobe, Japan. Every disaster with a potential impact on semiconductor supply, such as the 1989 Loma Prieta earthquake in California and the 1993 Sumitomo explosion, instantly jolt the DRAM spot market. The turbulent market stands on edge as Japan begins recovery from the devastating 7.2-magnitude earthquake of January 16, 1995.

Key Points

Dataquest wants to make these key points:

- The Kobe quake has caused no fundamental disruption of DRAM supply, although spot-market pricing for DRAMs quickly moved upward.
- As we said in a telebriefing on January 12, Dataquest expects DRAMs to remain a seller's market at least until mid-1995 and perhaps into the fourth quarter.
- Strong 1995 DRAM demand fueled by the strong market move to Pentium-class PCs serves as the basis for Dataquest's market outlook--not the recent quake.

The ultimate impact of the Kobe quake on contract-volume DRAM pricing remains uncertain. For *some* major buyers, however, earthquake-induced market uncertainty likely will dash already-limited bargaining power going into first-half 1995 negotiations.

DRAM Market Drivers

Worldwide unit shipments of PCs should achieve an impressive 16 percent growth rate this year, totaling 54 million units. Semiconductor capital spending surged during 1994. Even so, robust demand from the PC segment means a continuing shortage of most DRAMs until late 1995 or 1996.

PC shipments remain strong as of late January 1995, with little sign of a postholiday downturn. Dataquest expects more than 20 million Pentium-class PCs to ship worldwide during 1995. At

a minimum Pentium systems require 8MB of DRAM. By contrast, 486DX2 PCs--the high-volume runner during 1994--typically shipped with just 4MB of DRAM. This PC DRAM trend means a dramatic increase in megabytes of DRAM per PC. The growth in DRAM megabytes per system dramatically augments the worldwide impact of the PC market expansion.

The DRAM market also has become more complex in terms of suppliers' product offerings. Faster microprocessor speeds, wider data buses, and high-performance graphics are forcing DRAM manufacturers to make radical changes in their DRAM product portfolios. For suppliers, this 1995 scenario means some moderation of intense supplier-to-supplier competition. This also means more pricing power for suppliers in key DRAM segments.

DRAM Supply-Demand Outlook for February 1995

Table 1 shows Dataquest's estimate of worldwide DRAM supply-demand for the month of February 1995. A Dataquest report entitled "4Mb/16Mb DRAM Demand and Supply Forecast" serves as the basis for the table. (Dataquest will update this quarterly report during late February.)

Table 1

Estimated Worldwide Monthly DRAM Demand for February 1995

Configuration	Total Demand (Millions of Units)	Unmet Unit Demand (Expressed as a Percentage of Total Demand)
1Mbx4	58.2	10 percent
256Kx16	11.5	More than 20 percent
4Mbx4	12.3	10 percent
2Mbx8	3.7	More than 25 percent
1Mbx16	2.9	More than 50 percent

Source: Dataquest (January 1995)

This table highlights that DRAM buyers confronted a DRAM supply shortfall before the Kobe quake. As we said in recent telebriefings and written reports, the 1Mbx16 DRAM shortage should persist into 1996. By contrast, the 1Mbx4 shortage might become alleviated by year-end 1995.

The Quake's Impact on DRAM Pricing

The Kobe quake caused an upward blip in DRAM spot-market pricing. Although the fundamentals of DRAM supply-demand remain unchanged, most major buyers should expect some first-half 1995 reduction in negotiating power.

For example, Dataquest views the Texas Instruments' Kobe joint-venture plant as the most important DRAM manufacturing site in the affected area. A TI representative said that the Kobe plant will be requalified and fully operational during early February. Dataquest sees no

rational basis for expecting the current DRAM shortage to become even more severe. Regardless, some Japanese vendors have indicated that they expect the market to be a little tighter for the next two months.

For the time being, it appears that there has been an emotional response in DRAM prices to the Kobe earthquake. These increases quickly reached levels of nearly 10 percent on the U.S. spot market. Prices seem to be returning to lower levels. The DRAM spot-market decline, however, looks like it will be slower than the rise.

See DQ MONDAY dated January 30, 1995 for more DRAM pricing details.

DRAM Outlook

Following Dataquest's recent Dataquest Predicts--1995 and Beyond Conference in the Silicon Valley (January 25, 1995) several industry executives privately shared their 1995 DRAM outlook. Their perspective is that "sooner"--being early second-half 1995--or "later" the DRAM price-per-bit curve will dip downward.

Dataquest's DRAM supply-demand assessment indicates that suppliers will resist any downward break in DRAM pricing until late 1995. Purely on psychological factors the Kobe quake also signals the "later" scenario. Some suppliers have developed products strategies that should enable them to bypass the "commodity DRAM" pricing battles of past years. Even so, some semiconductor executives have already started to sleep uncomfortably.
By Ronald Bohn, Jim Handy, and Akira Minamikawa

Perspective

Memories Worldwide

Dataquest Predicts

DRAMs, Cache, and Flash Fuel Memory Market Growth

Abstract: *Dataquest provides five-year forecasts of market segments and overall analysis of the competitive landscape for the MOS memory industry, including DRAMs, cache RAMs, ROM, EPROM, EEPROM, and flash memory.*
By Ronald Bohn

Global Electronics Environment

Global pervasiveness of electronics means booming demand for key segments of the memory IC marketplace throughout the rest of this decade. Worldwide electronics equipment production totaled slightly less than $700 billion for 1994 and should break the $1 trillion barrier by the year 2000. Dataquest expects annual worldwide shipments of PCs to break the 100-million-unit barrier toward the end of the decade. The amount of memory—DRAMs and cache RAMs—in these boxes should continue to escalate dramatically. The semiconductor content—including semiconductor memories—in many electronic systems such as cellular phones, automobiles, and digital consumer electronics also should dramatically increase for the next five to 10 years.

Dataquest Predicts

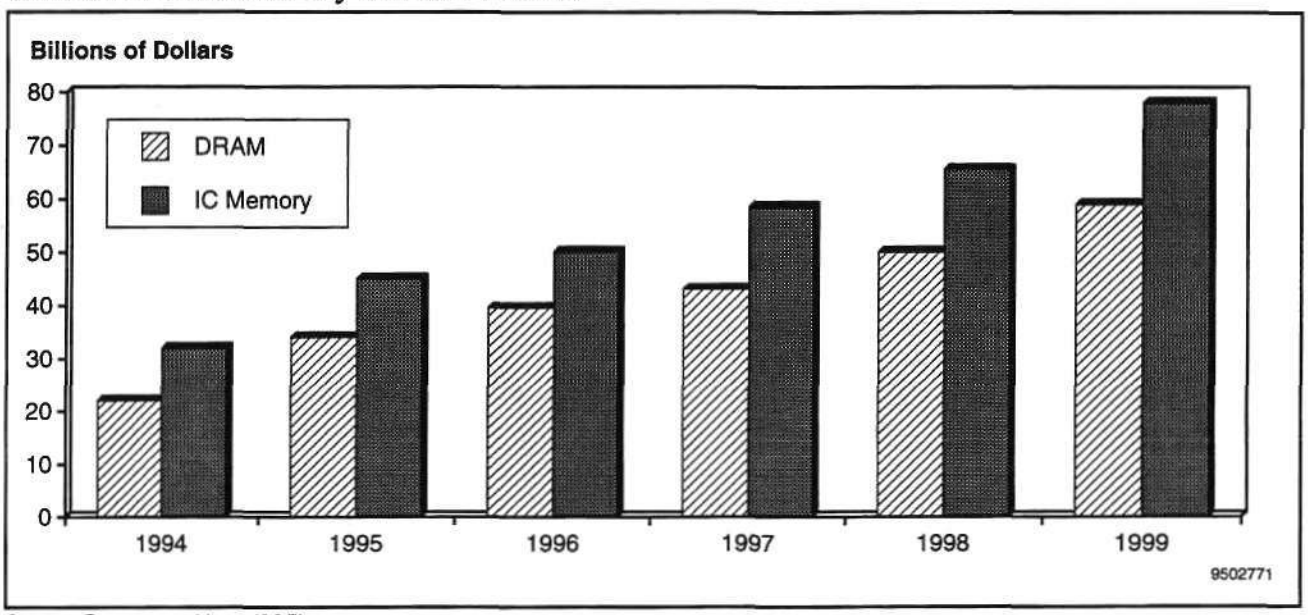
Worldwide MOS memory revenue should grow to $77 billion by 1999 (versus $32 billion during 1994). This marks a compound annual growth rate (CAGR) of nearly 20 percent for the 1994 to 1999 period. As indicated, Dataquest expects strong and uninterrupted growth in the PC and communications markets over the long term. Consequently, as shown in Figure 1, we foresee no downturn in the crucial DRAM segment.

Figure 1 also graphically illustrates the link between worldwide memory IC growth and DRAM growth.

Dataquest

Program: Memories Worldwide
Product Code: MMRY-WW-PD-9501
Publication Date: June 12, 1995
Filing: Perspective

Figure 1
DRAMs Drive Memory Market Growth



Source: Dataquest (June 1995)

Highlights

Forecast highlights include the following:

- Along with DRAM, flash and high-speed SRAM—cache memory—should be fast-growing segments for the long term.
- By contrast, the ROM market should grow slowly; this segment depends on the video game market that appears poised for a transition to CD-ROM-based technology.
- With the EPROM market declining slowly over time, EEPROM market revenue could equal or surpass that of the EPROM segment by 1997.

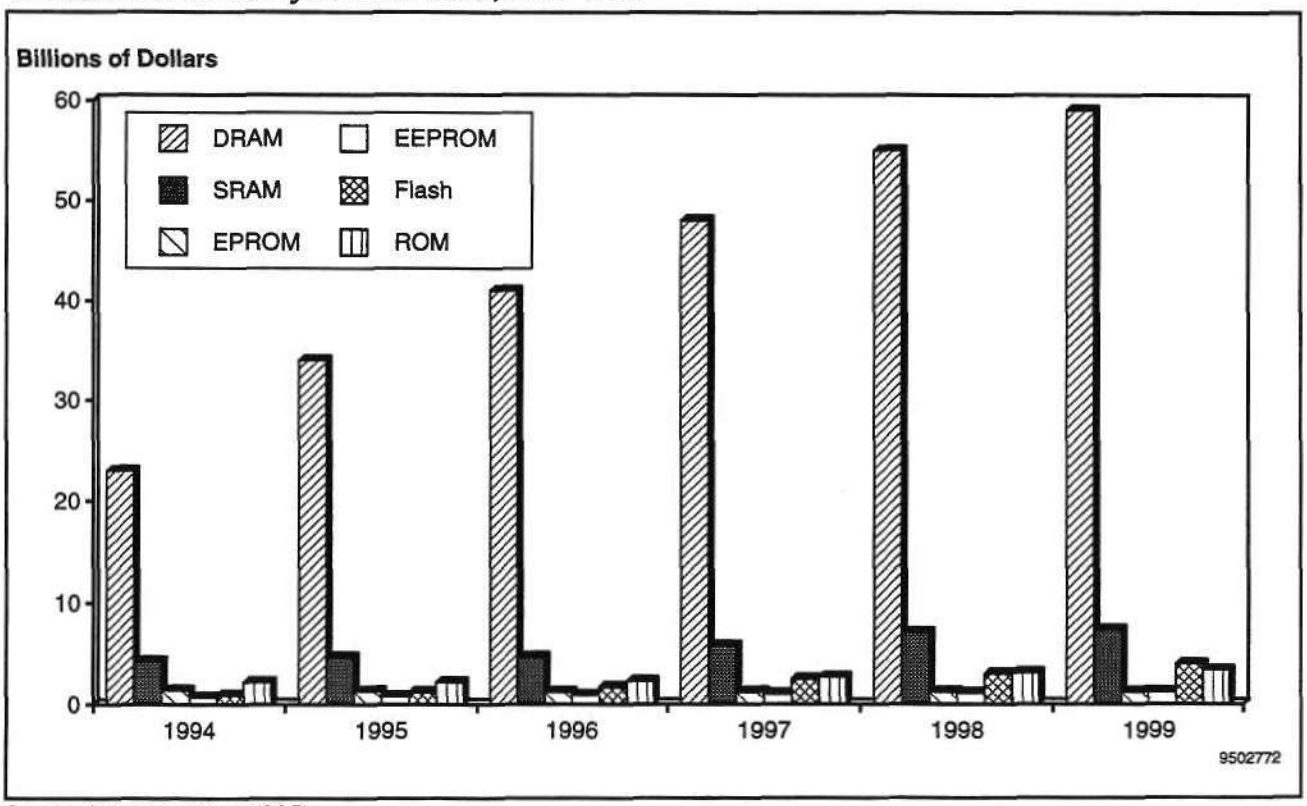
Near-Term Scenarios

Worldwide memory revenue should reach $45 billion for 1995, a 40 percent growth rate over 1994 (see Figure 2). DRAMs fuel memory market revenue and profit growth. DRAM revenue should hit $34 billion this year, a 50 percent growth rate over 1994. If DRAM suppliers can push the DRAM price-per-bit (PPB) curve upward during 1995 (versus 1994), the DRAM revenue outlook will become more robust.

Worldwide SRAM revenue should increase by 23 percent this year—reaching $5 billion—but the high-speed cache segments provide by far the largest portion of growth. The slow SRAM business remains in a near-recessionary state. Cache RAM will continue to drive SRAM revenue growth in the long term. Japan's consumer electronics market is a key user of slow SRAM, so a long-term rebound there would mean stronger SRAM market growth.

The newly emerging flash memory market should continue its growth cycle for both 1995—breaking the $1 billion level—and the long term (35 percent-plus CAGR for 1994 to 1999). At the time of the writing of this report,

Figure 2
Worldwide Memory IC Forecasts, 1994-1999



Source: Dataquest (June 1995)

Dataquest received reports that strong demand meant a firming up of 1Mb and 4Mb flash prices.

Nintendo has delayed consumer market shipments of its next-generation 64-bit video game until 1996. This means worldwide ROM revenue—which we project to increase by nearly 12 percent for 1995—faces a stiff challenge in terms of meeting this growth projection.

Another nonvolatile memory technology, EEPROM, should experience a healthy 21 percent growth this year. A host of industrial, handheld telecommunications, and consumer electronics applications fuels EEPROM market expansion. With the flash and EEPROM markets doing well, the EPROM market should experience a 10 percent drop in revenue each year for the next several years.

The result will be that EEPROM revenue should approach $1 billion by 1997, up from less than $600 million for 1994. EPROM revenue—which totaled $1.4 billion for 1994—should decline to slightly more than $1 billion for 1997.

Bullish DRAM Expectations

Dataquest has consistently noted in prior reports and telebriefings that DRAMs drive the MOS memory forecast and that PCs drive the DRAM forecast.

We base our bullish long-term outlook for the DRAM market on the expectation that worldwide PC shipments—which totaled less than 50 million units for 1994—will approach 100 million units for 1999. Dataquest's PC forecast calls for no cyclical downturn during the 1995 to 1999 period—nor does the DRAM forecast, as shown in Figures 1 and 2.

Inelastic DRAM Demand?

The near-term forecast calls for a relatively flat DRAM PPB curve. The forecast calls for a nondramatic increase in the worldwide price of 4Mb DRAM and some decline in the 16Mb DRAM price.

DRAM demand has been unyielding since 1993 and likely will remain so during the 1995 to 1996 period. This is great news for DRAM suppliers but is hard on buyers. This scenario means that DRAM demand likely will not decline sharply in the face of an increase in DRAM price. As noted, if DRAM suppliers can push up the DRAM PPB price curve this year—and if demand remains strong—the 1995 DRAM revenue outlook will become even brighter.

Cache SRAMs: Another Bullish Scenario

As with DRAMs, Dataquest expects an aggressive pace of growth in the cache RAM marketplace.

64-Bit PC Bus Drives Cache RAM Market

Intel's 64-bit "Pentium push" and Apple Computer's 64-bit migration to the Power Mac in part drive this scenario. Figure 3 highlights that the cache RAM market should benefit from the PC boom in the same way that the DRAM market will.

The line chart in Figure 3 provides Dataquest's worldwide PC forecast. Note that Dataquest defines a PC as being a fully assembled product when purchased by the end customer. For example, Dataquest excludes from the PC definition motherboards that the end customer assembles into a PC.

PC Boom

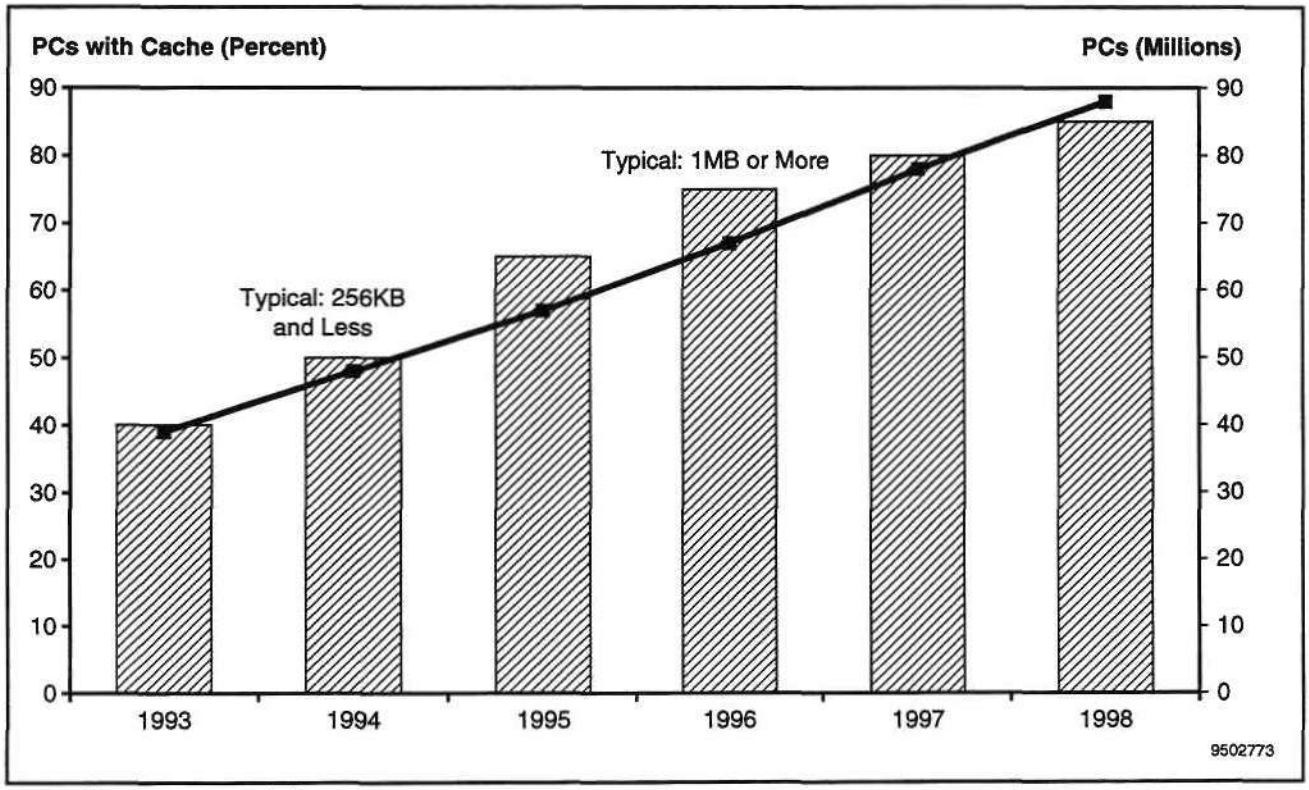
The chart in Figure 3 reads against the right vertical axis and shows for the year 1993 that worldwide PC shipments totaled slightly less than 40 million units that year. The line chart shows for the year 1998—again, reading against the right axis—that worldwide PC shipments should total nearly 90 million units that year. Worldwide PC shipments should approach 100 million units for 1999.

Worldwide PC shipments for 1995 will exceed 55 million units, a 20 percent increase over 1994. For 1996, worldwide PC shipments should grow at a similar rate and exceed 65 million units.

More PCs with Cache

The bar chart in Figure 3 provides an estimate of the growing percentage of PCs that will contain cache RAM. The bar chart reads against the left vertical axis and shows for the year 1993 that about 40 percent of PCs contained cache RAM. By contrast, 85 percent or more of PCs will contain cache RAM by the 1998 to 1999 time frame.

Figure 3
64-Bit PC Bus Means More and More Cache



Source: Dataquest (June 1995)

PC Caches Getting Bigger

The information in Figure 3 above the line chart also shows that the amount of cache RAM in PCs will escalate during this period.

Cache RAM Suppliers Are Drooling

What does Figure 3 mean for the cache RAM market? Dataquest forecasts that worldwide revenue from the sale of high-speed SRAM—which totaled $1.7 billion for 1994—will approach $3 billion by 1996. The figure signals continually strong long-term cache RAM demand.

From the perspective of a supplier of high-speed 32Kx8 SRAM (20ns and faster speeds), the 1994 to 1996 move from a 32-bit PC bus to a 64-bit bus looks like a potential doubling of demand. For example, 32-bit PCs used four of these 32Kx8 parts, while 64-bit PCs would need eight of them.

For cache RAM suppliers, however, the transition to 64-bit PCs will become complicated. The high-speed SRAM market actually consists of a series of micromarkets, including the following product technologies:

- 5V 32Kx8 15ns asynchronous
- 3.3V 32Kx8 15ns asynchronous
- 3.3V 32Kx32/32Kx36 15ns synchronous
- 3.3V 64Kx16/64Kx18 15ns synchronous

- 5V 128Kx8 15ns asynchronous
- 3.3V 128Kx8 15ns asynchronous

Near-Term Cache Market Transition

For cache RAM suppliers, these niches historically have translated into high profit margins—and will continue to do so—as long as any given supplier successfully manages a series of market transitions. These transitions include the following:

- First, the transition caused by the migration from the 256K density to the 1Mb density
- Second, and associated with the density shift, competition from the newly emerging synchronous SRAM architecture to the long-established asynchronous SRAM technology

For example, the high-volume runner last year was the 32Kx8 asynchronous SRAM 15ns driven by 486 PC demand. For the 1995 to 1996 period, however, Pentium PCs will drive demand to 1Mb devices. More than 10 suppliers are eyeing the high-speed 32Kx32/32Kx36 synchronous SRAM market. Meanwhile, the 128Kx8 asynchronous SRAM 15ns possibly offers a lower-performance, lower-cost Pentium cache alternative. As indicated, there is still another viable candidate—the 64Kx16/64Kx18 synchronous part—especially for P6 systems that should appear later this year.

The precise timing of this transition to 1Mb cache RAMs—which Dataquest believes will gain strong momentum by the fourth quarter of 1995—signals some challenge and a lot of opportunity for suppliers.

Even so, Dataquest's forecast augurs a very positive outlook for the cache RAM market. For example, strong 1996 demand for high-speed 1Mb SRAM (10ns to 44ns speed range) should push revenue from these segments over $1.5 billion for next year, a near tripling of revenue from 1994.

Memory PPB Trends

One determinant of whether any memory product technology achieves mass-market commercialization is pricing. In the memories world, this means the PPB.

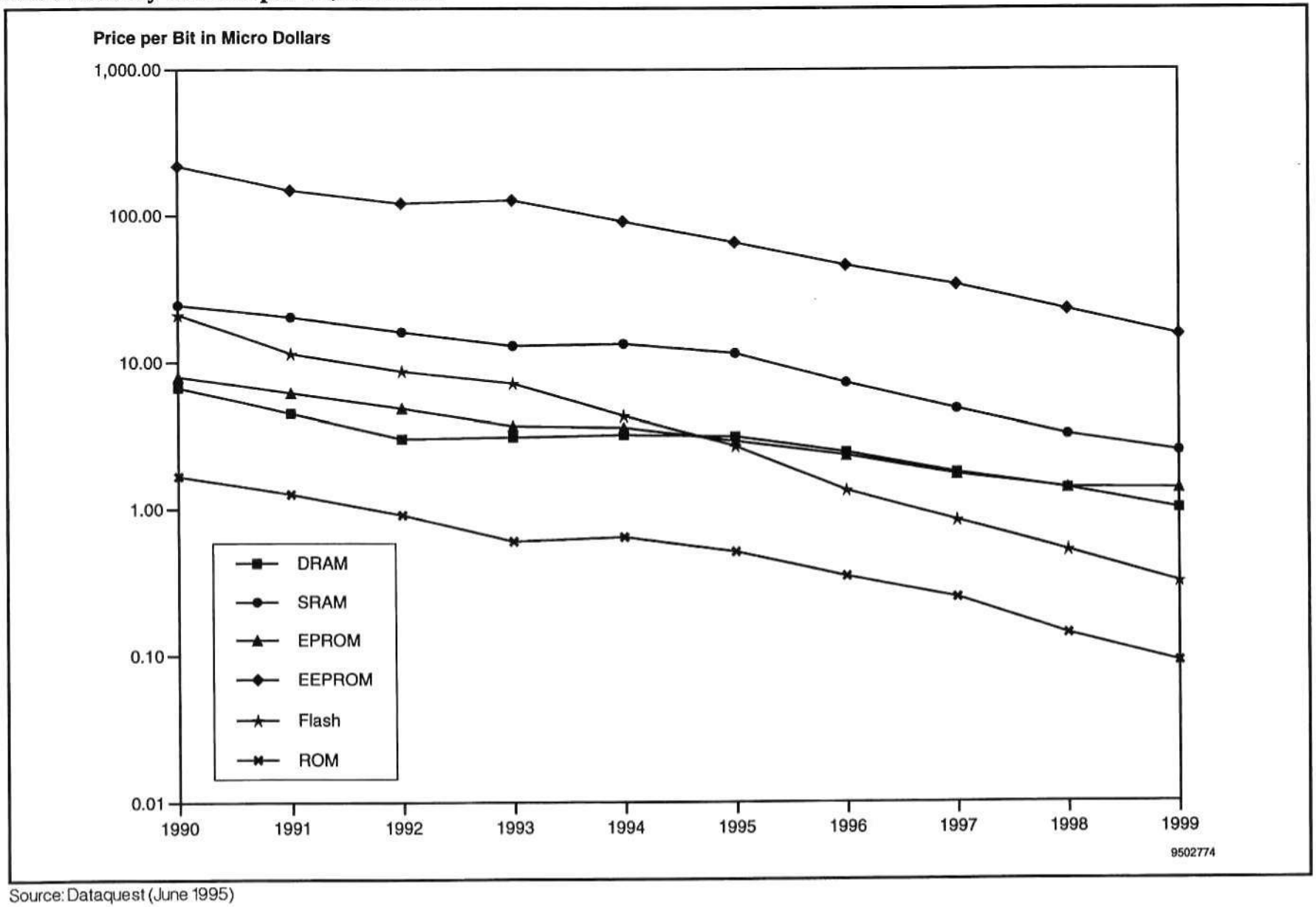
Background

A fierce marketing battle is being waged among suppliers of DRAM, flash, ROM, and EPROM for design-into applications. The PPB comparison becomes one factor—but a highly visible factor—among the many factors that determine whether a system uses DRAM, flash, ROM, or EPROM for its memory requirements. (For a variety of reasons, EEPROM and SRAM applications are less affected by the PPB trade-off.)

Memory PPB Curve

Figure 4 shows the history and Dataquest's forecast of the memory IC PPB curves.

Figure 4
MOS Memory IC Price per Bit, 1990-1999



Source: Dataquest (June 1995)

Some key trends shown include the following:

- The ROM PPB should remain the lowest memory PPB throughout this decade—although Intel's multilevel cell (MLC) flash technology threatens this outlook.
- The flash memory PPB already is falling under the DRAM PPB and EPROM PPB curves—and falls far below them later this decade.

From Dataquest's perspective, the flash PPB trend means flash should fulfill its "original promise" as a technology enabler, especially for low-power handheld systems. For handheld digital communicators and assistants to emerge—as Dataquest believes they will over time—the low-cost memory IC must be available. Flash appears poised to participate in the long-term mass-commercialization process.

We recognize that raw PPB is not the sole determinant of system design-in. For example, at the other end of the memory PPB spectrum, EEPROM—despite its high PPB—will win design-in to low-density applications. For these applications, the high-PPB concern fades because the total cost of the EEPROM part remains in the range of just several dollars at most.

Even so, flash IC suppliers will make a relentless marketing effort—full-featured flash at a lower PPB than DRAM, EPROM, and even ROM—if Intel's MLC technology successfully emerges. Meanwhile, some suppliers of EPROM plan to keep their EPROM price curve below that of both flash and DRAM, regardless of what other EPROM suppliers do.

Dataquest Perspective

The memory IC market continues to boom. Fueled by strong growth in the DRAM, cache RAM, and flash memory segments, the boom should continue throughout the 1994 to 1999 forecast period. Despite transitional issues, the robust long-term PC outlook means a dramatic long-term escalation in DRAM and cache RAM demand.

The impressive decline in the flash price curve signals flash's continued emergence as a technology enabler for low-power handheld technologies. Toward the end of this decade, DRAM will continue to drive the worldwide MOS memory market. Flash will be another key market driver that will enable the emergence of new system applications. The EEPROM market seems somewhat impervious to the flash "displacement" threat. Other memory technologies such as EPROM and ROM will resist displacement by flash. However, a "multilevel cell"-type drop in the flash price curve could eventually prove compelling for system designers.

For More Information...

Ronald Bohn, Senior Industry Analyst ..... (408) 437-8542
Internet address ..... rbohn@dataquest.com
Via fax ..... (408) 437-0292

Perspective

Memories Worldwide

Research Brief

A Review of the International Solid State Circuits Conference (ISSCC)

Abstract: *The IEEE's recent annual International Solid State Circuits Conference, ISSCC 1995, is a showcase of the R&D efforts of the leaders in the semiconductor industry. This year's conference was a fascinating show heralding the "giga" era. Gigabit DRAMs took center stage, while gigabaud communications, gigaflop DSPs, and giga-instructions-per-second CPUs will fill out the rest of the information superhighway chip complement. Intel announced the next-generation x86 microprocessor at this San Francisco conference. Many other extremely interesting innovations in memories, communication, data conversion, and even neural networks were presented, along with papers selected on their value, innovation, and the fact that a device was made to work in a laboratory environment.*
By Jim Handy (Memories Worldwide) and Jerry Banks (Microcomponents Worldwide)

The Conference Is Over, but Many Interesting Memories Linger On

DRAM

In light of the new era of gigabit DRAMs (2 to the 30th power, or 1,073,741,824 bits), NEC, Hitachi, and even Toshiba (the last of which was the only one of the three to not show a gigabit device) had evening parties to show off the cream of their research staffs to the press and analysts. At the NEC showing, one general manager waved in front of the audience a tie bar built around a gigabit die that looked to be almost two inches on each side. NEC's approach to producing this behemoth is to manufacture a wafer full of 256Mb DRAMs, find four adjacent working devices, and saw the wafer in such a way as to leave these four together, effectively making a 1Gb monolithic device. Surprisingly, NEC does not call this wafer-scale integration.

Dataquest

Program: Memories Worldwide
Product Code: MMRY-WW-RB-9501
Publication Date: May 15, 1995
Filing: Perspective

A more interesting trend in the show was the embracing of the concept of merging ASIC and DRAM technologies. There was a workshop about this subject the day before the conference, a paper by Toshiba showing an "Embedded DRAM" to be used with a sea of gates, and a position taken in the "DRAMs for Graphics" evening panel that the best choice for future graphics controllers would be to combine the frame buffer with the graphics accelerator ASIC.

What would drive this? Certain DRAM applications, such as MPEG decoders for set-top boxes and multimedia, and graphics accelerator cards, use a relatively fixed amount of DRAM on the order of 24Mb. This is limited by the resolution of the display, a statistic that does not change much over an extended period. Soon (before the turn of the century), 24Mb will be less than half of the density of a standard 64Mb DRAM, leading researchers to wonder how to use the rest of the die. It certainly looks as though this approach could catch on, but we still do not see too much SRAM added to today's ASICs (with rare exceptions, such as Sony's cache chip). So we cannot truly tell whether the DRAM/ASIC approach will be well accepted down the road.

One evening session promised to be an honest debate about the best DRAM architecture to use when implementing video systems. The session promised so much that it played to a packed auditorium. Unfortunately, six of the seven panelists were from semiconductor companies whose corporate position advocated one architecture or another, with only one company being an actual user of the devices, so the session ended up looking like the sort of posturing usually seen in trade shows. The sentiment we heard from audience members we later encountered was one of disappointment.

SRAM

Three extremely fast SRAMs were revealed by Toshiba (with Hewlett-Packard), NEC, and Hitachi, spanning access times from 3ns to 1ns. The scariest was a wave-pipelined device of Hitachi's that used a multiphase phase-locked loop incorporating a voltage-controlled oscillator made out of a rectangular array of 96 amplifiers. This design actually came from another ISSCC paper presented in an earlier year.

Flash Memory

As usual, everybody in the industry seemed to be ready to show off some new flash memory design. This is encouraging, but it would be refreshing to see some real activity in the market, enough to pose a threat to the stranglehold Intel and AMD have on flash, with a combined market share of almost 90 percent.

Seven flash papers were presented by Intel, Mitsubishi, Hitachi, Matsushita (with SunDisk), Toshiba, and, for the first time, Samsung. All but one featured 3.3V operation, indicating the resounding agreement that flash is destined for portable operation. Intel presented its experimental approach of storing multiple bits on a single cell, thereby multiplying the bit storage and slashing the per-bit price. Two of the remaining six papers dealt with 16Mb designs, and the rest with 32Mb designs, showing a sincere desire on the part of the flash manufacturers to get into business on the highest rational densities.

Ferroelectrics

Two papers (one from Rohm and one from Matsushita, Symetrix, and the University of Colorado) focused on the use of ferroelectrics. It surprised us a little that the 1Gb DRAMs presented by Hitachi and NEC in the DRAM session did not use ferroelectric dielectrics, as we have been predicting for years. The ferroelectric papers were about techniques to design nonvolatile memories using this technology. One offered a lifetime of 10^{12} cycles (1 trillion), while the other offered 10^{13} (10 trillion), highlighting the major strength of ferroelectrics over flash of a much higher number of read/write cycles. Today's flash devices offer about 10^{6} (1 million) cycles, or a 10-millionth as many.

The P6: Not Just Another x86

Intel's new microprocessor, now known as the P6, is proof positive that Intel has truly halved the development time of succeeding generations of x86 microprocessors. The P6 comes just two years after the Pentium. All prior generations of x86 microprocessors had taken four to five years between generations.

Intel does not call its approach to the newly revealed P6 CPU a multichip module, although the difference between Intel's approach and an MCM was utterly lost on us, as well as on others in the audience. The P6 uses a CPU chip with level-one caches similar in size and construction to those on the Pentium, then augments this with a 256KB secondary cache SRAM die mounted in the same package. Lots of fancy new architectural twists, many borrowed from the more advanced variations of the i960, have been added to push the performance significantly above that of the Pentium. The processor is designed to be connected to as many as three other CPUs on the same bus, supporting tightly coupled multiprocessing architectures. (Ironically enough, Intel Scientific Computers only uses loosely coupled processor arrays, so this twist will not be of any help to it.)

The heart of the architecture is what Intel refers to as "Dynamic Execution," the unique combination of three processing techniques the P6 uses to speed up software—multiple branch prediction, data-flow analysis, and speculative execution:

- Multiple branch prediction: First, the processor looks multiple steps ahead in the software and predicts which branches, or groups of instructions, are likely to be processed next. This increases the amount of work fed to the processor.
- Data-flow analysis: Next, the P6 analyzes which instructions are dependent on each other's results, or data, to create an optimized schedule of instructions.
- Speculative execution: Instructions are then carried out speculatively, and possibly out of order, based on this optimized schedule, keeping all the chip's superscalar processing power busy and boosting overall software performance.

The P6 is very fast, will rapidly scale to higher frequencies, and is built for high-volume manufacture. It uses a fine-grain 11-stage pipeline in which no single stage is required to perform a significant amount of work. This will allow Intel to rapidly increase the performance by simply increasing the clock. We believe that the present product announcement of 200 SPECint92 at 133 MHz is quite conservative. We would not be too surprised to see the P6 approach 400 SPECint92 in 12 to 18 months.

A detailed manufacturing and capacity analysis gives us reason to believe that Intel is bringing enough fab capacity online to support a production ramp for the P6 that could exceed that of the rapidly ramping Pentium.

This basically is a very fast scalable design. It is intended for the mainstream desktop and will be a mainstream notebook processor in 1997. Intel has the manufacturing muscle in place, and the closest significant competitor is still a generation behind.

Dataquest Perspective

As always, memories played an important role at the ISSCC, and we expect them to continue to do so. The job of the Dataquest analysts, then, is to sort out which ones should enjoy success, and to try to determine when and how their success will be attained. This will figure into any long-term prognostications we will make in future publications.

All in all, it was a fascinating show. There were lots of stunning advancements, like the mere fact that the 1Gb DRAM was introduced two—not three—years after the first paper heralding a 256Mb DRAM, or NexGen's use of IBM's five-layer metallization, along with C4 bonding and more precise layout tools, to reduce its die size by more than 40 percent without reducing process geometries.

As we always say, however, if you want to know what to expect in the next five years, ask Dataquest. If you want to see the future of six or more years out, go to ISSCC.

For More Information...

Jim Handy, Director/Principal Analyst ..... (408) 437-8228
Internet address ..... jhandy@dataquest.com
Via fax ..... (408) 437-0292

Dataquest
a company of The Dun & Bradstreet Corporation

Perspective

Memories Worldwide

Briefing

DRAMs: Today and in the Year 2000

Abstract: *Dataquest recently made a dramatic increase in its MOS memory forecast. This document describes the phenomenal markets driving this increase, and includes: forecasts by memory technology through 1999; forecast of DRAM supply and demand balance through 1996; highlights of DRAM, flash, and SRAM needs in the year 2000; analysis of market drivers for MOS memories; and factors driving today's and tomorrow's DRAM shortages. By Ronald Bohn*

Main Points

Dataquest's Semiconductor Group made a series of "Breakfast Briefings" presentations to clients throughout the United States in April. This newsletter provides highlights from the speech entitled "DRAMs, Flash, and Cache in the Year 2000." In addition to semiconductor clients, the audience included Dataquest's Wall Street clients.

The presentation emphasized these three main points:

- Dataquest has a bullish DRAM market outlook not only for the 1995 to 1996 period but also for the long term. We expect a 10 percent DRAM shortage in 1995. Despite an increase in DRAM fab capacity, Dataquest conservatively expects a DRAM shortage of nearly 5 percent throughout 1996.
- The cache RAM business remains lucrative, with high-speed SRAM in tight supply. The market will undergo several transitions (the presentation highlighted the transitional elements).
- Flash memory revenue grew more slowly during 1994 than originally expected. Even so, Dataquest views flash as a key enabling technology for the emerging low-power handheld applications, so flash should continue its market emergence.

Dataquest

Program: Memories Worldwide
Product Code: MMRY-WW-BR-9501
Publication Date: April 24, 1995
Filing: Perspective

This report focuses on the DRAM outlook including a "Year 2000" PC DRAM road map.

Worldwide Memory Forecast

Figure 1 presents a top-level view of Dataquest's preliminary worldwide memory forecast for the 1994 to 1999 period.

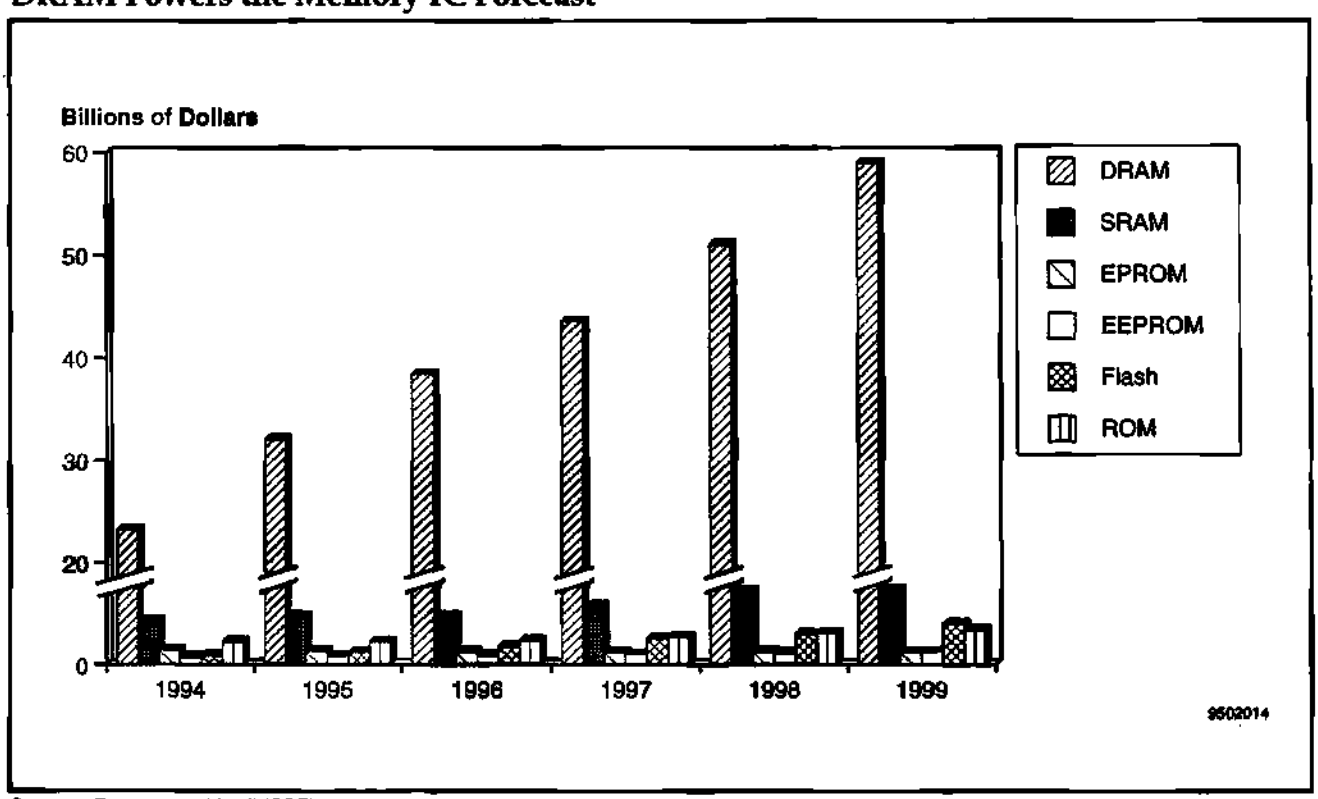
Figure 1 shows that the DRAM forecast towers over the other memory product forecasts. Dataquest expects worldwide memory revenue to total $43 billion in 1995, a 30 percent growth rate over 1994. The forecast for 1999 calls for worldwide memory revenue of nearly $80 billion.

The figure shows that DRAMs are the memory market driver. Dataquest expects worldwide DRAM revenue to reach $33 billion in 1995, a growth rate of more than 40 percent over 1994. Worldwide DRAM revenue should hit or exceed $60 billion by 1999. The figure shows no DRAM market downturn during the 1994 to 1999 period.

DRAM Supply and Demand

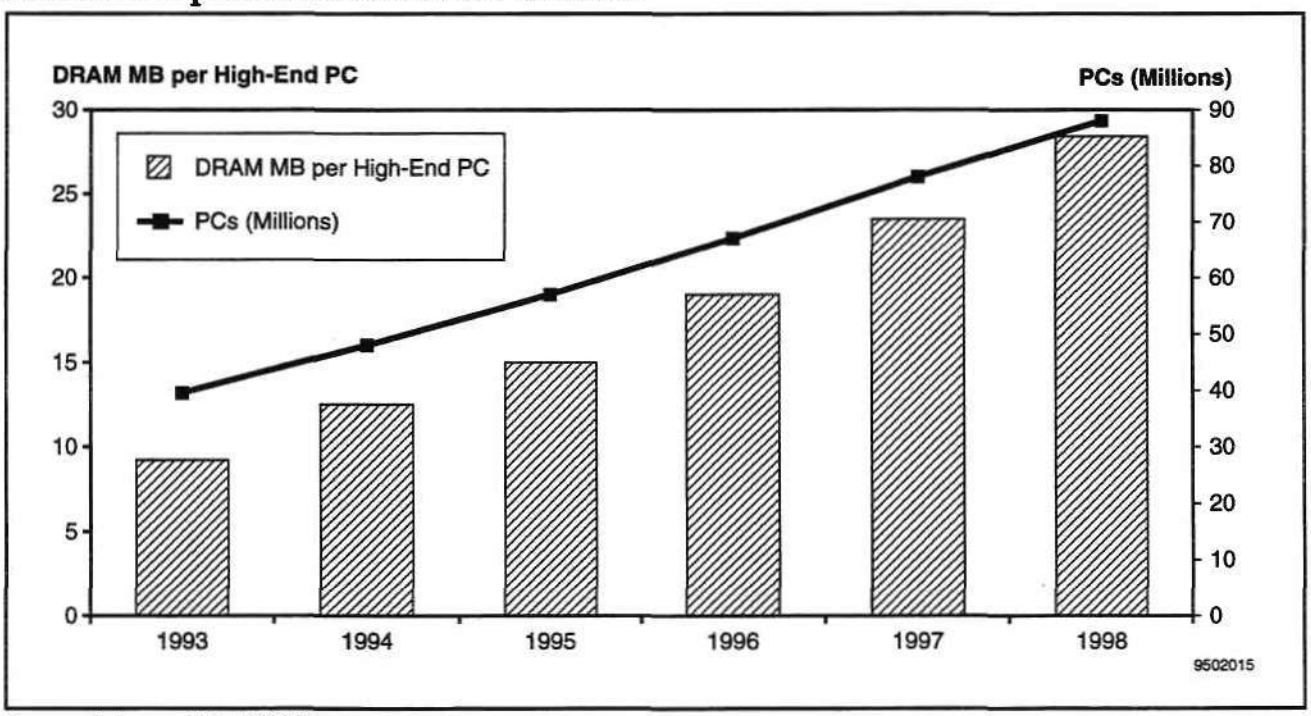
Figure 2 shows the relation between the PC market and DRAM demand. PCs drive DRAM demand. Dataquest estimates that PCs, primarily main memory, represent 65 percent or more of DRAM demand.

Figure 1
DRAM Powers the Memory IC Forecast



Source: Dataquest (April 1995)

Figure 2
PCs Drive Up Worldwide DRAM Demand



Source: Dataquest (April 1995)

Figure 2 is based on information from Dataquest's quarterly *DRAM Supply-Demand Report*. The report provides Dataquest's more comprehensive view of DRAM supply and demand. The DRAM report includes our worldwide electronic equipment production forecast, including the PC forecast. The core of the report is a 4Mb and 16Mb DRAM product forecast presented on a "supplier-by-supplier" and "product configuration-by-product-configuration" basis for each quarter of 1995 and 1996. The report links all of this information to our DRAM fab database.

PC Forecast

The line chart in Figure 2 provides Dataquest's worldwide PC forecast. The line chart reads against the right vertical axis. For example, the line chart shows for the year 1993—reading against the right axis—that worldwide PC shipments totaled slightly less than 40 million units that year. The line chart shows for the year 1998—again, reading against the right axis—that worldwide PC shipments should total nearly 90 million units.

Worldwide PC shipments for 1995 will reach 57 million units, a 20 percent increase over 1994. Worldwide PC shipments should grow at a similar rate in 1996 and exceed 65 million units.

We should note that Dataquest defines a PC as being a fully assembled product when purchased by the end customer. Dataquest excludes from the PC definition motherboards assembled into PCs by the end customer.

PC Main Memory "Upgrades"

The bar chart in Figure 2 shows the number of megabytes of DRAM in a high-performance PC that have been upgraded by the end user. The bar chart in the figure reads against the left vertical axis. The following section explains the meaning of this information.

A 100-MHz Pentium serves as an example of a high-performance PC for 1995. Pentium PCs will ship from PC factories this year with a minimum of 8MB of DRAM. By contrast, 486DX systems, the high-volume runner for 1994, shipped from the factory with a minimum of 4MB of DRAM.

Intel is making a major market push to the 64-bit Pentium and away from the 32-bit 486. Also, Apple has its 64-bit migration to the Power Mac well under way.

A Near-Term Doubling of DRAM Demand?

From a DRAM supplier's perspective, the move to a 64-bit bus such as Pentium means that the minimum amount of factory-installed DRAM will double from 4MB during 1994 to 8MB during 1996.

For DRAM suppliers the 64-bit Pentium also means a doubling in terms of PC main memory upgrades. For example, 100-MHz Pentiums that ship from the factory with just 8MB of DRAM quite likely will be upgraded to 16MB. The bar chart shows this for 1995 as read against the left vertical axis. By comparison, 486 PCs settled at an upgrade threshold of 8MB of DRAM.

The figure presents this dramatic picture of worldwide DRAM demand:

- Worldwide PC shipments will more than double during the 1993 to 1998 period.
- Meanwhile, the amount of DRAM in each PC—whether the minimum amount or the upgrade amount—will escalate more dramatically and should triple during this period.

This scenario serves as the basis for Dataquest's long-term bullish outlook on the DRAM market.

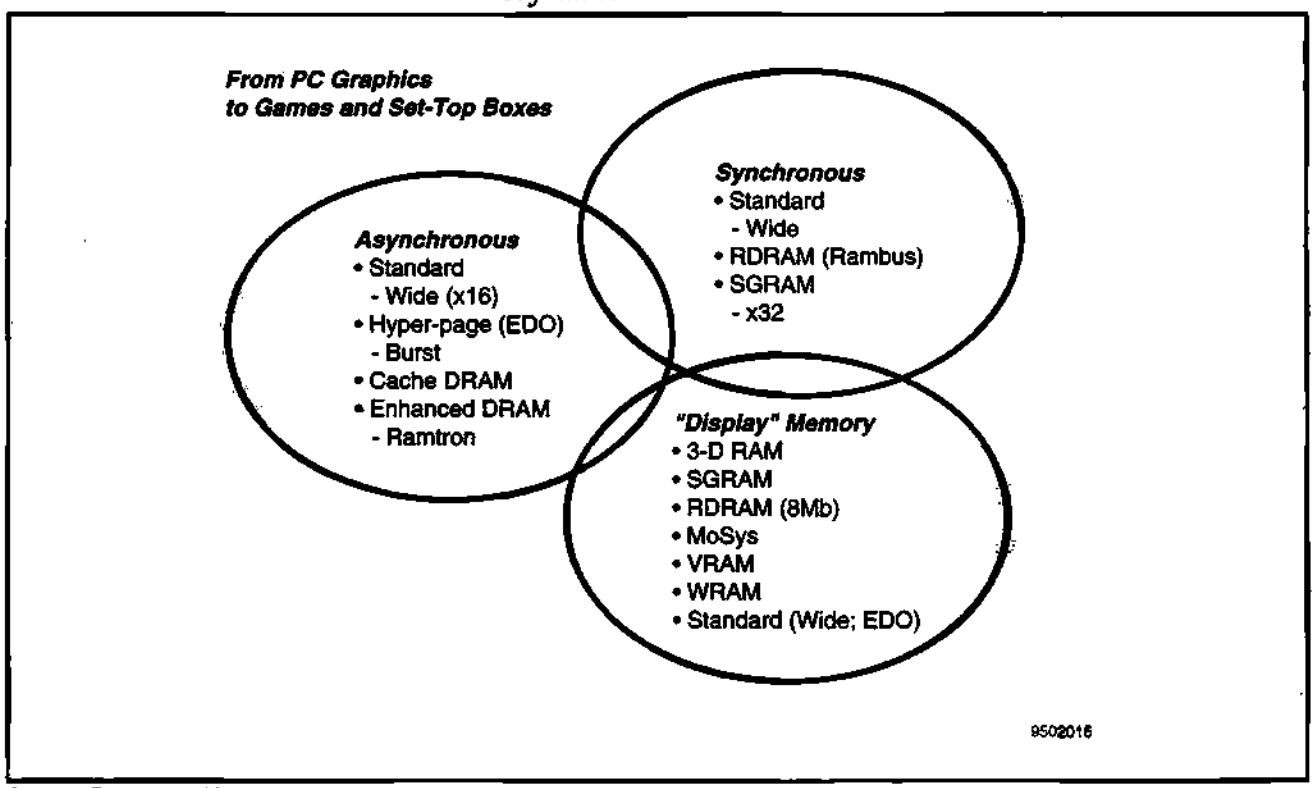
Emerging DRAM Architectures

The DRAM market is going through several transitions, including the emergence of new architectures. In a subtle fashion, Figure 3 is perhaps the most complicated graphic used in the presentation.

Note that absorption of newly added DRAM capacity represents another DRAM market transition.

In Figure 3 Dataquest identifies more than 10 DRAM architectures and logically groups them into three broad categories. The three circles in the figure show that the DRAM architectures are the asynchronous, synchronous, and "display" memory architectures.

Figure 3
Multimedia Accelerates Second Key Transition: New Architectures



Source: Dataquest (April 1995)

The "Lion King" CD-ROM served a starting point during the presentation for this complicated topic. Thousands of children were angry with their parents on Christmas Day 1994 because they were unable to watch Disney's newly released Lion King CD-ROM on the home PC. The parents were blamed, but DRAM and other factors were at fault.

The serious point is that the standard asynchronous DRAM architecture is unable to meet the performance requirements of multimedia-type PC graphics applications and newly emerging video game and set-top box applications. In DRAMs, "asynchronous" is a bad word.

The asynchronous circle in Figure 3 shows the DRAM world of yesterday and today. Although "asynchronous" is a good word in the telecommunications world, for example, as in asynchronous transfer mode (ATM), it is a bad word in the DRAM world because it means multiple system clocks. In DRAMs, multiple system clocks mean delays in terms of DRAM's ability to locate and process information, as shown in the Lion King example.

DRAM suppliers are making interim improvements in the asynchronous architecture in an effort to support multimedia display applications. For example, Figure 3's asynchronous circle shows that DRAM suppliers are moving toward wider configurations (for example, 1Mbx16). Unfortunately, most DRAM suppliers remain unable to rapidly ramp up supply of this highly desired device. This part likely will remain in severe shortage until 1997. There also continues to be a shortage of the 256Kx16 device. This device never emerged as more than a niche of the 4Mb DRAM market.

The asynchronous circle also shows reference to the hyper-page mode version also known as the extended data out (EDO) version. EDO DRAM offers a 5 percent DRAM speed improvement at virtually no extra cost to the end user—but multimedia applications demand a lot more than that.

Dataquest believes that the synchronous architecture will become predominant at the 64Mb density. All DRAM suppliers working on 64Mb DRAM include a synchronous DRAM (SDRAM) part in their 64Mb product portfolio. Suppliers extol the performance of the simplified, single-clock synchronous architectures. Although some suppliers warn that technical challenges exist in terms of using SDRAM on modules, they are confident about resolution of the technical issues.

The 64Mb DRAM, however, represents the next generation. Multimedia display applications require solutions today—which brings us to Figure 3's display memory circle. References to DRAM suppliers' move to wider configurations (x16) and the EDO version of standard DRAM reappear at the bottom of the display memory circle in Figure 3.

VRAM appears several notches higher in the display memory circle. The VRAM (that is, video RAM) has been DRAM suppliers' traditional offering for PC graphics applications. VRAM works quite well. The problem with VRAM from a user's perspective is its cost. It often costs twice as much as standard DRAM, which becomes unacceptable for cost-sensitive newly emerging applications such as set top boxes and video games.

The Rambus DRAM (RDRAM) appears several notches higher in the display memory circle. RDRAM also sits in the synchronous DRAM circle, where the inventor company's name appears, Rambus.

Dataquest views Rambus as a wild-card supplier in terms of newly emerging DRAM architectures. The RDRAM has won design-in to a Nintendo game system. Rambus, however, wants to position this device against synchronous DRAM for a role in PC main memory.

Dataquest looks for two key factors of success for Rambus to achieve in order to win its way into a majority of PC main memory applications. We are not sure they will be achieved by Rambus, but Dataquest awaits to see:

- Whether a major microprocessor company designs a processor that is compatible with the Rambus DRAM interface
- Whether a major PC company designs-in the RDRAM as the PC main memory

So far, Rambus won the Nintendo video game design-in. But we still look for major PC main memory design win.

PC DRAM Road Map

Table 1 provides a PC DRAM road map for the year 2000.

Table 1 looks at high-end PCs for 1995 and 2000. We use a 100-MHz Pentium for 1995 and a 400-MHz P7 for the year 2000. For 1995, we assume end users will upgrade the Pentium to 16MB of DRAM.

Table 1
PC DRAMs: 1995-2000

Device	1995 Specification	2000 Specification
DRAM	16MB per PC:	"45MB" per PC:
	16Mb, 60ns	64Mb
	Asynchronous	Synchronous
Processor	Pentium	P7
	100+ MHz	400 MHz
At ISSCC	1Gb DRAM	16Gb DRAM
	Synchronous	

Source: Dataquest (April 1995)

For the year 2000, the P7 will use 64Mb synchronous DRAMs. The fully upgraded system will contain "45" megabytes of DRAM that represent an upgrade range—32 DRAM megabytes on the low side to 64 DRAM megabytes on the high side. (We already noted Rambus' wild-card role in this scenario.)

256Mb DRAM might be popular by the year 2000. Table 1 includes a reference to the International Solid State Circuit Conference (ISSCC), which is held every February in San Francisco. Semiconductor and other electronics companies showcase their leading-edge R&D efforts at ISSCC. At ISSCC 1995, Hitachi and NEC separately demonstrated 1Gb synchronous DRAMs. The point is that both companies are confident that they will be able to start early production of 1Gb DRAM sometime near the year 2000.

Dataquest Perspective

Dataquest has a bullish position on the worldwide DRAM market. For example, the analysis in Dataquest's *DRAM Supply-Demand Report* reveals a 10 percent DRAM shortage for 1995 and, despite an increase in DRAM capacity, a DRAM shortage of nearly 5 percent throughout 1996.

Dataquest bases its bullish DRAM market outlook in part on the expectation that worldwide PC shipments should approach 90 million units by 1998. Another basis for our bullish perspective is that the amount of DRAM in each PC should dramatically escalate. The number of megabytes of DRAM in each PC—whether the minimum as shipped from the PC factory or the higher amount in PCs that have been upgraded by the end user—should nearly triple during the 1993 to 1998 period.

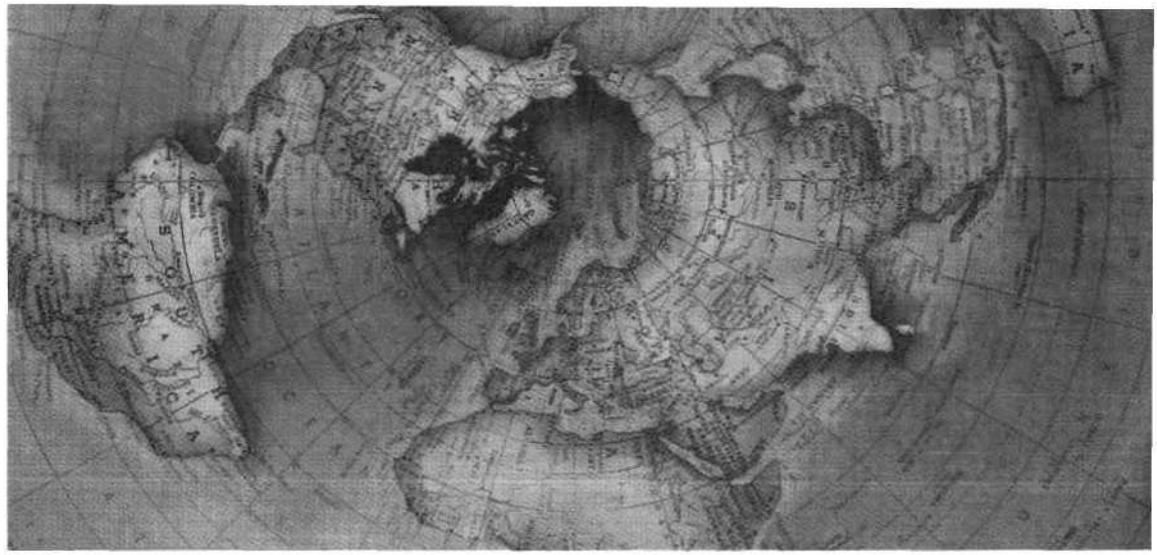
Although the asynchronous architecture predominates in today's DRAM market, the market is now shifting to other architectures. The emergence of multimedia applications creates opportunities for emerging architectures such as the Rambus DRAM. Dataquest's year 2000 road map for PC DRAMs calls for a 64Mb synchronous DRAM as the mainstream device—or perhaps a 256Mb part—with Rambus a key wild-card player.

MMRY-WW-BR-9501 Qty: 1
Mr. Joe Grenier
Dataquest Incorporated
1-1100
.,
--INTERNAL DIST.--

For More Information...
Ronald Bohn, Senior Industry Analyst ..... (408) 437-8542
Internet address ..... rbohn@dataquest.com
Via fax ..... (408) 437-0292

Dataquest
a company of The Dun & Bradstreet Corporation

Perspective



Memories Worldwide

Telebriefing Summary

The 1995-1996 DRAM Fab Outlook—Can PCs Absorb That Much DRAM Capacity?

Abstract: *Despite rampant addition of new wafer fabrication capacity, there remains a DRAM shortage that has been with us since 1992. Dataquest predicts the shortage to continue into the second half of 1996. In a recent telebriefing, the transcript of which makes up this newsletter, key Dataquest analysts explained why massive capital investment has not caused a supply/demand balance, or even the oversupply expected by other market watchers.*
By Jim Handy

Introduction

This is Jim Handy of Dataquest's Memories Worldwide service. First, let me introduce the speakers, then I'll give an overview of the subject and structure of the telebriefing. In the room here at Dataquest we have Clark Fuhs, Näder Pakdaman, and Calvin Chang of the Semiconductor Equipment, Manufacturing, and Materials Worldwide service (SEMM); Mark Giudici and Scott Hudson from the Semiconductor Procurement Worldwide service; and Mario Morales from our Research Operations Group. Ron Bohn and I represent the Memories Worldwide service.

What is this telebriefing about?

- Dataquest performs an analysis of DRAM supply and demand and publishes the results in a report updated quarterly.
- There has been a big increase in capital spending for semiconductor processing equipment. Despite all the new equipment coming online, the DRAM shortage will persist through 1996.
- This teleconference will describe the reasons that the DRAM shortage will continue, despite the installation of so much semiconductor processing equipment.

Dataquest

Program: Memories Worldwide
Product Code: MMRY-WW-BR-9502
Publication Date: June 19, 1995
Filing: Perspective

First, Clark Fuhs will speak about semiconductor wafer fabrication plant capacity, then I will return with a statement about the DRAM market. After these statements, we will open the phones to questions from the participants.

DRAM Supply-Side

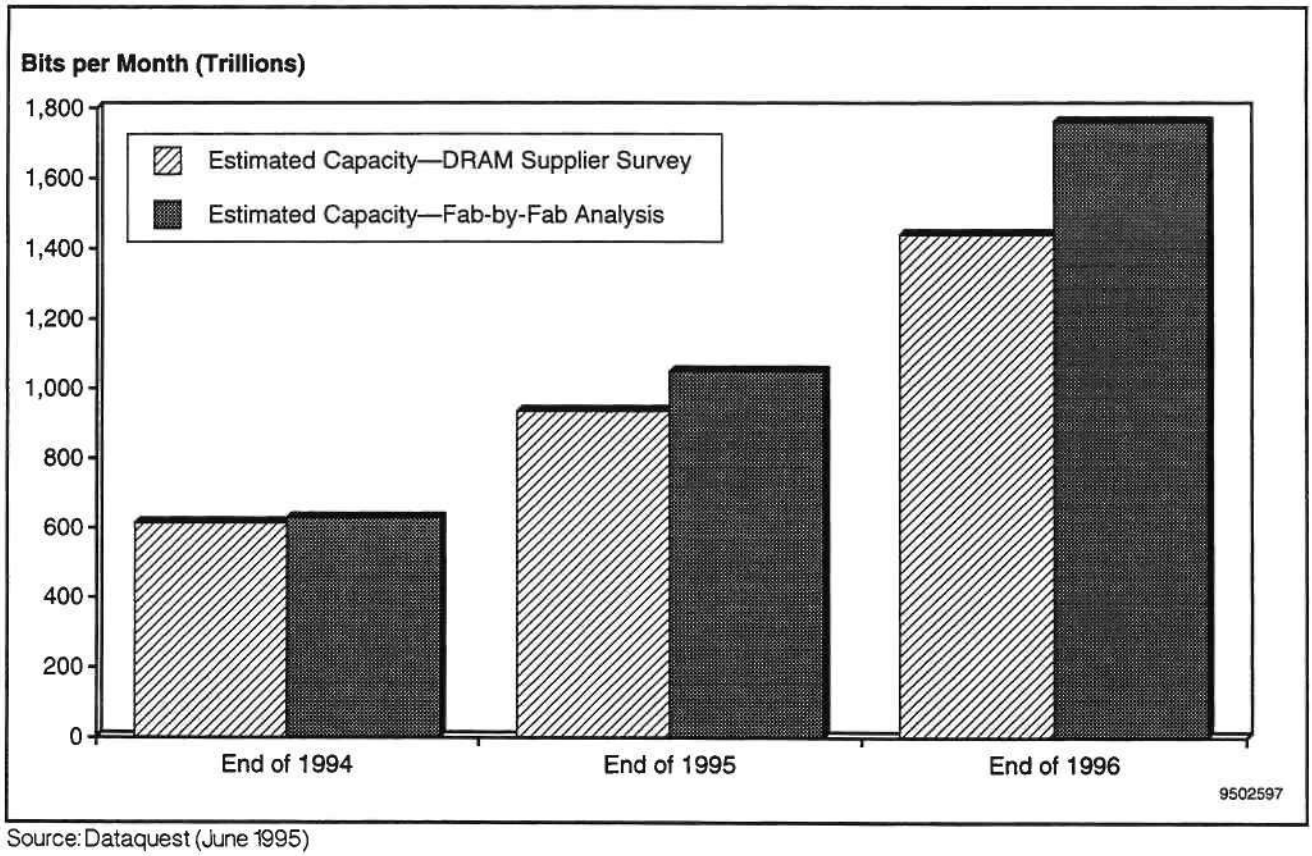
I am Clark Fuhs, a senior analyst from the SEMM group. We track most aspects of the actual manufacturing of semiconductors worldwide. Today we will briefly review the dynamic arena of DRAM capacity and supply.

The key source for our analysis today is a report Dataquest has just issued on 4Mb and 16Mb DRAM supply and demand. We titled it "DRAM Supply and Demand Report."

Supply-Side Analytical Methodologies

There are two supply-side methodologies, and their differences are outlined in Figure 1. Shown are three snapshots in time—at the ends of 1994, 1995, and 1996. The left bar in each year represents results of a survey of DRAM suppliers, which will be referred to by Jim Handy later. The right bar represents an estimate based on a fab-by-fab analysis of capacity and committed plans.

Figure 1
Estimated Fab Monthly Run Rates for 4Mb and 16Mb DRAMs



Source: Dataquest (June 1995)

The capacity estimate through the fab analysis includes the following assumptions: die size estimates, the effects of shrinks, and a gradual yield increase from today through the end of 1996 factored in on a company-by-company basis.

We have not included any capacity associated with unannounced capital spending increases or commitments over the next two years such as the recently announced acceleration of NEC's new U.S. facility—nor 6- to 8-inch wafer conversions.

As seen in Figure 1, these two methodologies have produced results within 3 percent of each other for the year just completed. But as we go into the future, the figure shows an increasing divergence. The conclusion here is that suppliers are not optimistic in the near term regarding their ability to increase yields on the 1x16 configuration for the 16Mb DRAM, and their outlook is conservatively hedged.

This leads to a question we get fairly often: What is the capacity of the market in 4Mb "equivalent units"? Unfortunately, from a fab perspective, this is not a very useful way to view capacity—and is a metric that we at Dataquest view may not provide an adequate picture of bit capacity. Why not? In a fab, capital spending and equipment purchases are driven by the requirement for wafers, or better yet, square inches of silicon.

Three Stages of Capital Spending

Let me highlight here the dynamics of how capital spending and bit supply are related. There are three identifiable parts to this cycle, and as you will see, we are in the later stages of part 2.

In the early to middle stages of a unit ramp in a specific DRAM density generation, square-inch requirements and equipment purchases are generally driven by bit demand. This is part 1 of the investment cycle, and it occurred in 1993 for the 4Mb generation.

In the later stages of ramp, as the next density generation starts to become available, we enter part 2 of the investment cycle. During this state, capital investment is still primarily driven by bit demand. However, the style of investment changes to install "convertible" capacity—in today's case equipment earmarked for 16Mb DRAM capacity, but initially running 4Mb parts. Most investments in 1994 into the present have been of this nature. The later stages of part 2, which we are in today, will also tend to include dedicated capacity for the next density generation.

So today there are three types of capacity we must consider—capacity dedicated to 4Mb DRAMs, capacity dedicated to 16Mb DRAMs, and capacity that is "convertible" between the two. Why do suppliers like "convertible" capacity?

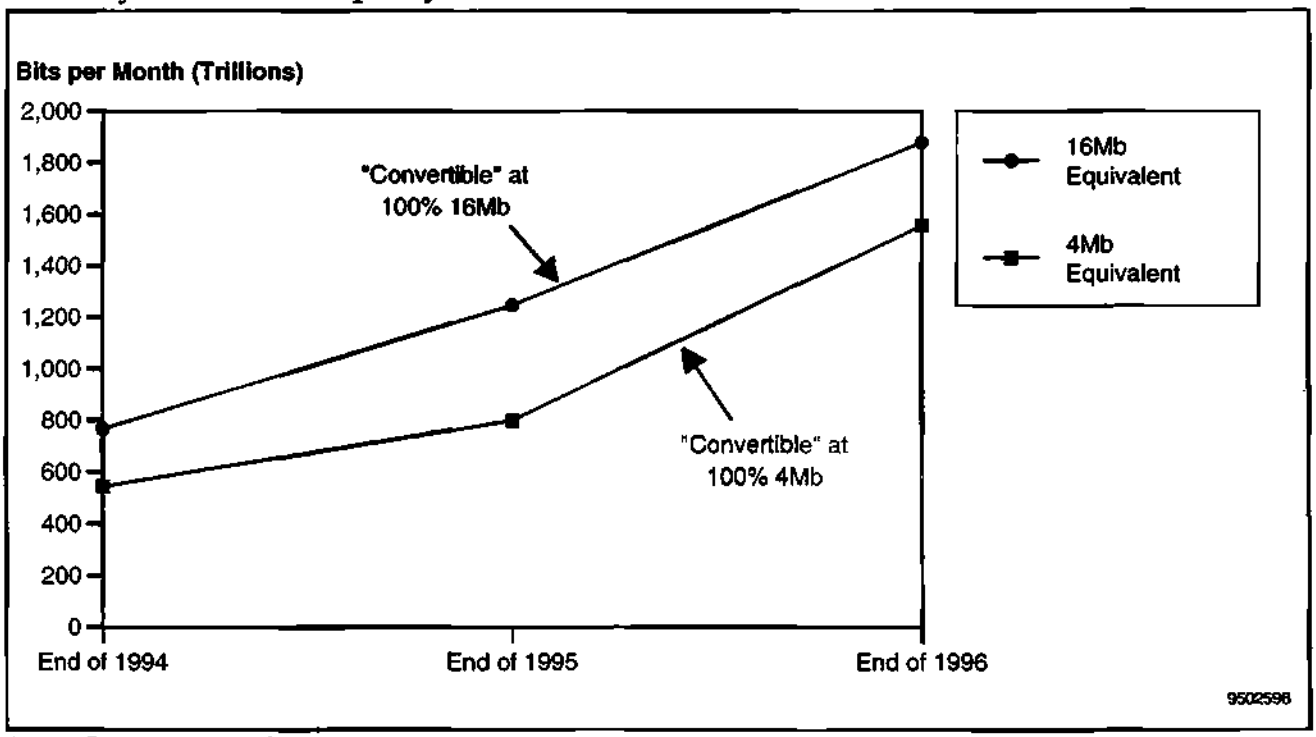
Based on die size ratios and the bit density ratio, as well as some other minor factors, a supplier can generally increase the bit capacity of a line by converting the line from 4Mb to 16Mb parts, with minimal incremental capital or equipment spending. This is accomplished because the bits per square inch are increased on the order of two or three times, meaning a supplier can double or triple the bit capacity of a line by conversion. Thus

part 3 of the investment cycle, typically lasting two years, creates bit capacity primarily by conversion rather than new equipment purchases. Thus a "pause" in the equipment market ensues. When all the capacity is converted, we begin part 1 of the cycle all over again.

Industry's DRAM Capacity

Back to the original question: What is the DRAM capacity of the industry? The answer is—it depends. It depends on how the "convertible" capacity is employed. The most useful way to view capacity is by a "window" and this is shown in Figure 2, using a fab-by-fab analysis. What I mean by "window" here is the area between the two lines that represent the possible capacity measured in terms of bits. Let's first relate this to Figure 1.

Figure 2
Monthly DRAM Bit Capacity "Window" for 4Mb and 16Mb



Source: Dataquest (June 1995)

At the end of 1994, Figure 1 shows that the monthly run rate of the industry was slightly more than 600 trillion bits. If all the "convertible" capacity were running 4Mb DRAMs at the end of 1994, the run rate would calculate to about 550 trillion bits per month, shown as the lower limit line in Figure 2. Likewise, if all of this convertible capacity were running 16Mb parts at today's yields, the capacity would calculate to slightly less than 800 trillion bits per month. Employing this methodology into the future, we have produced Figure 2 as a range of capacity over time.

I would like to emphasize that the width of the window increases in 1995 and shrinks in 1996. Because of the low yield and slow ramp issues of the 1x16 configuration part, suppliers are being forced to add more 4Mb capacity of a "convertible" nature today. This will increase the growth for the front-end equipment market during 1995 well beyond our current published forecast of 16 percent—probably not far away from 30 percent growth. Momentum factors will establish 1996 as a small growth year as well (originally we indicated a slight decline).

Our model indicates that the "pause" in the equipment market that we have been forecasting is unavoidable, however, because installing "convertible" capacity today by definition installs future "hidden" bit capacity and will likely cause a slight decline for wafer fab equipment in 1997. This conversion stage will also reduce the growth in the consumption of silicon in a like manner.

The trigger for the pause will be the availability and subsequent pull of the 1x16 configuration part into the end-use market. Until this happens, silicon square inch demand will continue to be driven by bit demand closely. The severity and length of the ultimate "pause" will be determined by how long the current boom lasts, basically building pent-up bit supply as well as the demand for bits during the conversion stage.

Now I'd like to turn it back over to Jim Handy for a review of demand.

DRAM Demand-Side

This is Jim Handy. Today's DRAM market is phenomenal. There has been an undersupply for two-and-a-half years, and in our recent analysis, the February 1995 version of the quarterly "DRAM Supply and Demand Report," we have found little reason to expect the current shortage to ease through the end of the report's forecast window, the end of 1996.

4Mb DRAM prices have slowly risen since the third quarter of 1992, yet DRAM use in megabytes per PC has gone up.

DRAM Pricing Alert

In the face of a strengthening yen against the dollar, Japanese suppliers of DRAMs have been able to raise average selling prices measured in dollars to stabilize the yen value of their worldwide DRAM sales. By all appearances, this trend will continue through the end of next year.

Our current North American contract-volume DRAM price forecast calls for firm pricing. We are aware that some Japan-based DRAM suppliers right now are considering an increase in the contract pricing for DRAMs. Korean and North American DRAM suppliers are waiting in the wings to see what happens. Should these changes materialize during second-quarter price negotiations, we will make appropriate changes in our price forecast.

Let's go over some of the background causes of the current DRAM shortage:

- PC demand is strong and shows no signs of letting up.
- Japanese DRAM suppliers, which accounted for nearly 50 percent of worldwide sales, were slow to react to the market and didn't increase capital spending until the fourth quarter of 1993.
- PCs have increased their per-system consumption of DRAM despite these stable/rising prices both in response to the requirements of advanced software as well as to decreases in the prices of CPUs, chipsets, and other system components.
- The 16Mb DRAM has met with limited acceptance in the traditional x1 and x4 organizations. A new x16 organization is the product of preference, and is late to market, forcing an increase in the consumption of 4Mb DRAMs unlike that seen in any other DRAM generation.

The PC market has stayed in a strong growth phase for some time now. However, the cause of this strength has varied over time. Two years ago growth was fueled by a rebound in PC shipments to the office. More recently, a big growth in home computer purchases including multimedia systems has driven the market. Now the business channel once again stands poised for important growth.

PC Forecast Revised Upward

We want to highlight today that Dataquest has just revised its worldwide PC unit-shipment forecast upward. Dataquest's PC shipment forecast calls for 57 million units to ship in 1995, and in excess of 65 million units in 1996. This means a strong 19 percent growth in worldwide PC unit shipments this year and an equally impressive 18 percent growth for 1996.

Within each of these PCs we see another jump in the amount of DRAM consumed. The minimum DRAM size will increase from the 4MB per PC that shipped in 486-based PCs in 1994 up to 6MB when the 8MB Pentium minimum is averaged with the 4MB 486 this year.

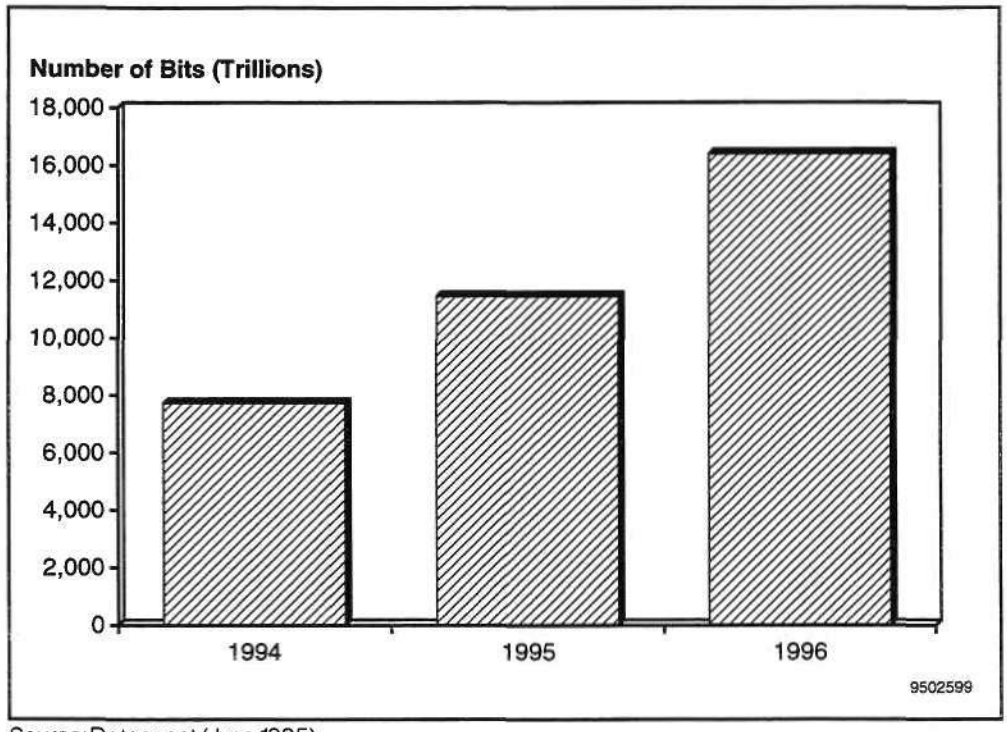
Now let's look at Figures 3 and 4. Figure 3 shows the annual bit demand of the total data processing market and other DRAM markets. We derive this number from our electronic equipment forecast, which includes PC and other data processing forecasts as well as forecasts for other DRAM applications such as printers, fax machines, video games, hard disk drives, and even digital set-top boxes. This is the demand side of our supply demand analysis, and is driven to a great extent by the health of the PC market.

DRAM Shortage Will Continue

In Figure 4 we see the difference between the *supply* of DRAMs and the *demand* based on the electronic equipment production forecasts used to generate Figure 3. This undersupply is expressed in percentage of bits, where a number less than zero indicates an undersupply of bits shipped into the market.

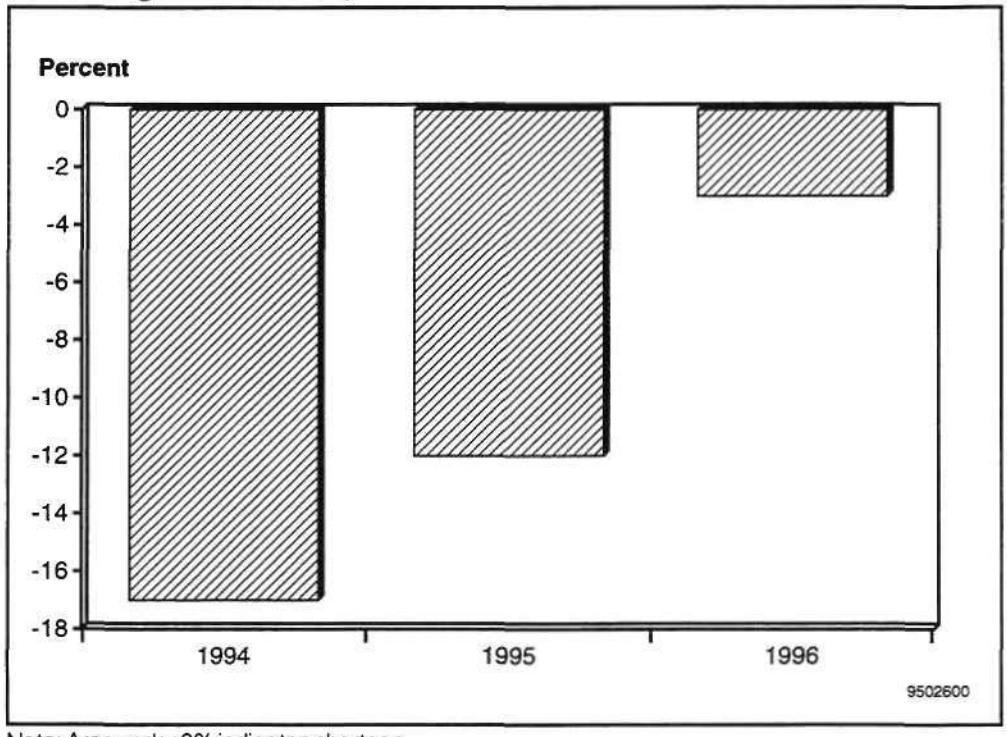
As long as there exists an undersupply, DRAM prices will either hold or go up. Despite a recent increase in our estimates for 4Mb DRAM production in 1995, Dataquest expects the shortage to continue through 1996, mostly

Figure 3
DRAM Demand in Bits



Source: Dataquest (June 1995)

Figure 4
DRAM Supply/Demand Scenario, 1995 to 1996 (Supply as Percentage of Demand)



Note: Area under 0% indicates shortage.
Source: Dataquest (June 1995)

because of the late start of the 1Mx16 ramp-up. Although the shortage will lessen, from nearly 20 percent in 1994 to less than 5 percent in 1996, it will still be a shortage, and prices cannot be expected to fall dramatically.

So what about all that added capacity, and, more importantly, why do some forecasters predict DRAM price plunges while Dataquest holds that the undersupply will continue? This misunderstanding stems from a commonly held belief that all convertible capacity will immediately be put into volume production of 16Mb DRAMs. This alone would at least satisfy DRAM demand, if not overwhelm it. Instead, a large portion of the convertible capacity is still being used to produce 4Mb DRAMs.

This begs the question: "Why don't DRAM suppliers convert all convertible capacity quickly to 16Mb devices?" The following is our explanation.

PCs account for more than two-thirds of all DRAM consumption. There is a phenomenon called "granularity," which forces PCs to diverge from using traditional organizations of DRAMs of x1 and x4. Instead, today the great majority of 16Mb density DRAM demand is for a 16-bit-wide organization. There are two reasons that the x16 version of the 16Mb DRAM is not available today in the volumes needed by the PC market:

- First: DRAM manufacturers waited to introduce the x16 version of the 16Mb DRAM until they had met reasonable production yields on the more traditionally accepted x1 and x4 versions.
- Second: Design, debug, and test of the x16 organization present challenges never before encountered by DRAM designers and manufacturers.

The result of this is that, despite the timely ramp-up of the 16Mb DRAM, the ramp-up of the 1Mx16 version is about 18 months behind the market. The need for this particular part has had to be filled by the 1Mx4 version of the 4Mb density, and four times as many of these parts are required to make up the difference.

The result is that, until the x16 organization of the 16Mb DRAM ramps into high-volume production, there will be a severe shortage, and an overwhelming consumption of 4Mb DRAMs to account for the difference.

We see strong price-ups in the spot market. However, this has not been the case in the contract market, mostly owing to the close business relationships most DRAM manufacturers try to maintain with their clients. Japanese DRAM manufacturers have pointed out to us that, while they have held the ASP for a 4Mb DRAM at 1,200 yen since mid-1992, they had every opportunity to raise prices. Their reluctance to raise the price to "what the market will bear" shows restraint in an effort to continue to satisfy their customers' needs. As I noted at the outset, we continue to carefully watch for any change in DRAM contract pricing, especially in North America.

Dataquest Perspective

In conclusion, although Dataquest has observed a very strong response to the current DRAM shortage in the form of plant expansions, we do not expect this new and existing capacity to be able to match demand through 1996. The result should be continued allocation, high spot-market prices, and the continuance of DRAM contract-volume prices to be keyed to a fixed yen value.

Transcript of Telebriefing

At this point the introductory statements ended and the forum was opened for questions. All callers remained anonymous.

Q: Can you tell me what your old PC and Pentium unit forecasts were, and can you give us a look at DRAM pricing? Where do you see the 4Mb this year during the various quarters and into next year?

Ron Bohn (RB): Our prior PC forecast worldwide for this year was approximately 54 million units; the Pentium forecast for this year was originally just over 20 million units. Our original worldwide PC shipments forecast for next year was in the low 60 millions. I do not know offhand what we said for Pentium for next year. On pricing we have the contract pricing for the 4Mb. We basically showed pricing above $12, but we had anticipated perhaps going a little bit under $12 for the end of this year, and that is one of the forecasts we are looking at right now. Maybe my associate can give us a little indication of what the 16Mb pricing is. I do not have that offhand.

Mark Giudici (MG): In the current quarter, volume pricing for the 1Mbx16 device is approximately $54 in the North American marketplace. With the current forecast we see it going down slightly to under $45 by the end of the year. However, as Ron was saying, this forecast will probably be revised upward to some extent as the supply and demand work through the marketplace. But this is the current forecast.

Q: So, do you expect 4Mb DRAM pricing to be over $12 by the end of this year? And in terms of spot market pricing, where do you see that in contrast to the contract pricing?

MG: Spot market prices definitely will be higher. As far as forecasting the spot market, that's like trying to find out which way the wind is blowing.

Q: How much of a premium do you see right about now?

MG: The premium is that the 4Mb level, the 1Mbx4 part, for example, ranges from between $15 on the low end to as high as $20 from what we have heard, so you can see there is quite a bit of variance between contract and spot. I have not gotten any spot price points on the 1Mbx16. I think the majority of those parts are going to contract users. The forecast for spot is difficult to call.

Jim Handy (JH): One thing you should keep in mind is that NEC and Toshiba in Japan announced a 5 percent price increase to make up for yen-to-dollar exchange ratios.

Q: For the various configurations of 16Mb DRAMS x 4s, x 8s, x16s, how many dice fit on the 8-inch wafer, and what are the yields for the various types at this time?

Clark Fuhs (CF): I can tell you generally the 4x4 and 1x16 average die size at present and a yield range that we are hearing from the marketplace. The 4x4 average is about 100 sq. mm., and the 1x16 is about 5 percent to 10 percent larger than that. We have heard of yields on the 4x4 of as high as 75 percent, but we estimate an average in the 70 percent region. We have heard a fairly wide range for the x16, anywhere between 40 percent and the low 50s. We are pegging basically about a 45 percent to 50 percent yield on those.

Q: What is your estimate for 1995 for PC unit shipments?

JH: The 1995 total PC unit shipment number is 57 million units. This includes all levels of PCs, from deskside through transportable.

Q: And how many Pentiums? Twenty-five?

JH: More than 25.

CF: I just remembered a number on the number of dice on the 6-inch wafer. You could fit about 150 of the 4x4-16Mb DRAMS on it; for the 8-inch wafer you multiply that by about 1.92.

Q: I have a couple of questions that relate to the 1996 analysis that you have here. First of all, I would like to look at the supply-side and demand-side question. On the supply side, in 1996 there seems to be a big differential between what you are estimating and what the suppliers are estimating, and I would like you to comment on that a little more. There are a lot of new suppliers coming onstream, and I'm wondering if their strong suit is in new fabs or new designs. Is it possible that the supply side that you're estimating may be a little high, that maybe the difficulty in bringing on new fabs has not been fully factored in?

On the demand side, the amount of memory per PC you are using is 4MB now, and 6MB in 1995. This seems to be about half of what I hear from some actual users. It seems to me that, if you're assuming 6MB per PC in 1995, your analysis may be a little light on the demand side, leading us to question a supply/demand balance by the end of 1996. What supply figures are you using in your analysis of 2 percent undersupply in 1996? Is that the estimate you have generated, or is that the estimate of supply that came from the manufacturers?

RB: First of all, let me talk about the demand-side question. We are talking in terms of megabytes per system. We were just talking about the PC/OEM level out the door. In terms of a full-upgrade scenario, we have a much higher number. The main thing we do not want people to do is to apply this number against our PC forecast, because that would overstate the demand side.

In terms of an upgrade scenario for PCs after they leave the PC/OEM, for 1995 we show an upgrade in the ballpark of under 16MB, which is much more in line with what you were talking about. Going out to 1996 the number increases more, somewhere under 20MB. So again, what we were highlighting was the megabytes per system at the PC/OEM level coming out the door. On the demand side, I just want to highlight one item. Figure 1 shows the forecast of what DRAM suppliers expect to be shipping. The higher bar that we alluded to shows the whole point of the telebriefing. What if the supplier really pushed to use the convertible 16Mb capacity for the production of 16Mb devices? I would like to turn this question over to Clark.

CF: We did a fab-by-fab analysis. A lot of the newer fabs coming online in 1996, some of which you alluded to, have been only mildly factored into our supply-side analysis. We have been rather conservative in how those would ramp up. The production yield on 16Mb is tracked by company in our model. The average across all companies is about 50 percent or so today, increasing by the end of 1996 to the 65 percent to 70 percent range. If yields do not pick up that much, then of course the window for the supply side would be pinched on the top end and the overall bars for the end of 1996 in Figure 1 would come closer together. As I described in my opening statement, we believe that the primary reason for the difference is that suppliers are not optimistic in the near term about how they're able to ramp yields. We took a realistic look at the market and have assumed ramp-up will take two years, and we would believe an increase to the 65 percent to 70 percent region would be a reasonable yield at full production. That is how we came up with the data in Figure 1.

Q: Which set of the supply-side bars in Figure 1 did you use in the supply-and-demand calculation that drives Figure 4?

JH: Let me embellish on Ron's megabyte-per-system number. I used minimum system configuration to highlight the effects the Pentium will have on the market. Last year the market was nearly 100 percent 486 and the absolute minimum configuration for 486 is 4MB. This year we are expecting nearly 50 percent of the market to be Pentium, and the absolute minimum configuration on the Pentium is 8MB, so the effect will be that the absolute minimum averaged out over all the systems to ship is going to be 6MB. That is a 50 percent lurch in one year. That is pretty significant, especially in the face of flat pricing. The way that we look at DRAM pricing, and the answer that Ron was giving you, is this: We look at the overall total DRAMs that go into the PC market, and we analyze this by the different levels of PC and therefore use different megabyte numbers for each level. We also take into account all the upgrades that are inserted as "after equipment" into systems that have already left the store and have been in use for a while in the office or the home, and so we do factor those in and we do come up with a much higher number. It's something I do not have here to share with you. You're right when you say that the 4MB and 6MB numbers are about half of what you've seen from other places; in fact, the numbers are about half of what you'd see if you looked at our numbers for overall DRAMs shipped into the PC channel. I hope this answers your question.

Q: How big is the U.S. market for DRAM SIMMs, the actual modules, and how does this affect where the demand for the DRAM chips is coming from? Is it coming from the aftermarket suppliers or from the OEMs, or both?

JH: It's kind of funny. There are two sides to the SIMMs market, and we are going to be doing a report in June that covers the market. This is one of those markets that fall in the cracks at Dataquest. In the past, the Semiconductor Group has said, "It's not a semiconductor so it should be covered by the Systems Group"; unfortunately, the Systems Group says, "We should watch over things that have CPUs in them." The net result is that we could have done a better job of covering this market than we actually have done. We are working to fix that right now, and that is what the June report is going to address.

Some argue that SIMMs are half of the entire DRAM market. Some believe that the SIMMs market is split up pretty evenly between DRAM manufacturers who produce SIMMs and aftermarket SIMM manufacturers. There's a very different complexion between the two kinds of suppliers. The aftermarket manufacturers tend to buy on the spot market at highly inflated prices and are somehow able to recoup and make a profit. Meanwhile, the DRAM manufacturers use internal transfer costs to account for the DRAMs that go onto the SIMM and they sell in contract volume almost exclusively to OEMs for the SIMMs that go into the PCs that ship from the OEMs to the dealer. So, in terms of sales channels, the DRAM manufacturers sell SIMMs to the OEMs. Once the boxes that are made by the OEMs go to a sales channel—a computer store or something like that—any upgrades are pretty much handled by the exclusive SIMM manufacturer, which also handles upgrades made after the equipment is installed in the office or home.

Q: Do you think the aftermarket is growing faster in terms of its demand for DRAM chips than the OEM side?

JH: We do not think so; however, there is something to watch that is kind of a hunch right now because we have only seen one possible cycle. We have seen the up and the down and we are expecting it to happen again. SIMMs are very appealing where there is some ambiguity as to which density DRAM gets you the cheapest 4MB, and right now there is no question about it. The 4Mb DRAM will give you the cheapest SIMM for a 4MB SIMM; 16Mb is not quite there yet, and a 1Mb, if you can get one, is going to be a more expensive solution. Because of that, OEMs are laying down DRAMs right on the motherboard. As we get to the point where 4Mb and 16Mb prices for the organization of parts that people want are tracking each other, and we expect that to be a very long period this cycle, then we'll think that SIMMs will be more popular in the OEM market, and so the SIMM market will blossom for OEMs.

As far as selling to the aftermarket, that's more difficult to say because an awful lot of that is the perception of need on the users' behalf. We've heard an argument that the advent of Windows 95 will reduce the main memory size required to support software, and there is technical merit to that argument, because in the virtual memory model that is supported by Windows 95, you do not need as much memory. But we don't buy that. We think that Windows 95 could increase demand simply because there will be a

commonly held perception, right or wrong, that you do need more memory for it. Depending on an awful lot of consumer-type things, the market could grow significantly or it could just grow at today's rate.

Q: What are your perspectives on the growth of the SRAM market, and how do you see EDOs impacting that growth?

JH: That's an interesting question. SRAMs are used for caches in PCs. Our belief is that caches are bought in PCs more for their perceived performance than their actual performance. As a result, things that have been very well positioned to make the SRAM cache obsolete have not sold very well in the past, and even three years ago. We do not know how long that is going to continue, how long caches are going to be popular in PCs, but we do not believe that EDO or synchronous DRAM or any other exotic DRAM architecture will be able to dislodge the commonly held notion that more cache is better.

Q: Could you comment on the current capacity of raw 8-inch silicon wafers? Also, is there going to be enough capacity to support all the planned fab increases in the next several years?

CF: Yes, we did a wafer supply/demand analysis for raw 200mm wafers about nine months ago. We did a fab-by-fab analysis as well as a supplier-by-supplier plant analysis and compared them, and we also compared them with a top-down analysis forecast. At that time the demand caught up with and outstripped supply by the end of 1995. Since our study, silicon wafer manufacturers committed about $1 billion of new capital for the expansion of 200mm facilities. So nine months later the crossover point where demand would exceed supply, where we would actually be put into a shortage situation that we are not into today, was also pushed out about nine months. Our outlook is that the capital will continue to come as the demand comes, because 8-inch wafer pricing is still pretty firm and is actually edging up a little bit. We are confident that the supplier base will be able to adequately respond to that need. Also, there is quite a bit of flexibility in the use of test and monitor wafers, which is a pretty high percentage of 200mm usage. That can be scaled down quite dramatically to make up any shortages or spot shortages that could exist.

Going back further in the food chain, we've heard that there is some concern about the polysilicon market—the raw bulk silicon supply that the wafer manufacturers buy from. In 1992 we actually tracked, on a rough basis, the utilization of those plants. We really do not cover that market in any more detail than that. In 1992 the capacity utilization was in the low to mid seventies, and it's probably in the mid eighties right now. There are two suppliers that have been expanding pretty aggressively over the last two years, and these two basically supply just under 50 percent of the market.

Again, our outlook is for fairly high utilizations going forward for these plants, but they will be just about balanced with a little bit more supply than demand. They will be able to stay ahead of the power curve. There is enough commitment to the investments, enough commitment to the market. We feel confident that the suppliers will be able to respond.

Q: Looking at 1995, 1996, and 1997, how much of the capital spending would support 16Mb/64Mb processing of 0.35 micron and better?

CF: I've got that—what mix of equipment is being shipped, what kind of technology that can support—but not with me. Suffice it to say the bulk of equipment shipped in 1994 was for 0.5 micron and the bulk that will ship in 1998 will be 0.35 micron production. As far as the exact numbers for the years in between, you would have to give me a call later.

Q: It is no secret that the DRAM vendors themselves said that the x16 configuration is the one the market wants. In your 1996 supply-and-demand analysis, what assumptions have you made about their ability to improve the x16 yields?

CF: I think I already stated that for 1994 we basically used an average yield figure of about 50 percent or so; that includes a mix of 4x4 and 1x16. The outlook for the end of 1996 is that the average yield would be in the 65 percent to 70 percent range, and I think that's fairly representative of the assumptions we made for the x16 yield ramp.

JH: Let me just add something to that. Those assumptions are based on the pale bars in Figure 1. You can see we are getting a little more conservative estimates from the DRAM manufacturers themselves, and that's represented by the lighter-colored bars. We do get a lot of input from DRAM manufacturers as to what they expect their capacity to do, and that is what that represents there. So we take all this into consideration when looking at supply and demand.

Q: Could you please provide more detail on the 4Mb DRAM pricing, by quarter; what you had predicted and what your estimate is as you look again at that pricing?

RB: First of all, our price outlook: We are definitely going to hold off until we see what happens with the contractual negotiations going on right now. Let me go over the 4Mb DRAM published price. This is for the first-year North American buyers. I will just highlight the 1Mbx4. For the first quarter of 1995 we had it at $12.66, second quarter around $12.50, third quarter at $12.25, and fourth quarter just around $12.00. If you look back six months ago, all these numbers for the end of this year are somewhat higher, so each quarter we see more and more factors that play into the hands of DRAM suppliers. The Kobe quake at the beginning of the year had no real impact on supply and demand, but psychologically it helped the suppliers. And the yen-to-dollar exchange rate we are highlighting today definitely is a fundamental factor, and it causes Japan-based suppliers to start looking at their profit margin and their DRAM revenue. The Japan-based suppliers really use a ¥1,200 price for the 4Mb DRAM in their forecast, in their bank loan applications and other functional analyses. It's of fundamental importance to them.

Q: What is the premium for EDO and 3.3 volts?

JH: We have already heard from one supplier that is not charging any premiums for the EDO whatsoever. The way that EDO is viewed both by suppliers and by users is that it's a zero cost option, as it should be, because it's

going to be widely supplied and it has near-zero die area penalty and so doesn't really cost anything for the DRAM manufacturers to crank out. It's a very popular option because it gives added speed at no extra cost. The early initiators of 4Mb DRAM EDO today ask for a 5 percent premium, which should disappear sometime next year. Because of that, Dataquest is forecasting that EDO DRAMs will have virtually displaced the standard fast page-mode DRAM by the end of 1997.

As for the 3 volts, I have always thought this was an odd kind of thing. The reason we have 3 volts is that DRAM manufacturers couldn't see a way that they could get down to submicron geometries without asking the world to go down to 3 volts with them. Several years ago they took this to the standards committees and asked for things to change. Now that DRAM manufacturers have a 5-volt interface on a part that works 3 volts internally, which they did not think was a reasonable thing to do back when the standards were being created, they are shipping DRAMs that are pure 3-volt DRAMs at higher prices than they were charging for 5-volt DRAMs with a 3-volt core. That switchover probably will not happen until there is an oversupply, because there is an existing market. It is kind of a feat of daring to go out there and sell a 3-volt part for less than any of your competitors. And actually 3-volt-only operation offers some benefits to the user. Because of that, DRAM manufacturers are taking advantage of the situation and are charging a premium. I would believe that the premium is somewhere around 15 percent, but Ron might be able to provide more information on that. We could talk offline if you need a precise number.

Q: You show a 12 percent shortfall in supply/demand. Is that evenly broken up between 4Mb DRAM and 16Mb DRAM?

RB: We show a shortage for the 4Mb DRAM in 1995. Just over 10 percent for the 4Mb DRAM in 1995; 1996, if you go for the full year, may be almost balanced. I will get to that in a second. For the 16Mb DRAM, a 13 percent shortfall for 1995 and about a 5 percent shortfall for 1996. Looking at the 4Mb DRAM, on a quarter-by-quarter basis, in the first half of 1996 we show a shortage of 5 percent to 10 percent, so we are looking at the fourth quarter of 1996 to see whether there will be a supply/demand balance or a kind of excess-supply scenario. We definitely view that as a hedge factor and are focusing a lot on it. Basically, the 16Mb DRAM has a clear 5 percent shortfall in 1996; and in a very aggregate level, maybe the 4Mb DRAM is close to a supply/demand balance, if you roll in the fourth quarter of 1996.

Q: When do you think you will be able to republish your estimated prices on the 4Mb DRAM? My understanding is that those prices will go up. Is that your feeling?

RB: The first thing we will do in our DQ Monday Pricing will be to provide guidance on that. Our next published forecast, the one that I cited here, is officially scheduled to come out in the May time frame. But independent of this, the DRAM memory forecast is being revised in the near term, so maybe sometime during April we will have a little more guidance on that. That is a little more on the worldwide perspective, but it should fit into all the scenarios that emerged based upon the contract negotiations.

Q: You mentioned that the pricing was North America pricing. How does this stack up regionally?

RB: In the pricing shown there, North American buyers are the preferred customers. This is, in most cases, the lowest pricing that we will really see. There may be some spot-market differentials or preferred pricing within a transfer price, but basically this is on the low side.

Q: I have a question about the yields. You are looking at 40 percent to 50 percent for the 16Mb DRAM, and 65 percent to 70 percent in 1996. Do you have best-case and worst-case scenarios, and what would that imply to the equipment market demands? Is the boom in equipment spending this year in anticipation of the low end of the yield forecast or the high end?

CF: Well, the boom in equipment this year is more in relation to what kind of capacity people have to add right now. The 1x16 yields are not high enough at present or the price per bit on a cost level low enough to translate to the pricing. So it's actually more economical to make 4Mb DRAM right now, and that's just on a "per-bit" basis. That requires a little bit more silicon, and that is why capacity was added this year. There is going to be more added convertible capacity that is initially going to be running 4Mb DRAM this year. That's basically the bottom line for 1995. As the 16Mb DRAM 1x16 yields increase and get to a level that is cost-effective for the supplier, on a price-per-bit basis, that will be part of what triggers a pull of the 1x16 configuration part into the end-use market, and that should trigger the conversion of 4Mb DRAM capacity to 16Mb DRAM capacity. The dynamics would then cause the equipment market to pause, because bit capacity can be added without new equipment. So that's the course of events that will take place, as we see it.

If 16Mb yields remain low, and the market never converts, the equipment boom will never go away. If you take the other side to the ultimate limit and yields shoot up to 80 percent tomorrow, you could see a pretty bad second-half 1995. We are basically watching the yield issues in the 1x16 DRAM. That's the key.

Q: Where is Korea on the yield curve here?

CF: Korea has basically been producing the 4x4 part. As of the second half of 1994 going into 1995, the two main suppliers of the 1x16 part were NEC and Toshiba. Ron and Jim might have some additional comments on that.

RB: The main comment on that is that Toshiba clearly is pushing ahead with the 1Mbx16. We heard that Hyundai will be ramping up in the second quarter and that Samsung and NEC were also ahead of the pack. A lot of the other suppliers we talked to about the 4Mb DRAM tell us that they are interested in extending the life cycle for the 4Mb DRAM density, that they wished they had ramped up the 1Mbx16 already, and that it is more and more tomorrow's story. So the 1Mbx16 ramp-up scenario is quite conservative, and we're not getting any reports that cause us to expect a big acceleration in the 1Mbx16 ramp-up in the near term.

CF: One additional comment: The 4x4 yields are high enough to warrant a lower price per bit. In fact, the 4Mbx4 DRAM can be purchased at a lower price per bit than the 4MB DRAM. The problem is that it is not the right part for the PC market and therefore demand is not being pulled, even with that lower price. That's why we have the scenario we do today.

Q: In the demand side, has any consideration been given in the Latin American situation?

JH: The PC Group is not represented in the teleconference right now, and someone from that group would probably be able to talk about that. In general, when the PC Group analyzes demand, it analyzes for existing markets more than hypothetical markets. Latin America is just starting to emerge—as soon will be India, China, Eastern Europe, and even Japan—and these are markets that we do not know an awful lot about but that look poised to increase PC consumption. If anything, I would tend to believe that our PC Group is conservative about forecasting what's going into those areas. Fortunately we are not predicting some glut of DRAMs, because if those markets open up, the shortage could be worse than it is now.

Analyst Bios

Ronald A. Bohn, Senior Industry Analyst, Memories Worldwide

Mr. Bohn is a Senior Industry Analyst for Dataquest's Semiconductor Memories Worldwide service. He is responsible for research and analysis in semiconductor memory pricing, supplier, and product technology trends including DRAMs and flash ICs. His responsibility includes strategic planning, competitive analysis, and consulting projects. He works with securities companies, banks, and other members of the financial community on semiconductor trends and also tracks world trade, intellectual property, and related legal trends for their impact on the electronics industry. At Dataquest he has forecast pricing of more than 100 semiconductor products. Mr. Bohn has written a series of reports on benchmarking and has assessed semiconductor life cycles from a component engineering perspective. This research served as a basis for Dataquest's PC "teardown" cost analysis. At Dataquest, he has also served as the analyst tracking semiconductor trends in the interactive CD-ROM player and PCMCIA markets. Prior to joining Dataquest in the mid 1980s, Mr. Bohn assessed worldwide electronic markets on a macro- and microeconomic basis for a market research company. He served as International Market Research Manager for the Korea Trade Center in the United States and has financial, legal, and government experience. Mr. Bohn received a B.A. degree from Cornell University, an M.B.A. degree from the University of California at Berkeley, and a J.D. degree from the Hastings College of Law.

Clark J. Fuhs, Senior Industry Analyst, Semiconductor Equipment, Manufacturing, and Materials Service

Mr. Fuhs is a Senior Industry Analyst for Dataquest's Semiconductor Equipment, Manufacturing, and Materials service in the Semiconductors group. He is responsible for research and analysis of semiconductor materials and trends in IC manufacturing techniques along with forecasting capital spending and the wafer fab equipment market. Prior to joining Dataquest, Mr. Fuhs was Strategic Marketing Manager for Genus Inc., a manufacturer of advanced chemical vapor deposition (CVD) and high

energy ion implantation equipment. During his 10 years at Genus, he held positions of Product Manager, several responsibilities in Product Marketing, and Process Engineer in the metal CVD group. In his most recent position, Mr. Fuhs was responsible for correlating process techniques with demand for equipment and materials. He has been involved with the Modular Equipment Standards Committee of SEMI, a trade organization, as chairman of a task force, authoring a standard. His experience also includes Chevron Oil, where he was a Process Engineer in the Richmond, California, refinery responsible for the hydrogen manufacturing plant. Mr. Fuhs earned a B.S. degree in Chemical Engineering from Purdue University in West Lafayette, Indiana, and received an M.B.A. degree from the University of California at Berkeley.

Mark Giudici, Director and Principal Analyst, Semiconductor Procurement Service

Mr. Giudici is the Director and Principal Analyst of Dataquest's Semiconductor Procurement service. He is responsible for tracking and analyzing emerging semiconductor procurement issues and trends. He also covers regional semiconductor prices and cost modeling issues including product/supplier analysis on MPU and ASIC markets. In addition, he has participated in various custom research projects involving procurement needs, contract manufacturing, system teardown analysis, and regional price differentials. Prior to joining Dataquest, Mr. Giudici spent eight years in both the computer and semiconductor industries, where he held a variety of financial and marketing positions. Most recently, he was a Product Marketing Engineer with American Microsystems, where he was responsible for cost modeling and marketing semicustom and foundry-custom semiconductor components. Mr. Giudici received his B.S. degree in Business Administration from the California State University, Chico and his M.B.A. in Business Management from the University of Oregon.

Jim Handy, Director and Principal Analyst, Semiconductor Memories Group

Mr. Handy is Director and Principal Analyst for Dataquest's Semiconductor Memories group. He is responsible for the forecasting and analysis of memory products and markets. Previously, he was strategic marketing manager for static RAMs at Integrated Device Technology (IDT). Before IDT, he was product marketing manager of memory and microcomputer-based products at Intel Corporation, National Semiconductor Corporation, and Siemens Corporation. Mr. Handy earned his M.B.A. degree at the University of Phoenix and holds a B.S.E.E. degree from Georgia Tech. He is the author of "*The Cache Memory Book*" (Academic Press, 1993), he is a frequent speaker, and his work has been widely published in the trade press.

For More Information...

Jim Handy, Director/Principal Analyst ..... (408) 437-8228
Internet address ..... jhandy@dataquest.com
Via fax ..... (408) 437-0292

Dataquest
a company of The Dun & Bradstreet Corporation

Market Analysis

Memories Worldwide

Quarterly Industry Review

Second Quarter 1995 Quarterly MOS Memory Regional Shipment Forecast

Abstract: *This is the third issue of a new deliverable of the Memories Worldwide service, which contains North American unit shipment estimates for 11 important MOS memory devices. This quarterly report contains a rolling four quarters of history, four quarters of forecast data, and top-five North American market vendor rankings for each device. Dataquest plans to expand this coverage outside the North American market into other regions.*

By Jim Handy

MOS Memory Forecast

Table 1 shows Dataquest's North American unit shipment estimates for the second quarter of 1995 for 11 important MOS memory devices. This table represents a rolling four quarters of history and four quarters of forecast data.

Dataquest

Program: Memories Worldwide
Product Code: MMRY-WW-QR-9503
Publication Date: December 25, 1995
Filing: Market Analysis

Table 1
MOS Quarterly Memory Shipments into North America, 1994 to 1996
(Thousands of Units)

Device Type	Density	Q3/94	Q4/94	Q1/95	Q2/95	Q3/95	Q4/95	Q1/96	Q2/96
DRAM	2Mb	5,003	5,812	5,748	7,185	7,106	7,028	6,951	6,875
DRAM	4Mb	121,047	128,917	136,198	147,094	155,401	164,177	173,449	183,245
DRAM	16Mb	11,090	17,017	22,184	26,621	34,705	45,244	58,983	76,894
SRAM	256Kb ≤35ns	20,133	23,834	30,849	38,870	50,310	65,118	84,285	109,093
SRAM	256Kb ≥45ns	18,641	18,096	14,439	14,728	11,752	9,377	7,482	5,970
SRAM	1Mb ≥45ns	6,949	7,286	9,428	9,805	11,766	14,119	16,943	20,332
EPROM	1Mb	7,422	7,719	8,155	8,775	9,270	9,794	10,347	10,931
EPROM	4Mb	3,044	3,362	3,699	3,958	4,354	4,790	5,270	5,797
Flash	1Mb	9,936	11,221	10,892	12,003	11,651	11,310	10,978	10,657
Flash	4Mb	1,399	1,925	1,846	2,381	3,096	4,024	5,232	6,801
ROM	16Mb	2,344	2,440	3,262	3,265	3,918	4,702	5,642	6,771

Source: Dataquest (December 1995)

DRAM

There is little change between last quarter's estimates of 2Mb VRAM sales and those for the first quarter of 1995. Although 1995 annual use will be above overall 1994 unit shipments, Dataquest continues to anticipate a mild downturn late in 1995 as these new DRAM architectures move to displace this device. North American market supplier rankings are as follows:

1. MOSel-Vitelic
2. NEC
3. Toshiba
4. Fujitsu
5. Hitachi

There is unsurpassed strength in the personal computer market, and Dataquest is continually upgrading the PC forecast. As a result, the estimate for the popular 4Mb DRAM, sold mainly to the PC market, is being increased slightly from last quarter's estimate. This does not come at the expense of any other devices, therefore it is not incongruous for us also to raise our estimates for shipments of the 16Mb DRAM. Rankings for 4Mb DRAM suppliers to the North American market are as follows:

1. Micron
2. Hitachi
3. Samsung
4. Texas Instruments
5. NEC

Rankings for 16Mb DRAM suppliers to the North American market are as follows:

1. Samsung
2. Mitsubishi
3. NEC
4. Toshiba
5. Hyundai

SRAM

The 35ns and faster 256Kb SRAM continues to grow in North America. Intel's rapid ramp of the Pentium CPU continues to drive the use of cache into a higher percentage of PCs, generating a phenomenal demand for this part. Cache memory continues to be perceived by most PC purchasers to be an important performance-enhancing feature. This generates huge demand for high-speed 32Kbx8 SRAMs. Intel's Pentium processor shipments this year are expected to reach nearly 30 million units, each of which could consume eight 32Kbx8 devices. Rankings for suppliers to North America are as follows:

1. Cypress
2. Integrated Device Technology
3. Alliance
4. Motorola
5. Toshiba

The North American market for slower versions of the 32Kbx8 continues to convert to the 1Mb density. As we have pointed out in the past, the third quarter of 1994 was the quarter in which this device's shipments peaked, and a ramp-down is in process. North American supplier rankings are as follows:

1. Hitachi
2. Samsung
3. NEC
4. Sony
5. Mitsubishi

Although the slower-speed 1Mb SRAM has reached the peak market share of its life cycle, and it can now be expected to lose market share to the 4Mb density, sales increased from the first quarter. We now expect to see continued growth through the term of this forecast. Rankings for suppliers to North America are as follows:

1. Mitsubishi
2. Hitachi
3. Samsung
4. Toshiba
5. NEC

EPROM

The market for 4Mb EPROM, used in growth applications, is increasing well in 1995. Wider availability of the 1Mb flash memory seems not yet to have eroded the 1Mb EPROM market in PC BIOS applications. Both densities are expected to continue to grow.

North American market rankings for suppliers of the 1Mb EPROM are as follows:

1. Advanced Micro Devices
2. Texas Instruments
3. Atmel
4. SGS-Thomson
5. Macronix

North American market rankings for suppliers of the 4Mb EPROM are as follows:

1. Texas Instruments
2. Advanced Micro Devices
3. SGS-Thomson
4. Toshiba
5. Hitachi

Flash

Unit shipments of the 1Mb flash memory continue to be relatively flat. Sales of the 1Mb flash in 1995 should be about equal to sales in 1994. Applications are undergoing a conversion this year from the 1Mb to the 2Mb density. Dataquest still expects the 4Mb flash's high growth to last through the year. The 4Mb flash memory is found in a wide array of telecommunications systems, ranging from LAN routers to cellular handsets.

North American market rankings for suppliers of the 1Mb flash memory are as follows:

1. Intel
2. Advanced Micro Devices
3. Catalyst
4. Fujitsu
5. Atmel

North American market rankings for suppliers of the 1Mb flash memory are as follows:

1. Advanced Micro Devices
2. Intel
3. Toshiba
4. Atmel
5. Mitsubishi

Mask ROM

The 16Mb mask ROM appears to have stopped growing suddenly from the first quarter to the second quarter, but we expect growth to resume later in 1995. Shipments of this device into the North American market amount only to about one-tenth the worldwide market. Because the bulk of the market for mask ROMs is in Japan, the North American market rankings are of less significance than the worldwide ranking given in Dataquest's Worldwide Memory Market Share statistics document (MMRY-WW-MS-9501, April 17, 1995).

1. Samsung
2. Sharp
3. Macronix
4. LG Semicon
5. Mitsubishi

Dataquest Perspective

The 1995 North American memory market continues to show strong signs of growth. Skyrocketing sales of the 4Mb DRAM continue, and the 16Mb DRAM and 2Mb VRAM also are on the rise.

Fast 32Kbx8 SRAM sales continue to be driven by the rapid ramp of Intel's Pentium processor, while slow SRAMs are growing at a far slower rate. EPROMs and flash memories are both growing at all densities, but the lower densities are being outshone by their bigger counterparts. North American sales of the 16Mb mask ROM, although in a lull, are expected to resume growth in the third quarter.

```
MMRY-WW-QR-9503                    Qty:   1
Mr. Joe Grenier
Dataquest Incorporated
1-1100
*/
--INTERNAL DIST.--
```

For More Information...

Jim Handy, Director/Principal Analyst..... (408) 468-8228
Internet address..... jhandy@dataquest.com
Via fax..... (408) 954-1780

Dataquest
a company of The Dun & Bradstreet Corporation

Perspective

Memories Worldwide

Telebriefing

When Will the DRAM Shortage End?

Abstract: *DRAMs have been in shortage since late 1992. At an aggregate level, the DRAM shortage should end during 1997. However, a recent telebriefing (June 23, 1995) highlighted the complexities of the DRAM supply-demand scenario when presented on a "product configuration" basis. For example, current trends signal a continued shortage of the x16 DRAM configurations during the very midst of the 1997 oversupply of the 4Mbx4 part.*
By Ronald Bohn

Introduction

This is Ron Bohn of the Memories Worldwide Service. In the room here at Dataquest are Jim Handy of the Memories service; Mark Giudici of the Semiconductor Procurement service; and Mario Morales of Dataquest's Research Operations group.

DRAM Supply/Demand Quarterly Statistics

Dataquest bases today's telebriefing on Dataquest's most recent assessment of worldwide DRAM supply-demand. In North America, we call this report the *DRAM Supply/Demand Quarterly Statistics*. The report links Dataquest's worldwide electronic equipment production forecast—the DRAM demand side—to our fab database, which is the DRAM supply side. From this we generate our worldwide 4Mb DRAM and 16Mb DRAM forecasts. The report presents the DRAM forecasts on a supplier-by-supplier, product-configuration-by-product-configuration basis.

Key Points

The telebriefing emphasizes three main points:

- First, at an aggregate level, the DRAM shortage should end during 1997—perhaps two years from now, in about second quarter 1997.

Dataquest

Program: Memories Worldwide
Product Code: MMRY-WW-BR-9504
Publication Date: July 31, 1995
Filing: Perspective

- Second, even so, some wider configurations of DRAM will remain in shortage throughout the entire 1995, 1996, and 1997 period. For example, the current mismatch between 1Mbx16 DRAM supply and demand will remain severe over the next several years. Supply will not meet demand for the x16 devices until the post-1997 period.
- Third, 1997 looks like a year of transition for the worldwide DRAM market. Several "newly emerging" multimedia-type applications should accelerate their consumption of DRAMs during 1997. For example, during the second half of 1997, newer DRAM applications such as graphics-rich video game systems and digital set-top converter boxes quite likely will join PCs in absorbing some of the worldwide DRAM supply.

PC Forecast

At this point, we will review Dataquest's worldwide PC forecast. Dataquest defines a PC as being a fully assembled system when received by the end user. Other microprocessor-based board products will be described later.

The current Dataquest PC forecast shows that 57 million PCs will ship worldwide in 1995. This represents a nearly 20 percent increase over the 1994 level. We expect 26 million PCs to use Pentium-level MPUs during 1995. For 1996, Dataquest expects worldwide PC unit shipments to increase by 18 percent, at 68 million units. During 1996, 53 million of these PCs will contain a Pentium-level MPU. The worldwide forecast for 1997 is 77 million PCs; this represents a 14 percent growth rate. We expect worldwide PC shipments to reach 100 million units during the year 1999. (Note that subsequent to the telebriefing, Dataquest made some nondramatic changes in the PC forecast.)

Board-Level Products

As indicated, there are additional board-level products that incorporate microprocessors and use DRAMs. Dataquest's DRAM supply-demand database now includes two new categories: upgrade motherboards and industrial boards.

Upgrade motherboards are boards most often used to upgrade older PCs. Also, some end users use them to assemble their own PC. For the 1994-to-1995 period, worldwide shipments of upgrade motherboards totaled about 4 million units each year. For the 1996-to-1997 period, shipments should total about 5 million units per year.

Industrial boards are boards used in systems such as medical imaging equipment and factory automation systems. Some of these industrial boards are known in the market as VME boards or FutureBus boards. An example application is ultrasound imaging equipment. For the 1995-to-1997 period, worldwide unit shipments of industrial boards should total about 3 million units each year.

DRAM Supply-Demand

We will now look at Figures 1 through 3. These figures provide the DRAM supply-demand outlook for the years through 1997. The figures are based on information from the *DRAM Supply/Demand Quarterly Statistics* report.

Top-Level View

Figure 1 shows combined 4Mb and 16Mb DRAM supply expressed as a percentage of demand for the 1994-to-1997 period. Note that the areas below 0 percent in the figure show DRAM market shortage while areas above 0 percent indicate DRAM oversupply.

Figure 1 presents a top-level view of the supply-demand scenario by using 4Mb DRAM equivalents or 16Mb equivalents.

The key message from Figure 1 is that:

- For 1994, at an aggregate level, there was a nearly 20 percent shortage of 4Mb/16Mb DRAMs.
- For 1995, there is a 10 percent shortage.
- For 1996, the shortage narrows to about 5 percent.
- By contrast, for 1997 there could be an aggregate 20 percent oversupply of 4Mb/16Mb DRAMs.

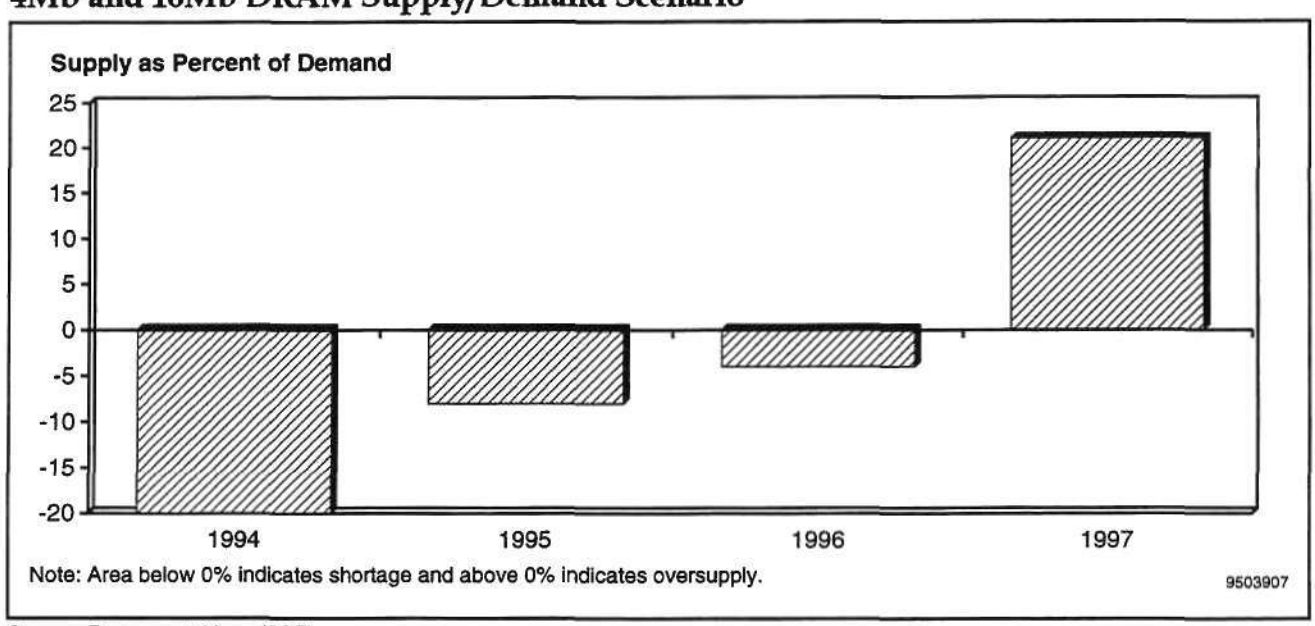
Note that the 64Mb DRAM will have little market impact until the year 1998.

DRAM Supply/Demand by Product Configuration

Figures 2 and 3 show differing scenarios for DRAM supply-demand in terms of specific product configurations.

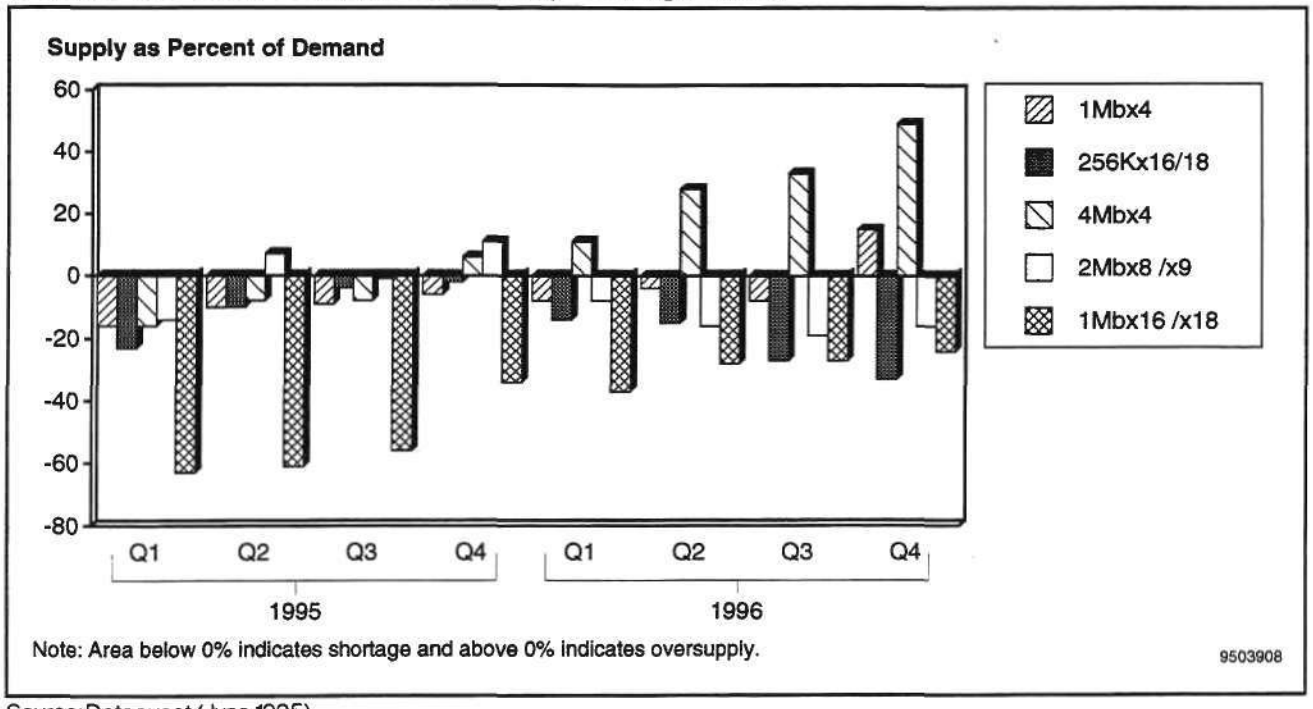
Figure 2 shows the quarterly 1995-to-1996 outlook for the 1Mbx4 configuration, the 256Kx16 organization, the 4Mbx4 device, the 2Mbx8 part, and the 1Mbx16 configuration.

Figure 1
4Mb and 16Mb DRAM Supply/Demand Scenario



Source: Dataquest (June 1995)

Figure 2
DRAM Quarterly Supply/Demand by Configuration



Source: Dataquest (June 1995)

Dataquest's outlook is as follows:

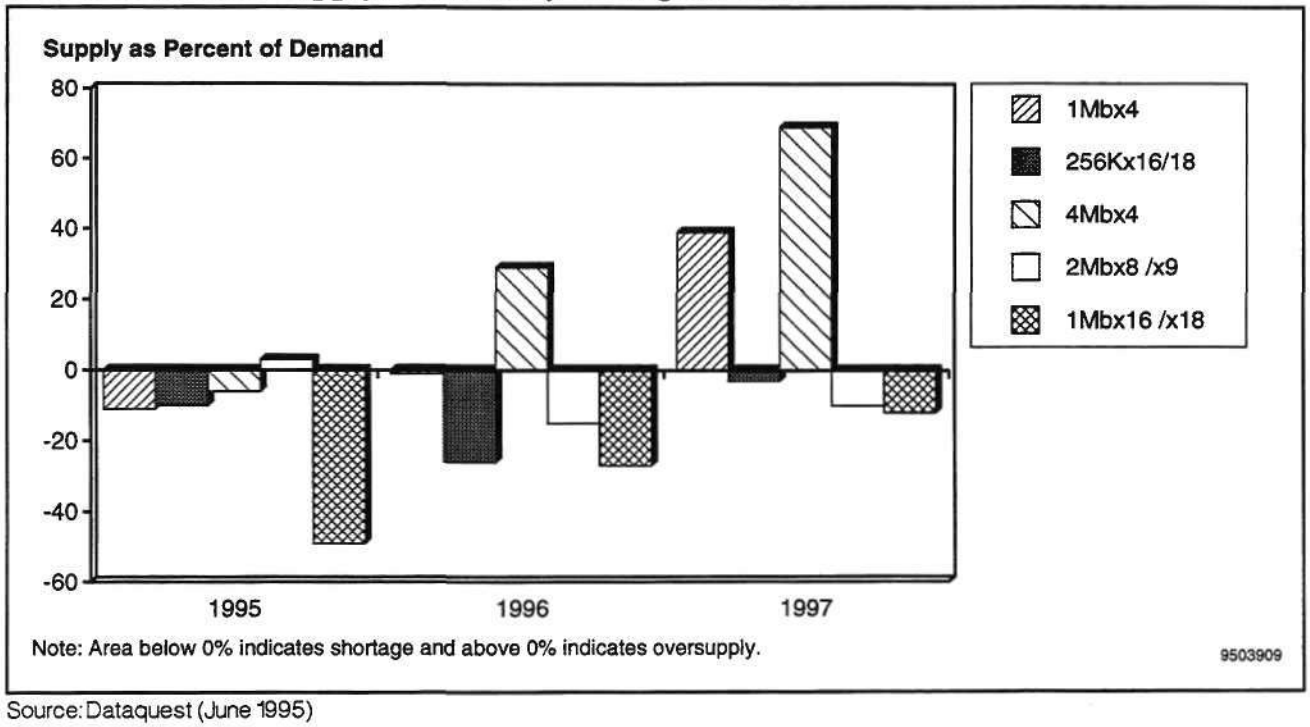
- 1Mbx16, 256Kx16 configurations – Figure 2 shows a continuing shortage of the 1Mbx16 DRAM and the 256Kx16 DRAM throughout the entire forecast period.
- 1Mbx4 device – Figure 2 shows a shortage that lasts throughout all of 1995 and most of 1996. The figure shows this 1Mbx4 shortage should end toward the end of 1996.
- 4Mbx4 organization – Figure 2 shows that this is the device that will move into oversupply most quickly and also to the greatest extent. Figure 2 shows an oversupply of 4Mbx4 DRAMs during the first half of 1996 – which under current market conditions could become a large oversupply about one year from now.
- The 2Mbx8 device – Figure 2 shows a somewhat bouncy 1995 supply-demand scenario for the 2Mbx8 part. Figure 2 shows by early 1996 there will be a 2Mbx8 shortage.

Strong demand from the workstation market and very high end PCs right now means a 1995 shortage of the 4Mbx4 device. Many suppliers will ramp up the 4Mbx4 DRAM during 1995. However, the critical PC end market will not fully absorb this 4Mbx4 ramp-up during the 1996-to-1997 time frame.

Also, the 2Mbx8 is somewhat of a DRAM market anomaly as of midyear 1995. The background is that some major PC OEMs have pushed out their original schedule for use of this part until late 1995 or 1996. This means some extra 2Mbx8 parts are temporarily available. Figure 2 shows that, by early 1996, however, PC OEMs will ramp up demand, leading to a shortage.

Figure 3 shows the annual outlook through 1997 for the same configurations (1Mbx4, 256Kx16, 4Mbx4, 2Mbx8, and 1Mbx16).

Figure 3
1995-1997 DRAM Supply/Demand by Configuration



Source: Dataquest (June 1995)

The basic message of Figure 3 is that, under current market conditions, Dataquest expects an oversupply of 4Mbx4 DRAM to occur during 1996. The 4Mbx4 should remain in oversupply through 1997. The 1Mbx16 and the 256Kx16 devices will be in shortage throughout the 1995 to 1997 period. The 2Mbx8 devices will be in short supply during 1996 and 1997. Dataquest also expects strong long-term demand for Toshiba's newly announced 512Kx32 DRAM.

The 1Mbx4 device will be in oversupply during 1997. The 1Mbx16 and 2Mbx8 shortages could force some PC demand "back" to the 1Mbx4 DRAM. This would moderate any 1997 oversupply of the 1Mbx4 device. By contrast, unsatisfied PC demand for the x16 and x8 devices will do much less to moderate a 1997 oversupply of the 4Mbx4 DRAM.

Dataquest Perspective

The DRAM shortage will continue throughout 1995 and 1996. At an aggregate level, the DRAM shortage should end about two years from now. For this reason the year 1997 looks like a pivotal year of DRAM market transition.

The continuing emergence of multimedia-type applications including multimedia PCs, digital set-top boxes, and video games drives very strong demand for wide configurations of DRAM. This trend signals a continued shortage of the x16 DRAM and x8 DRAM configurations during the very midst of the 1997 oversupply of the 4Mbx4 part.

Transcript of Telebriefing "Questions and Answers" Session

This concluded the opening statement to the telebriefing. A live question-and-answer session followed between the telebriefing audience and Dataquest analysts. The identity of all callers remained confidential.

Q: Regarding Toshiba's newly announced 512Kx32 DRAM, where do you see the application for that part and do you see any followers into that market?

Ron Bohn (RB): We are not sure about any followers into the market at this time. A main application should be the set-top boxes. Partly for this reason, our opening statement made reference that we might see the set-top box finally blossoming into a significant consumer of DRAMs during late 1997. At this time, there is a lot of interest among set-top box manufacturers in the 256Kx16 DRAM. An alternative would be the 1Mbx16 DRAM. The 512Kx32 DRAM really fits the granularity requirements of set-top box applications. Right now, the market remains uncertain about which DRAM technology will best serve the set-top box market. The candidates include standard asynchronous (fast page mode), asynchronous Extended Data Out (EDO—a.k.a. hyper page mode) or synchronous DRAM. Regardless, we certainly see the 512Kx32 configuration as fitting very nicely with multimedia granularity requirements should the set-top boxes merge as a real strong consumer of DRAMs in several years.

Q: Looking at Figure 1 where you show the potential oversupply in 1997 caused by overbuilding of the 4Mbx4 DRAM, is this intended to be your projection of the way you think the way things will be? Or is it intended to portray what will happen if most of the DRAM manufacturers do what you think your survey says they are going to do?

RB: The latter. We are trying to send out a wake-up call that Dataquest's analysis shows that DRAM suppliers are very aggressively continuing to focus on the 4Mbx4 DRAM. DRAM suppliers may lack confidence in their ability to build the 1Mbx16 device. There is also uncertainty by DRAM suppliers about the future role of the 2Mbx8 part.

We believe DRAM suppliers will do several things to avoid the 4Mbx4 oversupply picture shown in Figure 1. One response is that they eventually could shift some capacity away from the 4Mbx4 DRAM to a 4Mb slow SRAM. Should the Japanese consumer electronics market rebound in a couple of years, those applications would use this slow SRAM part. Next, DRAM suppliers may want to unleash their capacity more slowly than they are currently planning. But the main thing they could do is to start focusing on building wider configurations of DRAMs. We want to mention again the 256Kx16 DRAM. Although the 4Mb DRAM is a relatively mature technology, the wide x16 version should remain in shortage throughout the 1995-1997 period. A main message today is that we still believe there would be DRAM revenue growth during 1997 as a result of a shortage of wide DRAM. We do not forecast any harsh cyclical downturn in the DRAM market but at this point in time our analysis indicates the shaping of oversupply of 4Mbx4 configuration.

Q: The last time we had this conference (March 1995), it appears that there was no DRAM oversupply in sight. What factors led you to change your opinion on this a couple of months later?

RB: We had not talked very much at any prior telebriefings about the year 1997. We certainly talked in prior telebriefings about a market shortage through 1996.

Every quarter we do a lot of analysis in terms of looking at DRAM supply and demand, and this telebriefing reflects the result of our most current analysis. One area of concern that we now have is the PC forecast for the year 1997. The PC unit growth rate worldwide that we mentioned in the opening statement is 14 percent. This 1997 rate is somewhat slower (than the 1995 PC worldwide growth). What is particularly slower in 1997 is the growth rate for the North American PC markets. The PC growth rate for the United States in 1997 is about 8 percent. So at this point, in terms of what we said before, we said we are not expecting a cyclical 1997 DRAM downturn. We are saying that our analysis at this point clearly indicates that some key configurations of 16Mb DRAMs confront a potential oversupply unless suppliers alter their strategy to better match the emerging demand patterns.

Q: We have two related questions about the 4Mbx4 that you are showing going into some surplus. First, what is the percentage of market share for the 3.3-volt and 5-volt parts? Second, what do you see happening in 1996, specifically if the United States starts to have an economic slowdown that is larger than forecast in the newspapers right now?

Jim Handy (JH): I am going to answer the question in reverse order, so the first shall be last and the last shall be first. First of all, what happens if there is a slowdown in the U.S. economy? That's always a wildcard in any kind of a forecast. We tap into The Dun & Bradstreet economists and ask for their help since we are a division of the Dun & Bradstreet Corporation. We do the best we can to figure out what is going on in the world economies, the exchange rates, and all of that. If terrible economic things were to happen that sent the U.S. economy (or any other major world economy) into a tailspin, it would have a profound influence on the spending pattern of PC buyers. This is not our forecast, but if these economic events were to occur, this could free up a lot of DRAM supply further up the food chain very quickly. The result would include reduced unit shipments of DRAM. There is room for a phenomenal downturn in the pricing for DRAMs. Our estimate is that that most DRAM suppliers could be selling the 1Mbx4 DRAM that today sells for $13 profitably for under $6.

With regard to the 3-volt question, DRAM manufacturers pushed most of the 3-volt requirements. Now that they have gotten to a point where they can produce 3-volt or 5-volt parts, they keep charging a premium for the 3 volt part.

What we see for the 3-volt DRAM's share is about a third (33 percent) of all shipments. This increases to about one-half (50 percent) in 1996.

RB: I would like to add one thing regarding your U.S. economic question. Dataquest's PC forecast for 1995 estimates that about 22 million PCs will

ship in the United States. For 1996 we expect a 16 percent growth rate, which will push up shipments to about 26 million PCs in the United States. For 1997, Dataquest forecasts an 8 percent growth rate for the United States, translating into a total of under 30 million PCs. Right now our PC analysts are looking very carefully at any potential impact of a U.S. economic downturn and the impact on the PC market. In aggregate, they still feel comfortable with this U.S. forecast. They are expecting a softening of the U.S. economy sometime during the second half of 1996 or the first half of 1997. The current PC forecast assumes a 1996 or 1997 U.S. economic slowdown. So we are still comfortable with this PC forecast for the United States over the next couple of years. (Note that subsequent to the telebriefing, Dataquest made some nondramatic changes in the PC forecast.)

Q: How do you see the supply/demand mix by function—EDO DRAM versus standard synchronous DRAM versus Rambus DRAM?

JH: The supply/demand for those different devices is kind of a sketchy thing. EDO is something that is going to be a relatively simple switch for DRAM manufacturers. Most DRAM manufacturers have in place the mechanism where they can determine their mix of EDO product to fast page mode product (today's standard) at a very late level in production. This allows DRAM manufacturers to cater to the needs of the market till the last month or so of the production cycle.

By contrast, for synchronous DRAM, that is not the case at all. It looks as if there is going to be a very strong undersupply of synchronous 16Mb DRAMs for quite a while, probably for at least the next two years. However, for the 64Mb density, it looks as if most manufacturers are planning to produce a large portion of their product in some sort of a synchronous version. The manufacturer's votes are not all in yet as to which of the synchronous architectures are going to make up the bulk of the 64Mb DRAM sales. But since the peak shipments of the 64Mb DRAM will not happen until the end of our 1999 forecast cycle, there is plenty of time for DRAM manufacturers to respond to long-term demand.

RB: Just one more thing about Rambus. The synchronous DRAM technology that Jim just discussed includes the Rambus technology. The outlook for the Rambus technology depends in part on a business issue—the royalty rate charged by Rambus. Some DRAM companies we have talked to are quite comfortable with the royalty rate they pay. At the other extreme, some of them completely disfavor paying what they call another DRAM tax. Rambus is working on this, so that is one factor beyond technology that influences our analysis of the Rambus DRAM.

Q: You have given us some figures of different boards, the PC, the upgrade, and the industrial boards. How do you estimate the rest of this market demand for video and other applications?

RB: Dataquest has a very detailed worldwide electronic equipment production forecast. Our analysis has a unit shipment forecast of equipment production that we present in the report. These projections carry out over time. For the DRAM Supply/Demand report, the forecast extends to 1997.

For each of the electronic equipment types, with as much detail as possible, we estimate the DRAM demand from each equipment type. We aggregate

these detailed demand estimates into our total demand forecast. That is a short description of our DRAM demand analysis.

Q: What is your average memory requirement for PCs for 1994 through 1997?

RB: First, we will start with DRAM installed as PC main memory at the OEM's factory. In 1994, the PC averaged just over 6.25MB of PC factory-installed DRAM. This average will not become a "round" number because we must factor in the shift from 486 PCs to Pentium PCs and later to P6 PCs. For 1995, 7.4MB were installed at the PC factory. For 1996, the PC average becomes 9.5MB, and for 1997, 11.4MB.

Now we turn to fully upgraded PCs. These are PCs that have had additional memory installed after leaving the PC factory. The memory "upgrade" occurs at the retail store, or end buyers might buy a module later at an electronics store. For 1994, the fully upgrade PC had just under 14MB of DRAM. For 1995, the upgrade becomes 16MB. For 1996, the upgrade increases to 22MB, and for 1997, 25MB.

Q: I have two questions. What specifically caused the market for 256Kx16 DRAM to go up recently? What are the current prices for each device listed in Figure 2?

RB: To understand the 256Kx16 DRAM, you have to go back into several years of 4Mb DRAM history. The prevalent 4Mb market interest during the early 1990s was for the 1Mbx4 device. There was an intermediate width part—the 512Kx8—that never really took off in terms of PC demand. Another part was the 256Kx16 DRAM, which tied into some graphics applications. Demand for the 256Kx16 device never seemed to really materialize either. In the midst of the continuing DRAM shortage, demand started to emerge from some video and set-top box applications that could use wide configuration parts like a 1Mbx16 or 256Kx16 DRAM. So the search by the video games and set-top box companies for any supply of DRAM at competitive price diverted attention to the 256Kx16 part. Instead of "winding down" and fading from market interest—which happened with the 512Kx8 DRAM—the 256Kx16 device has started to generate reasonably impressive demand. The continuing severe shortage of the 1Mbx16 DRAM means the 256Kx16 shortage will also persist.

Mark Giudici (MG): I will provide DRAM pricing based on the June 1995 forecast of North American marketplace for the parts shown on Figure 2. The 1Mbx4 device in second quarter 1995 sells for about $13. The price will increase by fourth quarter 1995 to $13.35. For the year 1995, the price averages to just under $13.10. For full-year 1996, the increased supply of 4Mb DRAM should lower the price to about $12.45.

The 256Kx16 DRAM sells as of second quarter 1995 for $14.80 in the North American market. The price increases to $15.57 in the fourth quarter of this 1995. The full-year 1995 averages at $15.17. The price for 1996 will be $14.68, a little bit of a decline versus the current price.

The next product in Figure 2 is the 4Mbx4 part. We will price the device that uses the 400 mil package, which is the highest volume runner today. The current price in the North American market is $41.50 for large volume

buyers. The price will go down to about $34.20 in the fourth quarter of this year. The full-year 1995 price averages to $40. The 4Mbx4 price should decline to $30.65 for 1996, reflecting the start of an oversupply.

The 2Mbx8 device (300 mil package) is priced at $51.82 for the second quarter of 1995. By fourth quarter 1995, the price will increase to $52.26. The full-year 1995 price is $51.93 for this device. The 2Mbx8 price in 1996 is expected to be about $44.22 based on our survey.

The 1Mbx16 part sells as of second quarter 1995 for $53.90. By fourth quarter 1995, the price will be $54.50. For full-year 1995, the price is just over $54. For 1996, we forecast a price of just over $48. This 1996 price represents a 1Mbx16 price decline versus 1995. In retrospect of DRAM price history, however, the 1Mbx16 price decline for 1996 is far less than expected for the ramp-up of a new DRAM device.

Q: I am curious about the burst mode EDO DRAMs. Do you think those will have an impact on the market, or are they going to play a small role? Will producers be switching over to a fully synchronous part?

JH: From where we sit, we still do not find an awful lot of designers who are using, or planning to use, burst EDO. That could be because of the fact that it was announced so late, or could be that we are just not talking to the right people. Regardless, we are not finding an awful lot of sockets for burst EDO at this time. On the other hand, we do see that the standard asynchronous EDO DRAM has caused the acceptance of synchronous DRAM parts to become delayed by about one year. The reason is that system designers tend to stay with something that is not a big paradigm shift, if you will excuse my using the expression.

System designers like to stay with familiar technology for as long as they can. Fast page mode asynchronous DRAM started to run out of market steam some time ago. This technology could no longer meet the performance requirements at a certain system frequency (the frequency varies depending upon to whom you talk). The next logical step to take would be synchronous DRAM. However, EDO—or hyper page mode—asynchronous DRAM came onto the market scene. This delayed the timing at which the asynchronous technology would run out of performance steam. With that the acceptance of the synchronous architecture becomes delayed.

Burst EDO is an attempt to push things out just a little bit more. That could be very appealing to designers. So far we have not found system designers who have said resoundingly that they are going to use burst EDO, so we guard our bets on the success of burst EDO at this point.

Q: Could you tell me if you have any information concerning DIMMs versus SIMMs?

RB: Right now we are doing a study of the module market. We will be focusing on the worldwide and North America markets. We are getting some information on that now. What we plan to do is to have a report on the DRAM module market that will include an assessment of emerging module technologies like DIMMs. The report should appear during August 1995.

Q: What are the cost targets for 4Mbx4 EDO DRAMs in 1995 and 1996 in the 3-volt version?

JH: Our pricing usually reflects the high-volume devices in the more current market. We do not have a published forecast on this part because today's order volumes are far from high volume.

MG: Although we do not survey the price of a low-voltage EDO part, the price premium for a low-voltage part ranges from 10 percent to 15 percent at this time. The EDO technology should not command much of a price adder throughout its life. For a rough estimate of the 3V 4Mbx4 EDO DRAM pricing, add a 15 percent price adder over the prices given earlier for the 4Mbx4 DRAM.

Q: Our question concerns the supply side of the DRAM equation. We see some estimates that as much as $30 billion of spending on new DRAM plants in the next few years. In your forecast, going forward, do you assume that all the DRAM capital will be spent, or do you assume that some producers abort plans for a variety of reasons?

RB: In our DRAM Supply and Demand report, we do include a very careful look at DRAM fab by fab, so we try to factor in an expectation of what capacity yield utilization will be. We have one of our fab database people here, Mario Morales, in Research Operations group. He tracks all unit shipments of memory products. Mario also works closely with our fab analysts on worldwide fab database including DRAM fabs.

Mario Morales (MM): At this time, first I will give you our worldwide capital spending numbers for 1994 and also what we expect to see for 1995. For 1994, we had a total of $22.8 billion spent on semiconductor capital equipment. This capital goes toward running processing equipment, test and assembly, and also property and plant. This spending includes some computer equipment.

In 1995, we expect the worldwide spending to increase by over 50 percent. We estimate about $33 billion to $35 billion of capital spending in 1995.

JH: Let me add something to that. The way we relate capital spending to DRAM supply is not on a purely economic model of just looking at "dollars in" versus "DRAMs out." We are in constant communication with DRAM manufacturers. We keep a database of every fab that we can track down worldwide. For example, Mario Morales can generate the number of DRAM fabs from our database. It is a pretty large number. The result is a sharper focus on DRAM production (in Dataquest's DRAM report) than indicated by quickly comparing "dollars in" with DRAM "dollars out."

Q: On the 4Mbx4 DRAMs, do you have feeling for the demand breakdown of 2K refresh versus 4K refresh for the current year as well as for next year?

JH: In a word, "no." We have tried resolving that technical issue last year regarding the 2Mbx8 DRAM. We found then that not only is it hard to get a good deal on the supply side but also far harder on the demand side. This is not just a problem for Dataquest, this is also a problem for DRAM manufacturers, a pretty important problem. We will try to keep our clients posted

on that battle, as it comes to a resolution, but the issue could not be any farther from resolution than it is right now.

Q: What are the major applications for each type of DRAM listed in Figure 2?

RB: The No. 1 application for DRAM would be the PC. For the 1Mbx4 device, the No. 1 application is the PC. For the 256Kx16, it would be graphics applications. For the 4Mbx4, it would be the workstation application. For the 1Mbx16, the No. 1 application is the PC. For the 2Mbx8 DRAM, the varied applications mix includes PCs, workstations, plus some others.

Q: Going back to your figures for the main memory PC content, I just want to get a little qualification. Is it an average of new systems being shipped, or is it an average across the total spectrum of installed base plus new shipments?

RB: At the first level—the PC "factory level"—that is an average of new PCs. It is much more complicated regarding the second level—the fully upgraded PC, which includes new PCs and the installed base.

For example, for the fully upgraded PCs, the "average" is going to be a really complicated mix of numbers. Some of the 1994 PC memory upgrades would occur in the same year when the PC shipped. Some of the fully upgraded PCs for 1994, however, might have shipped during 1993 or even 1992. Another complication: There may be some PCs that shipped back in 1993 that do not get fully upgraded until this year or next year. So for the PC main memory at the OEM level it is an average; but at the fully upgraded, it cuts across the spectrum of new PCs and the installed base.

Q: So how should we regard that number?

RB: Use it as a benchmark. If you have to get into deep analysis of it, you will have to contact us directly and we can talk about that.

Q: At the start of this conference, you mentioned that in 1997 there could be a big transition into multimedia applications like set-top boxes and video games. How confident are you really in those being a mainstay of demand, particularly video games? I would hate to see DRAMs as being driven by the whims of 13-year-olds playing games

RB: A couple of things. First of all, the multimedia trend is actually having an impact already in terms of the graphics application. Forget video games for a moment, and instead consider PC graphics applications. The video RAM highlights the impact of low-end multimedia PC on the DRAM market. Ultimately the video RAM faces replacement from PC graphics.

In terms of confidence level, at this point we recognize that DRAM consumption by applications like set-top box and video games is quite low. We do believe that in the longer term the set-top box market should start emerging. Regarding video games, DRAM demand (for games) does not mean that kids will ever drive DRAM market trends. These are just some areas of emerging DRAM demand that might become stronger during 1997. I think in the long term clearly the PC remains the king in terms of DRAM

consumption. Tracking the PC market is the best way to plan spending on DRAM R&D and construction of DRAM fabs.

JH: Let me just add something to that. Maybe we are somewhat sweeping in how we define "multimedia" systems. We include set-top boxes as multimedia. This means when we count multimedia systems, we are counting high-end graphics applications in PCs for which Apple Computer is a very important multimedia provider.

Q: I have two questions. Both relate to 16Mb low-voltage DRAM. First question, you mentioned early on that 33 percent of 16Mb shipping during 1995 are 3-volt and that this is going to increase to 50 percent for 1996. Other than mobile computing products, what are the 3-volt applications? The second question, when do you expect that the 3-volt premiums on 16Mb DRAMs to diminish?

JH: Any low-energy applications could be a 3-volt application. That pretty much means all PCs. Any application of the newer version of the 486 from Intel or the P54C could be 3-volt applications. There are actually level translators between the processor and the DRAM to convert the processor's 3-volt signal into 5-volt DRAM signals. The reason why users are largely using 5-volt parts in portable application is because DRAM manufacturers are charging more for the 3-volt than they are charging for a 5-volt part.

The current supply and demand imbalance brought about the 3-volt price premium. If there were an oversupply of DRAMs, 3 volts would be a way for DRAM manufacturers to take market share away from each other (via lower 3-volt pricing). They do not need to do that right now. Because of that, they are capable of keeping the premiums up there. If suddenly the 3-volt premium went away because of an oversupply, 3-volt parts would make up a larger percentage of the devices shipped in all of the systems than mentioned before.

Q: Have you covered the 5-volt versus 3-volt DRAM markets today? What is the graph you have on this?

JH: We did not provide a graph on 5-volt versus 3-volt. All of the questions asked about 3-volt DRAMs fall outside the official scope of the telebriefing.

Q: The numbers on Figure 2—are those mostly 5-volt parts or are they mixed?

RB: The total market. It incorporates all 5-volt and 3-volt. The figure provides an aggregate look by configuration.

Q: How do you see the shortage in the DRAM supply affecting video RAMs?

RB: The video RAM market has been to some extent a separate market. The main memory is the key part of the PC. There is also what we call display memory, whether it is video RAM, Windows RAM (WRAM) or some newly emerging technologies like the Rambus part. This display memory segment has always been about 10 percent of the DRAM market. We see somewhat separate trends for display memory (versus main memory).

There is a lot more uncertainty regarding the emergence of the new display memory technologies. We believe that the video RAM will have a continued good life cycle for very high performance systems. But if you are talking about display memories for PCs, cost is a real big issue. Video RAM is typically much more expensive than the equivalent density of the standard DRAM. So there are several different competing architectures for display memory applications. The market is really not certain at all regarding which DRAM technology will prevail for display applications.

(This was the final question.)

Note: For additional information on the *DRAM Supply/Demand Quarterly Statistics*, please call 800-419-DATA (800-419-3282).

MMRY-WW-BR-9504 Qty: 1
Mr. Joe Grenier
Dataquest Incorporated
1-1100
.,
--INTERNAL DIST.--

For More Information...
Ronald Bohn, Senior Industry Analyst ..... (408) 437-8542
Internet address ..... rbohn@dataquest.com
Via fax ..... (408) 437-0292

Dataquest
a company of The Dun & Bradstreet Corporation

Perspective

Memories Worldwide

Telebriefing

Will Cache and Flash Stay Hot in 1996?

Abstract: *Dataquest expects strong growth in the cache and flash memory markets. This report is based on a recent telebriefing and includes the telebriefing's question and answer session.*

By Ron Bohn, Jim Handy, Mark Giudici, and Scott Hudson

Dataquest's Semiconductor group analysts held a telebriefing on November 10, 1995. Dataquest analysts who participated were Mark Giudici and Scott Hudson of the Semiconductor Procurement Worldwide program, Dale Ford and Mark Gaare of the Semiconductor Applications Markets Worldwide program, and Ronald Bohn and Jim Handy of the Memories Worldwide program. This article provides the opening statement and several tables used in the briefing, plus a transcript of the key portions of the telebriefing's question and answer session.

Key Points

Dataquest expects the cache RAM and flash markets to remain hot during 1996 but for differing reasons. This telebriefing emphasized the following main points:

- First, the PC market migration to the Pentium processor's 64-bit bus has started to drive system manufacturers to use new cache RAM technologies. A key issue to monitor will be whether the supply of 32Kx32 synchronous burst cache RAM will meet demand in a timely fashion in 1996 and 1997.

Dataquest

Program: Memories Worldwide
Product Code: MMRY-WW-BR-9505
Publication Date: December 18, 1995
Filing: Perspective
(For Cross-Industry, file in the Semiconductors Volume 2 of 3 binder behind the **Memories Worldwide** name)

- Second, the uncertainty about the ramp-up of this 32Kx32 part stems from several factors, including the fact that most suppliers are still unfamiliar with wide-configuration devices. Despite Intel's effort to provide guidance to cache RAM suppliers as to how many 32Kx32 units will be required for the next several quarters, Intel cannot control how many 32Kx32 parts will actually be built by the suppliers.
- Third, in the flash market, flash memory will remain in a shortage throughout 1996, driven by demand from a wide range of applications, including communications, computing, transportation, and consumer electronics. By 1997, a large increase in flash capacity should restore supply-demand balance in the flash market.

PC Forecast

Before discussing cache RAMs, the analysts reviewed Dataquest's PC forecast. The current Dataquest PC forecast shows that 58 million PCs will ship worldwide in 1995. For 1996, Dataquest expects worldwide PC unit shipments to increase by nearly 20 percent. The 1996 forecast shows total PCs at 69 million units. The worldwide forecast for 1997 is now 79 million PCs.

Dataquest expects that 26 million PCs will use Pentium-class MPUs in 1995. Pentium-class processors include Pentium processors and other 586 processors as well as Pentium Pro and other 686 processors. During 1996, 54 million PCs will contain Pentium-class MPUs in 1995. By 1997, more than 70 million Pentium-class PCs will ship worldwide.

Vibrant Cache RAM Outlook

Dataquest views the SRAM market as a large market broken into three main segments: slow SRAM, PC cache, and high-end SRAM. The slow SRAM market is the largest and is expected to account for $2.6 billion of a total 1995 SRAM market of $5.8 billion. Second is the PC cache market. The smallest portion is the higher-priced SRAM versions at the high-performance end of the spectrum.

The 1Mb cache RAM market should vault into prominence during 1996. We just issued a new *Worldwide MOS Memory Forecast* (MMRY-WW-MS-9504, October 30, 1995) that covers the period from 1994 through 1999. This forecast shows that revenue for 1Mb cache RAM will increase from less than $1.4 billion in 1995 to $2.1 billion in 1996. This translates to a healthy 50 percent-plus growth rate for 1996.

Probably the most closely scrutinized portion of the SRAM market is the cache market. The big questions participants in this market have today are as follows:

- What will PCs use as cache memory in the next year and in the next several years?
- What will be the effect of the switch from the Pentium to the Pentium Pro?
- How can SRAM suppliers make sure that they do not rely too heavily on what might become on an oversupplied part?
- What must system vendors do to assure that they will have adequate supply?

32Kx32 Transition

Nothing drives cache like the advent of a new processor. PC purchasers appear to rationalize the need for cache by the fact that they are on the leading edge: If they are paying top dollar for the highest-performance CPU they can get, they had better buy a cache to avoid suffocating the expensive processor with a too-slow main memory. Add to this Intel's new thrust to replace existing processors with the next generation on a two-year rhythm rather than the older three-to-four-year cycle and you have a rapidly expanding PC cache market. This happened with the Pentium ramp, and the effect on the SRAM market is that there was no summer-season oversupply of SRAMs in Taiwan in 1995 as there had been in 1992, 1993, and 1994.

Pentiums PCs now use the 32Kx8 SRAM, in part because it is readily available at a reasonable price. Table 1, which lists the wide 1Mb SRAM offerings of several SRAM vendors, shows that many of these companies are gearing up to produce a 32Kx32 bursting pipelined synchronous cache device. The main reason for this is that Intel is pushing hard to make this the most widely used cache SRAM in Pentium systems. Intel is reported to be asking for more than 90 million of these in 1996, a number that would support over 85 percent of all Pentium-class systems sold.

Table 1
Wide Cache SRAM Sourcing

	16Kx16 Synchronous	32Kx18, 64Kx18 Synchronous Burst	32Kx32, 32Kx36 Synchronous Burst
Alliance			X
Cypress			X
Fujitsu			X
Hitachi			X
IBM		X	X
IC Works		X	
IDT			X
ISSI			X
Micron	X	X	X
Mitsubishi			X
Motorola	X	X	
NEC		X	X
Paradigm		X	
Samsung		X	X
SGS-Thomson			X
Sharp	X		X
Sony			X
Toshiba			X

Source: Dataquest (November 1995)

More than 16 SRAM companies have announced plans to support this part in one way or another. Samsung has announced that it plans to make 50 percent of all parts used. Sony has announced that it will build 1 million a month, starting in January. Micron is already making about 1 million units per quarter of the higher-priced version, a 32Kx36 that supports parity. Other manufacturers are keeping their projected run rates quiet, but if they are all able to ramp at the aggressive rates they have set their sights on, there should be a dramatic oversupply in the very near future.

Based on 1994 worldwide unit shipments, leading suppliers of fast 32Kx8 SRAM include (in ascending order) Winbond, Integrated Device Technology, Alliance Semiconductor, Cypress Semiconductor, and Motorola.

Dataquest also noted that there has been a continuing shortage of 3V cache RAM. We believe 3V cache RAM will remain in tight supply well into next year.

Potential 1996 Outcomes for 32Kx32

Table 2 shows that there appear to be three possible outcomes to this race. These three outcomes are not intended as a forecast but rather to provide an analytical framework for tracking this emerging technology.

Table 2
Synchronous Burst 32Kx32 Cache RAM Market Possibilities

Outcome	Potential Winners	Potential Losers	Related Factors
No. 1: "Timely" 1996 ramp-up	Early suppliers of synchronous burst 32Kx32 cache; suppliers with small 32Kx32 die size	Suppliers who over-commit to asynchronous 32Kx8 cache	1996 Pentium PC unit growth rate
No. 2: Supply ramps up much faster than demand	Suppliers committed to a broad range of SRAM types	Suppliers too narrowly focused on synchronous burst 32Kx32 cache	In which quarter of 1996 will 32Kx32 cache demand take a step function upward?
No. 3: Supply ramps up much more slowly than demand	Suppliers committed to asynchronous 32Kx8 cache, asynchronous 128Kx8 cache; early suppliers of synchronous burst 32Kx32 cache, until purchasers tire of limited supply	System OEMs who are unable to secure sufficient supply	Some suppliers of synchronous 1Mb cache market will focus on the 64Kx16/18 configuration

Source: Dataquest (November 1995)

The first possible outcome shown on Table 3 is that SRAM vendors will ramp at an acceptable rate to meet Intel's needs and that the 32Kx32 will quickly become a success story.

Table 3
Leading Suppliers of Flash Memory
(Based on 1994 Worldwide Revenue)

1994 Rank	Supplier	1994 Market Share (%)
1	Intel	50.9
2	Advanced Micro Devices	23.8
3	Atmel	7.4
4	Toshiba	5.7
5	SGS-Thomson	4.1
6	Fujitsu	1.6
7	Sharp	1.2
8	Catalyst	1.1
9	Mitsubishi	1.1
10	Texas Instruments	0.8
	Others	2.4

Source: Dataquest (November 1995)

The second possible outcome is that all 16 vendors will ramp the market into a very severe oversupply. Massive losses would be sustained as the price of the 32Kx32 SRAM dropped to well below $10.

The third possible outcome is that SRAM vendors, despite their aggressive ramp-up plans, will stumble. If they stumble badly, there will be a serious undersupply of the 32Kx32, which, if it lasted long enough, would cause Intel to look for other cache solutions to support the Pentium processor. From our perspective, should Intel drop the 32Kx32 SRAM it is unlikely that it would go back to this part.

In the first two possibilities—the oversupply outcome and the satisfactory ramp-up outcome—the cache of choice for 1996 would become the 32Kx32. In the third scenario—the undersupply—the 32Kx8 SRAM would maintain its current lead as the preferred PC cache component, with the 128Kx8 SRAM being the likely contender for 1997. Although top-level indications point to a 1996 oversupply of the 32Kx32 device, most vendors for this part have no experience in mass-producing synchronous 1Mb SRAMs, either because they do not have a production 1Mb process, or because they have never supported mass production of a synchronous product.

Note that none of the three potential outcomes counts on any decline in the PC market. Dataquest believes that the current strength of the PC market is sustainable for 1996 as well as the long term.

The next question is the effect of Intel's new Pentium Pro processor. Although the only version of the Pentium Pro that Intel has revealed to the general public uses a dual-cavity package with a multichip module approach, Dataquest believes that this is an interim approach, aimed solely at the high end. It is our understanding that a second version of the Pentium Pro will be used to support the desktop PC and that this version will use a dedicated cache bus to communicate with two upgraded 32Kx32 SRAMs. These devices are reported to run using a 2.5V version of the standard TTL interface and will need to meet tighter timing specifications than current versions of the 32Kx32.

Dataquest believes that this is why Intel is pushing so hard for widespread sourcing of today's 32Kx32. If Intel can help cultivate a ready supply of these parts, then the transition to the Pentium Pro follow-on SRAM—a 32Kx32 device—will run far more smoothly. The 32Kx32 SRAM would enable Intel to avoid the more expensive dual-cavity package. In other words, Dataquest believes that the Pentium Pro is already having a profound effect on the direction of SRAM suppliers. From our perspective, Intel needs the support of several strong SRAM vendors to cost-reduce future versions of its Pentium Pro. This need is driving Intel to create a 32Kx32 SRAM market for the Pentium PC.

So what should the cache RAM suppliers do? Specifically, how can cache RAM suppliers partake of this market without being caught in an oversupply? The only answer is to diversify. No matter how many of the 32Kx32 SRAMs sell, it will continue to be a good policy to maintain a share of the more standard business, that of the 32Kx8 and/or the 128Kx8 products. These devices should continue to be used in volume in non-PC applications like digital cellular phones, LAN cards, and modems. By keeping an interest in different parts for different markets, the supplier can respond more quickly to adverse pricing or an oversupply in the 32Kx32 SRAM market.

What should SRAM purchasers expect? They can look forward to a lot of 1996 competition in the 32Kx32 market. They should also monitor the 32Kx8 cache market. We do not anticipate any further tightening of the 32Kx8 market by vendors that would shift capacity to the 32Kx32. Although there is heightened interest in the 32Kx32, Dataquest believes that those vendors unwilling to continue to support the fast 32Kx8 have already gotten out of this market. The fab switch has been made by most suppliers.

Our key recommendation is that PC OEMs wanting to provide the best cache solution at the lowest cost should seriously consider using cache modules with an approach that supports both asynchronous and synchronous parts. The year 1996 will be a bad time to try to support caches that are soldered onto the main board. Synchronous/asynchronous cache modules have already been standardized, so the answer already exists and is simply waiting to be used.

The PC cache market is always changing. Dataquest sees a rapid swing from the 32Kx8 to the 32Kx32, driven by the needs of both the Pentium and the Pentium Pro. We believe that successful manufacturers and successful users will watch the market extremely closely and will position themselves to facilitate a quick response to any changes in the market.

1996 Flash Shortage

Worldwide flash memory revenue will reach or exceed $1.5 billion for 1995, which is a 50 percent increase over 1994. Flash memory revenue for 1996 will increase by 40 percent to exceed $2 billion. We expect worldwide flash revenue to increase by another 40 percent during 1997.

Table 3 shows the world's leading suppliers of flash memory in 1994.

Table 3 shows that Intel and Advanced Micro Devices (AMD) rank as the world's leading suppliers, by far. Several other companies, however, are also strongly committed to flash technology. By the end of 1995, we expect that more companies will become new members of what we will call the $100 million flash club. These suppliers include Atmel, Fujitsu, and Toshiba. Also, recently, Mitsubishi and Hitachi announced 16Mb 3V-only flash products that they will second-source. Meanwhile, SGS-Thomson has a strong long-term commitment to EPROM technology but also has a very active flash memory program. A host of other suppliers, such as Texas Instruments, Macronix, and others, have also announced flash memory strategies.

PCs, Wireless Drive Flash Market

A wide range of applications propels the flash market's growth. Applications range from desktop PCs and rigid disk drives to memory cards, cellular phones, and network devices. The mainstream densities are 1Mb, 2Mb, and 4Mb, followed by the 8Mb.

Our main observation regarding flash's role in PC applications is that, during 1995, flash has emerged as the technology of choice for the PC BIOS. During 1995, our teardowns of Pentium PCs have shown that the Pentium market is shifting to the use of flash for the BIOS. The emergence of plug-and-play PCs and the increased need for PC diagnostics to support home PC users contribute to flash's growth in the PC market.

Wireless communication and other mobile applications are driving the flash market to 3V technology. During 1995, worldwide unit shipments of cellular and related broadband Personal Communications Services (PCS) systems will total about 40 million units. By 1997, shipments will reach 65 million units. Low-voltage flash memory will compete against high-density low-voltage EEPROM technology in these markets. Worldwide unit shipments of digital cellular phones will be just over 10 million units during 1995 but will approach 40 million units by 1997. Not only will the digital cellular market expand, but the amount of flash used in cellular phones also can be expected to increase. Also, low-voltage flash is well suited to other wireless communication applications like Japan's Personal Handyphone System (PHS).

Dataquest expects that the current flash memory shortage will persist throughout most of 1996. The AMD-Fujitsu alliance and the Intel-Sharp team are increasing capacity; however, demand for flash will continue to outstrip supply for the next year. In the flash market, 1997 should be a transitional period. A lot of new capacity will become available—and a host of higher-density flash applications should start to emerge—with a supply-demand balance likely in 1997.

Telebriefing Questions and Answers

Dataquest analysts then answered audience questions.

Q: Could you share with us your quarterly pricing expectations in 1996 for the 32Kx32 as well as the 32Kx8, 3.3V?

MG (Mark Giudici): Right now we are conducting our quarterly survey. The preliminary price points we have for the 15ns 3.3V 32Kx32 indicate a first-quarter 1996 price of $27, going down very gradually by the fourth quarter of 1996 to $24. This is our current forecast; however, we do expect pricing to come down as the supplies increase over the first half of 1996. For 32Kx8 SRAM 3.3V pricing, on a preliminary basis, we expect a mild price decrease—from $4.60 for the fourth quarter of 1995 to $4.45 for late 1996.

RB (Ron Bohn): I would like to add something about the 32Kx32. Jim Handy and I have been talking a lot to the major suppliers. They are looking at the third quarter of next year as being sort of a potential time for a step function down-pricing of that device.

Q: What do you think of comments regarding a weak 32Kx8 pricing in Taiwan over the last few months?

RB: Jim Handy will probably have additional comments about this. Historically, we do not always view what happens in the Taiwan market as the best indicator of what happens in terms of North American contract-volume pricing. Taiwan does serve as an indicator, but our perspective is that the Taiwanese market had overheated. Pricing was much higher, extremely high over the past several years, than in other world regions. When suddenly the PC motherboard business started to shift away this year, the whole Taiwanese market went into a panic. It looks as if there is no demand there, or very little demand, so the pricing has tumbled to the other extreme. We do have an office in Taiwan, so we are really on top of this. We also have offices in Hong Kong, Japan, Korea, and Singapore. We do not always find what happens in Taiwan to be the best indicator of what will happen worldwide in fast SRAM markets, such as the North American market.

JH (Jim Handy): I will add something to that. You have to realize that Taiwan does march to the beat of a different drummer. It has a bunch of motherboard manufacturers whose business declined from Intel's entry into the motherboard business. Those motherboard manufacturers likely are among the lowest-ranked on Intel's allocation list. The manufacturers are not getting a whole lot of Pentiums. Pentiums are where the caches are going. Taiwanese motherboard manufacturers tend to use a different part because they can get it cheaper, so Taiwanese suppliers build those parts for Taiwanese motherboard manufacturers. This is a mixed-voltage 32Kx8 in which the power supply is 5V with the I/O pins guaranteed not to go high enough to burn out the Pentium's data input pins. North American manufacturers are quite reluctant to use a part like that, so they pay a premium to use a straight 3V part. When the Taiwanese market goes away for the mixed 32Kx8 part, there is no replacement market anywhere in the world for it. That part is really having the pricing catastrophe right now.

Q: I would like to know your projected production volume for 32Kx32 in 1996.

JH: The way that we forecast is by density more than by organization, so we do not have a set number on that. We believe the 1995 supply will total fewer than 4 million units. Starting with the 90 million units that we estimate Intel is targeting for 1996—which breaks down to 8 million units a month—we look at what we believe are suppliers' production capabilities. In the early part of next year, it likely will be on the order of 3 million to 4 million units per month. To ramp up to 3 million to 4 million units per month is a pretty aggressive ramp. Assuming a successful aggressive ramp-up—which remains uncertain—more than 10 million units might be built each month toward the end of 1996. If that does happen, that will cause the potential oversupply that I mentioned in the early part of the telebriefing.

Q: You mentioned earlier that, in 1996, the use of discrete components for cache might not be the best approach. You suggested modules might be a better solution than discrete SRAMs. Can you clarify this a little more?

JH: We are allowing for a level of uncertainty as to what is going to happen in the market. We sense there is going to be a pretty sudden transition away from the 32Kx8 to the 32Kx32. The precise timing of this transition is going to be a bit hard to call. Many suppliers who are professing to manufacture the 32Kx32 have never made a synchronous part in volume before. Some of the companies have never made a 1Mb density SRAM in volume before. So these are real uncertainties about the sources of supply.

You should position yourself to switch from the 32Kx8 to the 32Kx32 pretty rapidly once it becomes established in volume. However, it would not be too surprising if the volume picked up and then dropped off. Or that the supply and demand balance became a 32Kx32 oversupply and then became an undersupply—and then become an oversupply again. Rapid ramps like that tend to be somewhat unstable. In that case, you do not want to have a motherboard that counts on 32Kx8 and a different motherboard that counts on 32Kx32. You will never know how many of which blank of motherboard you will need to have in inventory at any one time. The way you can get around that is by using cache modules where the specifications will allow you to use either 32Kx8 or 32Kx32 devices on the cache module. There is that support for this. There is a standard SIMM specification that allows you to unplug an asynchronous module and plug in a synchronous module.

RB: By contrast, in the DRAM market, interchanging modules for asynchronous parts and synchronous parts still lack a standard. That is an action for which the market waits. What Jim Handy highlights is that, in the cache RAM market, there is a solution that is available already to manage the uncertainty as you make the transition next year.

Q: What do you think the percentage of PCs will be to use modules instead of discretes for cache?

JH: Most of them. What we see happening is that Intel is seeking to support 85 percent of Pentium PCs with cache. That percentage is kind of out of line with what is going on in the cache market right now. We know that, in 1994, 40 percent or fewer of all PCs contained caches, even though there were

sockets for them in almost all PCs. We anticipate this year that the number is probably still under 60 percent, but for the number to climb to 85 percent in 1996 is still a pretty steep climb. We believe that what is going to happen instead is that nearly all PCs will have cache module sockets on them. However, probably somewhere on the order of 50 percent will actually ship with cache.

Q: This question is regarding flash. What do you see as pricing trends going from now through 1996 for the 2Mb, 4Mb, and 8Mb densities?

MG: Our survey is still in process. We start at our preliminary estimates for the 12V 256Kx8 product: Starting at the fourth quarter of 1995, the range runs from $9 to $10.50. For the first quarter of 1996, we expect a $10 price, declining gradually to $9.50 by the fourth quarter of 1996. These are relatively stable price points, reflective of the tight marketplace. The 5V-only part generally takes about a 50 cent-to-75 cent premium over the prices that I just gave.

Let us look at the 512Kx8 devices, starting with the 5V 4Mb part in the TSOP package. For the fourth quarter of 1995, the $16.50 price will stay flat into the first quarter of 1996 because of the tight market. By the third quarter of 1995, pricing could decline somewhat to $15.50. If you look at the 8Mb device, there is not much differential in price there because the 4Mb part is in such high demand now. The 8Mb device currently sells for $18 on some contract-volume orders. For the first quarter of 1996, the price might become $17. We expect more ample supply of 8Mb flash for next year.

Q: I think you mentioned that 60 percent of the PC systems in 1995 shipped with cache. Is that the right number?

JH: It was less than 60 percent.

Q: What was the percentage within the Pentium-system class?

JH: It would have been higher than that. We do not have an official 1995 statistic. This is kind of a raw estimate. We anticipate that a very high percentage of Pentium systems used caches this year, probably on the order of 80 percent.

Q: Would you expect that percentage to change within Pentium systems? It sounds like you think it is going to be coming down.

JH: Yes. When the Pentium represents a higher-priced processor, the cache becomes more cost-justified. As I said in the opening statement, new, high-priced processors justify a few extra dollars to make sure that that very expensive processor does not become throttled by a slow memory. The price of the Pentium continues to come down, so it finds itself in lower-priced systems. Then you are going to enter the realm of more cost-conscious buyers who are less willing to spend extra money to get the extra processor performance.

Q: Are you thinking that synchronous DRAM or burst EDO or any of these other main memory architectures are going to have an impact here? Or is that just kind of flavored into the whole?

JH: We actually pulled a part of the opening statement because it got too long. New technologies like synchronous DRAM and burst EDO will have a role in unified memory architecture (UMA) systems. UMAs will aim at the very low end of the PC spectrum—the very cost-conscious buyer. UMA ends up having severe bus conflicts between the processor and the graphics controller. There is a high likelihood that people will employ more cache in the cheaper UMA system to achieve more performance out of the cheaper system—rather than to use less cache. So we actually see synchronous DRAMs being used in a higher percentage of systems with cache (versus systems that use standard EDO).

Q: You mentioned that your PC forecast for next year is about 69 million units, and about 60 percent will be using cache. How does that square with Intel's pushing for 90 million units of SRAM next year?

JH: First of all, I believe that the 60 percent we were talking about was Pentium-class. So you are talking about 60 percent of 55 million units. Now 90 million SRAMs would cover 45 million PCs. That is a whole lot more than 60 percent of the 55 million Pentium-class PCs. So we do believe that manufacturers are being asked to build an abundance of these parts.

RB: I just want to point out a definition. Dataquest has a rather conservative definition of a PC. We define a PC as being a fully assembled box received by the end user. By contrast, some microprocessor and other semiconductor companies have another definition that is a little bit broader. The broader definition includes board-level products (industrial boards, upgrade motherboards). If you take Dataquest's total PC number for this year or 1996, you can add another 10 percent to 15 percent to our PC unit forecast. This provides you with some semiconductor companies' measurement of the PC total market. This is an important point of definition.

Q: Two questions on the flash market. You say that 1996 demand will outstrip supply. What is your percentage of how much more demand than supply? Second question: Do you see more acceptance of the Intel SmartVoltage design versus the AMD 5V design?

RB: I will begin by answering the second question. Predicting the outcome of the marketing war between AMD and Intel is sort of impossible. Intel's position is that they have certain major customers with whom they work closely regarding SmartVoltage. Intel is very supportive and service-oriented and pleased with its position with these customers. Now, AMD has quite an aggressive push for the 5V-only technology. The way we look at it, AMD and Intel are by far the market leaders. Both supply the NOR technology that is the lower-density de facto standard. We do not have a forecast, however, of AMD's 5V-only technology versus Intel's SmartVoltage.

Regarding the first question about the detailed supply/demand, we are adjusting our forecast because we have an application analysis that looks into that. We just changed our forecast on flash, and we are incorporating that information at this time for later publication.

Q: Regarding the flash configurations you mentioned for pricing, were they also the ones you see to be the industry sweet spots for 1996 to 1997?

MG: Yes. The x8 configuration in the TSOP package is the basic device, whether it be 1Mb, or 4Mb, or 2Mb, or 8Mb. The x8 configuration seems to be where the flash market is going. The TSOP package is fast becoming the standard package type for this part, too.

RB: Next year, you would expect a stronger market to emerge for the 16Mb density. So, in 1997, the 16Mb part should become important for higher-density applications. We continue to see the low-density flash, whether it is 1Mb, 2Mb, or 4Mb densities, having market vitality for the next couple of years. You should continue to monitor these parts well into 1997 or even 1998.

(This ended the telebriefing.)

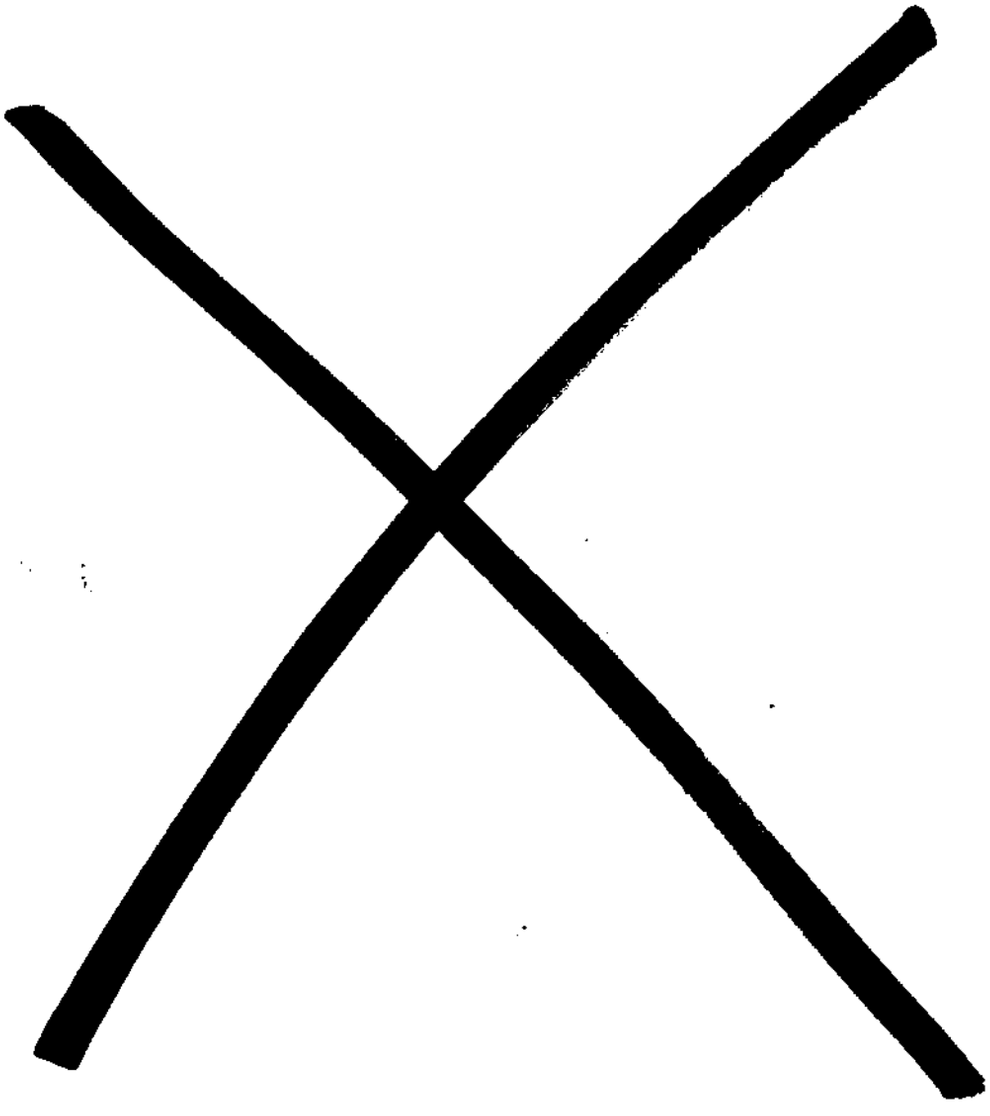
Qty: 1

MMRY-WW-BR-9505
Mr. Joe Grenier
Dataquest Incorporated
1-1100

--INTERNAL DIST.--

For More Information...
Ron Bohn, Principal Analyst ..... (408) 468-8542
Internet address ..... rbohn@dataquest.com
Via fax ..... (408) 954-1780

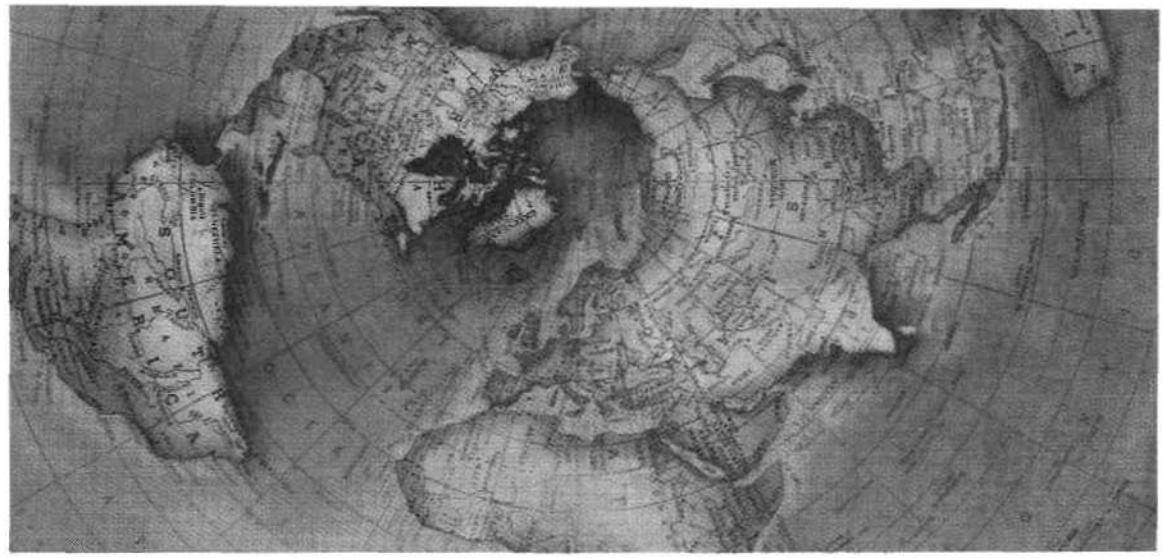
Dataquest
a company of The Dun & Bradstreet Corporation



Market Analysis

Dataquest

Market Analysis



Memories Worldwide

Market Analysis

Dataquest's MOS Memory Forecast Upgraded, Again

Abstract: *Dataquest has once again upgraded the MOS memory worldwide forecast. This will come as absolutely no surprise to those who participate in the MOS memory market. PC growth has stayed strong for over three years, while fab capacity has lagged. New CPUs have been aggressively ramped by Intel, while Microsoft has introduced the second popular release of its Windows operating system. Demand has also maintained strong growth in telecommunications, more than making up for the lag in high-end consumer electronics sales. Add these together, and you get a recipe for growth today, tomorrow, and for the foreseeable future.*

By Ron Bohn and Jim Handy

New Upgrade to MOS Memories Forecast

After having evaluated the worldwide market, inputs from memory vendors and purchasers, survey results, and forecasts of other groups within Dataquest, we have determined that the MOS memories worldwide forecast must again be adjusted upward. The market has benefited and should be expected to continue to benefit from a combination of strong end markets in many areas plus a worldwide shortage of several devices triggered by late capital spending, new use patterns, and rapid new product ramps.

Shortages drive prices up. The end-market ramps increase unit volume. Multiply these two sustainable upsurges, and the result is a formula for prolonged strong growth in the memory market in general.

We expect worldwide MOS memory revenue to total more than $48 billion in 1995, a growth of 51 percent over 1994. The memory market continues to move through an exceptional period of growth driven by DRAM, cache

Dataquest

Program: Memories Worldwide
Product Code: MMRY-WW-MA-9502
Publication Date: November 13, 1995
Filing: Market Analysis

SRAM, and flash technologies. Dataquest expects robust long-term growth in most segments including DRAM, graphics RAM, cache RAM, flash, and EEPROM. Dataquest expects memory revenue to grow at a compound annual growth rate (CAGR) of 25 percent from 1994 to 1999, with worldwide revenue reaching more than $97 billion in 1999.

What's Driving This Growth?

Dataquest's six memory product forecasts—DRAM, SRAM, flash, EPROM, EEPROM, and ROM—have been mutually guided by the following assumptions:

- PC applications, including multimedia-type display applications, will drive stellar growth of the worldwide memory market throughout the rest of this decade.
- The forecast assumes no severe cyclical downturn in the memory market over the long term.
- New memory capacity and new memory market entrants should become noticeable in the world markets by mid-1997—making that year a key transitional period.
- Communications applications ranging from low-voltage wireless systems to hubs and routers used for computer networking provide additional sources of growth for the worldwide memory market.

Dataquest continues to expect Intel's Pentium ramp-up to cause a near doubling of a PC's DRAM and cache RAM requirements from 1994 to 1996. Intel's Pentium Pro (former P6) migration will drive similar memory consumption growth from 1996 through 1998. Dataquest also has increased the near-term and long-term PC forecasts since the prior forecast. For example, we increased the long-range forecasts of PC unit shipments by more than 5 percent since the prior forecast.

A major event that occurred since the prior forecast was Microsoft's introduction of the Windows 95 operating system. Dataquest aggressively forecasts that nearly 30 million units of Windows 95 will ship into the installed base by year-end 1995. The installed base includes both PC units that ship with Windows 95 "preinstalled," plus retail sales units. Dataquest expects Windows 95 to saturate the market after 1995. Windows 95 applications such as next-generation video games and new versions of applications such as PowerPoint will justify the use of a 16MB DRAM main memory in many PCs by the middle of 1996.

The four nonvolatile memory technologies reflect differing market characteristics, although at times they compete head-on for applications. Flash memory is enjoying a banner year during 1995 in part because of constrained supply. Limited supply of flash memory means unexpected near-term growth in the mature EPROM market. Diversified applications mean a bright long-term outlook for the EEPROM market. By contrast, the mask ROM market depends primarily on video game demand.

Dataquest expects each to perform differently in the forecast window. Flash should continue to expand and benefit over the forecast horizon. Our outlook for the EPROM market has changed since the prior forecast because of

the flash supply constraint. The EPROM market will show market growth from 1995 to 1996, then decline somewhat noticeably in the later period as more flash capacity comes on line. EEPROM market revenue quietly surged during 1994, and we expect impressive growth for the next several years. EEPROM market revenue could equal or exceed EPROM revenue by 1998, a reversal of history. The mask ROM market should be relatively flat through the forecast period.

Technology-by-Technology Assessment

DRAM

DRAMs drive the memory market, and PCs drive the DRAM market. DRAMs will generate 75 percent of worldwide memory revenue this year. The DRAMs used in PCs now alone account for nearly 50 percent of the memory market's revenue. DRAMs will generate nearly 80 percent of worldwide memory IC revenue by the year 1999.

Worldwide DRAM revenue should exceed $36 billion for 1995, a growth of 60 percent over 1994. This growth rate is somewhat stronger than but consistent with the prior forecast. Fueled by the twin engines of growth—Intel and Microsoft—DRAM revenue should grow at a 25 percent-plus CAGR during the 1994 to 1999 period. Worldwide DRAM revenue should total nearly $78 billion by 1999.

Our updated forecast shows stronger DRAM revenue growth when compared with our prior long-term revenue forecast. We base the change on the upward revision of the long-term worldwide PC forecast combined with our aggressive outlook on Windows 95's impact over the forecast period. For this reason, the current forecast reflects higher DRAM pricing than our prior forecast.

Dataquest continues to expect no severe cyclical downturn throughout the forecast period. The DRAM market will show revenue growth every year during this cycle. We expect total DRAM bit shipments to more than double every two years. The year 1998 should serve as a short-term revenue growth "cooling off" period.

Intel's Pentium/Pentium Pro/P7 ramp-ups during 1996, 1997, and 1998 will have a dramatic impact on a PC's main memory use. Combined Pentium Pro and Windows 95 ramp-ups will cause 10 percent or more of PCs to ship with 32MB of DRAM from the OEM by 1997.

Other changes since the prior forecast include stronger 1995 demand for the 4Mbx4 DRAM and a stronger 1996 to 1997 demand outlook for the 2Mbx8 DRAM. Although the yen has weakened (against the dollar) considerably since the spring 1995 forecast, Japan-based suppliers are expected to slowly and grudgingly lower any DRAM prices to account for the weaker yen.

SRAM

Worldwide SRAM revenue is expected to total $5.8 billion in 1995, a 40 percent-plus growth rate over 1994. This growth rate is much stronger than the prior forecast in part because of higher cache RAM pricing during most of 1995. The fast SRAM segments, which include cache RAM, continue to outpace the SRAM growth rate, while slow SRAM revenue lags the overall growth rate.

Dataquest expects a similar rate of SRAM revenue growth in the long term. SRAM revenue will expand at more than a 15 percent rate from 1994 to 1999, led by rapidly expanding use of cache memory in PCs. By contrast, the outlook for slower-speed SRAM remains less optimistic, slowed by a weak market for high-end consumer electronics goods. This balances the high growth of cache SRAMs, dampening the overall SRAM growth rate.

Dataquest's PC outlook has a favorable impact not only on the DRAM market but also on the cache SRAM market. The sharp unit shipment ramp of the 64-bit Pentium-class PCs is driving high growth in the cache SRAM market, because purchasers of PCs using newer, more pricey CPUs tend to look to cache as a means of assuring that they get their money's worth out of this larger investment. The wider 64-bit CPU bus is also driving the cache needs of such systems to be double that of their 32-bit counterparts.

For well-positioned suppliers of higher-speed 32Kx8 SRAM, the movement from a 32-bit CPU bus to a 64-bit bus has effectively doubled their unit demand. Four of these 32Kx8 devices are used in each 32-bit PC, while 64-bit PCs need eight of them. The 1Mb cache market will gain momentum during 1996.

The slower-speed versions of the 1Mb SRAM have been available for several years, yet continue to fail to win market acceptance. The high-end consumer electronics market has a dramatic effect on slow SRAMs, and today's protracted economic slump in Japan is postponing the acceptance of the 1Mb SRAM density. This delayed conversion to 1Mb from 256Kb means SRAM unit shipments will decline in 1996 and 1997, but will rebound in 1998. If this situation continues for a long enough period, there is the possibility that the 1Mb density will never really gain acceptance and the 4Mb density will be far enough along to take its place. However, our current forecast assumes that the 1Mb density will regain lost ground in 1996.

Flash Memory

Worldwide flash memory revenue should approach $1.5 billion for 1995, an impressive 50 percent growth rate over 1994. Dataquest foresees flash demand continuing to exceed supply for most of 1996. The AMD-Fujitsu alliance likely will make the greatest contribution to worldwide flash capacity during the late 1995 to 1996 period.

To reinforce our prior forecast assumptions, Dataquest expects flash to emerge as the fastest-growing worldwide memory market in the long term. Driven by newly emerging applications, flash memory revenue should average more than 36 percent annual growth from 1994 to 1999. Worldwide flash revenue should exceed $4.5 billion by 1999.

Flash technology remains inherently attractive because of its ruggedness, nonvolatility, low-power requirement, and rewrite capability. In terms of flash's functionality, the technology effectively performs a host of roles including code storage, mass data storage/manipulation, and system configuration setting. From Dataquest's perspective, the continued lowering of the flash PPB curve—combined with attractive functionality—means that flash remains positioned as the fastest-growing semiconductor memory market during the forecast horizon. Intel's multilevel cell technology could enable a step-function drop in the flash PPB by the end of this decade.

EPROM

Worldwide EPROM revenue should exceed $1.5 billion for 1995, a slight growth over 1994's sales. The prior forecast anticipated a decrease in EPROM market revenue in 1995. Constrained supply of flash memory caused some unsatisfied demand for lower-density flash to shift to EPROM. Long-term EPROM revenue should decrease at a 5 percent average rate from 1994 to 1999. The EPROM market will gradually decline to a $1.1 billion market by 1999.

EEPROM

Worldwide EEPROM revenue should reach $750 million in 1995. This represents stronger growth than did our prior forecast. The venerable EEPROM market is now moving through an especially impressive growth phase because of its suitability for a host of low-power telecom, industrial, automotive, consumer, and other applications.

Dataquest expects continued long-term growth of the EEPROM market. Worldwide EEPROM revenue should exceed EPROM revenue by 1998. Average growth of the EEPROM market should be about 21 percent from 1994 to 1999, almost reaching $1.5 billion by 1999.

Mask ROM

Video games continue to command the predominant share of ROM demand and video game sales expectations drive ROM fab spending. A single major customer, Nintendo, commands considerable attention from Japan-based ROM suppliers in terms of their product strategies and fab capacity plans. Video games continue to drive the ROM market; however, a decline in the video game market might cause ROM suppliers to become more responsive over time to the needs of other applications such as laser printers.

Worldwide ROM revenue should total nearly $2.4 billion for 1995, an 8 percent growth over 1994. Dataquest expects mild growth in this mature technology over the long term. Unit shipments will decline, however, as a market move to higher densities (16Mb and 64Mb) should be offset by a slower decline in the ROM market average selling price. ROM revenue should grow an average of less than 5 percent from 1994 to 1999. ROM revenue should approach nearly $2.6 billion in 1999.

Average per-bit ROM prices will remain about one-fourth that of flash memory through the forecast period. Although a quick advance in Intel's multilevel cell flash technology could alter this scenario, current trends signal that flash cannot be expected to displace ROM if price per bit is the major consideration.

Dataquest Perspective

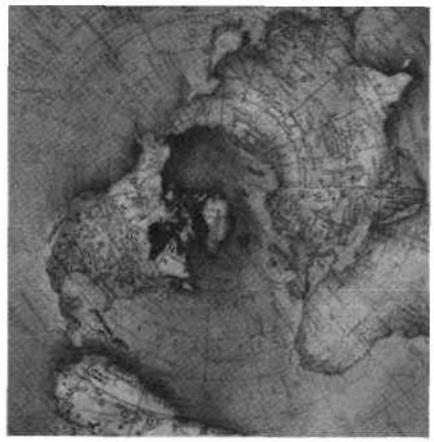
For many semiconductor market observers, two key products serve as benchmarks for the state of the industry's health and outlook—x86 processors and DRAM. One year ago, following Dataquest's 1995 Semiconductor Conference, we raised the provocative question, "When will the DRAM party end?" Our answer was, barring a major near-term change in the PC market, not until the post-1995 period at the earliest—and likely not until later. Fast-forwarding to October 1995, once again Dataquest answers not until the post 1996-period at the earliest. For the long term, a bright PC outlook also means a bright outlook for the DRAM market.

Because of the transition to new architectures (synchronous), density (1Mb), and voltage (3 volt), the cache RAM market should be especially lucrative but also turbulent during the 1996 to 1997 time frame. Companies that fail to successfully execute during this transition face a dismal SRAM future. By contrast, less familiar names might soon emerge during 1996 as the major players in the PC cache market.

Meanwhile, other memory technologies such as flash, EEPROM, and high-bandwidth RAM, among others, enjoy exciting futures. Invisible as they seem, microcontrollers and digital signal processors now appear in applications everywhere—joined by the EEPROM or flash technologies (and in some cases both). The flash shortage likely will persist throughout 1996. New flash capacity should restore supply-demand balance by the 1997 time frame. The EEPROM market looks increasingly resilient. The mature EPROM technology has a future, although a smaller set of suppliers led by SGS-Thomson will shape its role.

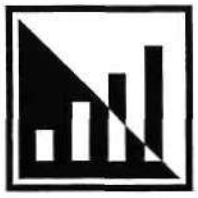
For More Information...

Jim Handy, Director and Principal Analyst ..... (408) 468-8228
Internet address ..... jhandy@dataquest.com
Via fax ..... (408) 954-1780



Dataquest

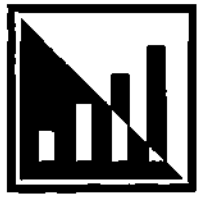
Worldwide MOS Memory Forecast



Market Statistics

Program: Memories Worldwide
Product Code: MMRY-WW-MS-9504
Publication Date: October 30, 1995
Filing: Market Analysis

Worldwide MOS Memory Forecast



Market Statistics

Program: Memories Worldwide
Product Code: MMRY-WW-MS-9504
Publication Date: October 30, 1995
Filing: Market Analysis

Table of Contents

List of Tables

Note: All tables show estimated data.

List of Tables (Continued)

Note: All tables show estimated data.

Worldwide MOS Memory Forecast

Worldwide MOS memory revenue should total more than $48 billion for 1995, a growth of 51 percent over 1994. The memory market continues to move through an exceptional period of growth driven by the DRAM, cache SRAM and flash segments. Dataquest expects robust long-term growth in most segments including DRAM, graphics RAM, cache RAM, flash, and EEPROM. Dataquest has increased its memory revenue growth outlook since the prior forecast (May 1995). Memory revenue should grow at a compound annual growth rate (CAGR) of 25 percent during the 1994 to 1999 period, with worldwide revenue reaching more than $97 billion for 1999.

Forecast Assumptions

The following top-level assumptions guide Dataquest's forecast. The baseline assumptions associated with the six memory product forecasts—DRAM, SRAM, flash, EPROM, EEPROM, and ROM—appear in the sections that discuss those forecasts. The assessment highlights changes in assumptions since the prior forecast.

Dataquest's worldwide memory IC forecast assumes the following:

- Personal computer applications including multimedia-type display applications will drive stellar growth of the worldwide memory market throughout the rest of this decade.
- The forecast assumes no severe cyclical downturn in the memory market over the long term.
- New memory capacity and new memory market entrants should become noticeable in the world markets by mid-1997, making that year a key transitional period.
- Communications applications ranging from low-voltage wireless systems to hubs and routers used for computer networking provide additional sources of growth for the worldwide memory market.

Dataquest continues to expect that Intel's Pentium ramp-up will cause a near doubling of a PC's DRAM and cache RAM requirements during the 1994 to 1996 period. Intel's Pentium Pro (former P6) migration will mean a similar scenario during the 1996 to 1998 period. Dataquest also has increased the near-term and long-term PC forecasts since the prior forecast. For example, we increased the long-range forecasts of PC unit shipments by more than 5 percent since the prior forecast.

A major event that occurred since the prior forecast was Microsoft's introduction of the Windows 95 operating system. Dataquest aggressively forecasts that nearly 30 million units of Windows 95 will ship into the installed base by year-end 1995. The installed base includes both PC units that ship with Windows 95 "preinstalled," plus retail sales units. Dataquest expects Windows 95 to saturate the market during the

post-1995 period. Windows 95 applications such as next-generation video games and new versions of applications such as PowerPoint will justify the use of 16MB of DRAM in many PCs by the middle of 1996.

DRAM

DRAMs drive the memory market, and PCs drive the DRAM market. DRAMs will generate 75 percent of worldwide memory revenue this year. The DRAMs used in PCs now alone account for nearly 50 percent of the memory market's revenue. DRAMs will generate nearly 80 percent of worldwide memory IC revenue by the year 1999.

Worldwide DRAM revenue should exceed $36 billion for 1995, a growth of 60 percent over 1994. This growth rate is somewhat stronger than but consistent with the prior forecast. Fueled by the twin engines of growth—Intel and Microsoft—DRAM revenue should grow at a 28 percent CAGR during the 1994 to 1999 period. Worldwide DRAM revenue should total nearly $79 billion by 1999.

This long-term forecast represents stronger DRAM revenue growth versus the prior long-term revenue forecast. We base the change on the upward revision of the long-term worldwide PC forecast combined with our aggressive outlook on Windows 95's impact throughout the forecast horizon. For this reason, the current forecast reflects higher DRAM pricing vis-a-vis the prior forecast.

Dataquest continues to expect no severe cyclical downturn during the forecast horizon. The DRAM market will show revenue growth every year during the forecast cycle. For example, total DRAM bit shipments should more than double every two years. The year 1998 should serve as a short-term "cooling" period in terms of revenue growth.

DRAM Forecast Assumptions

The following summarizes the strategic assumptions that serve as the basis for the DRAM forecast:

- Dataquest expects very strong PC demand throughout the forecast horizon.
- Despite fab capacity increases, DRAM undersupply will persist into 1997 for most DRAM configurations and product technologies.
- At the 16Mb density, the synchronous architectures (SDRAM, Rambus, and MoSys) will start head-to-head competition with the asynchronous architectures (EDO and Burst EDO) during the first half of 1996.
- The 64Mb DRAM will have little market impact until the post-1997 period, with the 64Mb price-per-bit crossover expected during 1999.
- The synchronous architectures will predominate at the 64Mb density starting early in the product's life cycle.

The explicit basis for our high-growth DRAM outlook for both the near and long term is as follows:

- Dataquest expects worldwide unit shipments of PCs to more than double during the 1994 to 1999 period; PC shipments should expand from fewer than 50 million units for 1994 to nearly 110 million units for 1999.
- DRAM pricing will be higher during the 1995 to 1997 period than would be indicated by the historic DRAM price-per-bit curve.
- The amount of DRAM in each PC likely will more than triple during this period. For example, the PC market move to 64-bit buses (Pentium-class or the PowerPC) means that the minimum amount of factory-installed DRAM will nearly double from 4MB during 1994 to 8MB during 1996. During 1996, Windows 95 will require even more memory—from 12MB to 16MB—for many applications.
- 16Mb DRAM unit shipments will peak during the 1997 to 1998 time frame at slightly less than 1.2 billion units; 4Mb units should peak this year at somewhat more than 1.3 billion units.

Intel's Pentium/Pentium Pro/P7 ramp-ups during the 1996 to 1998 period will have a dramatic impact in terms of PCs' main memory. For example, Dataquest conservatively estimates that the combined Pentium Pro and Windows 95 ramp-ups mean that 10 percent or more of PCs will ship with 32MB of DRAM from the PC factory by 1997.

Other changes since the prior forecast include stronger 1995 demand for the 4Mbx4 DRAM and a stronger 1996 to 1997 demand outlook for the 2Mbx8 DRAM. Although the yen has weakened (against the dollar) considerably since the spring 1995 forecast, Japan-based suppliers likely will slowly and only grudgingly make any price DRAM declines because of the weaker yen.

SRAM

Worldwide SRAM revenue should total $5.8 billion in 1995, a 40 percent-plus growth rate over 1994. This growth rate is much stronger than the prior forecast in part because of higher cache RAM pricing during most of 1995. The fast SRAM segments, which include cache RAM, continue to outpace the SRAM growth rate, while slow SRAMs lag the overall growth rate.

Dataquest expects a strong rate of SRAM revenue growth in the long term. SRAM revenue will expand at a 15 percent-plus rate during the 1994 to 1999 period, led by the rapidly expanding cache segments. By contrast, the outlook for slower-speed SRAM remains less optimistic, dampening the overall SRAM growth rate.

SRAM Forecast Assumptions

The following assumptions provide the basis for the SRAM forecast:

- 1Mb SRAMs have suffered from a lack of market acceptance, although that scenario will change.

- Dataquest expects heightened 1995 to 1996 demand for 256Kb SRAM in the 10ns to 19ns and 20ns to 44ns speed ranges from Intel's aggressive ramp-up of Pentiums.
- The transition of Pentium cache designs from the 256K density to the 1Mb density should start toward the end of 1995 and gain momentum during 1996.
- New cache SRAM growth will be triggered by the late 1995 introduction of the Pentium Pro CPU (formerly known as the P6).
- Total SRAM unit shipments will peak in 1995 and will then decline for several years. This will be caused by delays by OEMs in converting from the 256Kb to 1Mb density. The use of lower-density parts is causing unusually high unit shipments of SRAMs as a whole. Unit shipments will grow again after 1997, when the conversion has taken its toll.

Slow SRAM

The slower-speed versions of the 1Mb SRAM have been available for several years yet continue to fail to win market acceptance. The high-end consumer electronics market has a dramatic effect on slow SRAMs, and today's protracted economic slump in Japan is postponing the acceptance of the 1Mb SRAM density. This delayed conversion to 1Mb from 256Kb means SRAM unit shipments will decline in 1996 and 1997, but will rebound in 1998.

The delayed acceptance of the 1Mb SRAM and the technical difficulties of manufacturing a mass-produced TFT have delayed production of the 4Mb SRAM. This density is also behind normal life cycles and is expected to continue to suffer as long as the 1Mb density does. If this situation continues for a long enough period, there is the possibility that the 1Mb density will never really gain acceptance and the 4Mb density will be far enough along to take its place. However, this forecast assumes that the 1Mb density will regain lost ground in 1996.

High-Growth Cache RAM Market

Dataquest's PC outlook has a favorable impact not only on the DRAM market but also on the cache SRAM market. The sharp unit shipment ramp of the 64-bit Pentium-class PCs is driving high growth in the cache SRAM market, because purchasers of PCs using newer, more pricey CPUs tend to look to cache as a means of assuring that they get their money's worth out of this larger investment. The wider 64-bit CPU bus is also driving the cache needs of such systems to be double that of their 32-bit counterparts.

For well-positioned suppliers of higher-speed 32Kx8 SRAM, the movement from a 32-bit CPU bus to a 64-bit bus has effectively doubled their unit demand. Four of these 32Kx8 devices are used in each 32-bit PC, while 64-bit PCs need eight of them.

Heightened 1995 demand for asynchronous 256Kb SRAM in the 10ns to 19ns and the 20ns to 44ns speed ranges will push revenue from these

two segments over $1.3 billion this year (versus $750 million for 1994). Meanwhile, the cache RAM market will start its transition to high-speed 1Mb SRAM toward year-end 1995. Manufacturers of 64-bit PCs are now deciding whether to design-in higher-performance/higher-priced synchronous SRAM such as the 32Kx36 device, to use lower-performance/lower-priced asynchronous 128Kx8 devices, or to stay with more conservative 32Kx8-based designs, which are the current vogue.

Dataquest has noticed that a move from 256Kb to 1Mb started to occur at the beginning of this year. The 1Mb cache market will gain momentum during 1996. Strong 1996 demand for 1Mb SRAM in the 10ns to 19ns and the 20ns to 44ns speed ranges should push revenue from these segments to more than $1.9 billion next year, nearly four times' the size of the same market in 1994.

Nonvolatile Memories

The four nonvolatile memory technologies reflect differing market characteristics although at times they compete head-on for applications. Flash memory—the newly emerging nonvolatile technology—is enjoying a banner year during 1995 in part because of constrained supply. Limited supply of flash memory means unexpected near-term growth in the mature EPROM market. A wide range of applications use EEPROMs including industrial, telecommunications, and consumer systems. Diversified applications means a bright long-term outlook for the EEPROM market. By contrast, the mask ROM market depends primarily on video game demand. ROM suppliers, however, are starting to devote more resources to other applications such as laser printers.

Dataquest expects each to perform differently in the forecast window. Flash should continue to expand and benefit over the forecast horizon from the continued emergence of low-voltage handheld systems for telecom and computing applications. Our outlook for the EPROM market has changed since the prior forecast because of the flash supply constraint. The EPROM market will show market growth during the 1995 to 1996 period and decline somewhat noticeably in the post-1996 period as more flash capacity comes on line. EEPROM market revenue quietly surged during 1994, and we expect impressive growth for the next several years. EEPROM market revenue could equal or exceed EPROM revenue by 1998, a reversal of history. The mask ROM market should be relatively flat through the forecast period.

Flash Recaptures Market Attention

Worldwide flash memory revenue should approach $1.5 billion for 1995, an impressive 50 percent growth rate over 1994.

The flash market has undergone a remarkable spin of scenarios since 1993:

- An unexpected flash shortage during 1993 drove up flash revenue, profits, and market expectations.
- The flash market grew impressively during 1994, but was somewhat disappointing to some participants because of sky-high expectations.

- The conservative expectations for 1995 proved just that—"conservative" because limited supply has meant higher flash prices, stronger revenue growth, and impressive profits.

Dataquest foresees flash demand continuing to exceed supply for most of 1996. The AMD-Fujitsu alliance likely will make the greatest contribution to worldwide flash capacity during the late 1995 to 1996 period. At the time of the writing of this report, Intel just announced its $1.6 billion Israeli flash fab.

To reinforce our prior forecast scenario, Dataquest expects flash to emerge as the fastest-growing worldwide memory market in the long term. Driven by newly emerging applications, flash memory revenue should have more than 36 percent CAGR during the 1994 to 1999 period. Worldwide flash revenue should exceed $4.5 billion by 1999.

Flash Memory Forecast Assumptions

Dataquest bases the flash memory forecast on these assumptions:

- Flash remains a key enabling technology for a profusion of low-power handheld systems and peripherals; flash will enable the emergence of a host of other applications, such as digital cameras and automotive navigation systems.
- The flash market will remain supply constrained throughout most of 1996, meaning higher flash pricing than originally expected.
- A major increase in flash capacity will occur during 1997, meaning tremendous growth in terms of bit shipments but also a steep drop in flash price per bit (PPB) during the post-1996 period.

Flash technology remains inherently attractive because of its ruggedness, nonvolatility, low-power requirement, and rewrite capability. In terms of flash's functionality, the technology effectively performs a host of roles including code storage, mass data storage/manipulation, and system configuration setting. From Dataquest's perspective, the continued lowering of the flash PPB curve—combined with attractive functionality—means that flash remains positioned as the fastest-growing semiconductor memory market during the forecast horizon. Intel's multilevel cell (MLC) technology could enable a step-function drop in the flash PPB by the end of this decade.

EPROM

Worldwide EPROM revenue should exceed $1.5 billion for 1995, a slight growth profile versus 1994. The prior forecast anticipated a 1995 decrease in EPROM market revenue. Constrained supply of flash memory caused some unsatisfied demand for lower-density flash to shift to EPROM. Long-term EPROM revenue should decrease at a 5 percent CAGR during the 1994 to 1999 period. The EPROM market will gradually decline to a $1.1 billion market by the 1999 time frame.

EPROM Forecast Assumptions

The following assumptions serve as the basis for the EPROM forecast:

- Market leader SGS-Thomson will continue to assume a leadership role in terms of EPROM technology and market trends.
- There will be a noticeable decline in total EPROM revenue, but not until the post-1996 period.
- Despite competitive challenges, the EPROM market will exist well beyond the end of the 1999 forecast horizon, with SGS-Thomson leading in terms of long-term supplier commitment to the product technology, joined by "less familiar" suppliers such as Atmel, Cypress, and Macronix.

EEPROM

Worldwide EEPROM revenue should reach $750 million for 1995, a 34 percent growth rate over 1994. This represents stronger growth vis-a-vis the prior forecast. The venerable EEPROM market is now moving through an especially impressive growth phase because of its suitability for a host of low-power telecom, industrial, automotive, consumer, and other applications.

Dataquest expects continued long-term growth of the EEPROM market. Worldwide EEPROM revenue should exceed EPROM revenue by the 1998 time frame. The EEPROM market should grow at a 21 percent CAGR during the 1994 to 1999 period, almost reaching $1.5 billion by 1999.

EEPROM Forecast Assumptions

Dataquest bases the EEPROM forecast on the following set of assumptions:

- EEPROM demand will continue to be driven by high demand for microcontrollers for a host of industrial, telecom, and consumer embedded applications; this is great news for suppliers because it reduces competition (versus the intense level of direct competition in segments of the DRAM, cache RAM, and flash markets).
- The EEPROM market will continue to enjoy a yearlong window of opportunity over the flash market in terms of low-voltage applications, for example:
  - EEPROMs today satisfy many 3V-only applications (in advance of the 3V-only flash market).
  - EEPROMs likely will satisfy sub-3V applications in advance of the sub-3V-only flash market.

Mask ROM

Video games continue to command the predominant share of ROM demand and ROM fab spending. A single major customer, Nintendo, commands considerable attention from Japan-based ROM suppliers in terms of their product strategies and fab capacity plans. Video games continue to drive the ROM market for the meantime. Market forces,

however, might cause ROM suppliers to be more responsive over time to the needs of other applications such as laser printers. For example, some suppliers report that major customers (nonvideo game customers) request support of their ROM requirements in order to win the customer's business for other memory ICs.

Worldwide ROM revenue should total nearly $2.4 billion for 1995, an 8 percent growth over 1994. Dataquest expects mild growth in this mature technology over the long term. Unit shipments will decline, however, the market move to higher densities (16Mb and 64Mb) should be offset by a slower decline in the ROM market average selling price. ROM revenue should grow at a CAGR of less than 5 percent during the 1994 to 1999 period. ROM revenue should approach nearly $2.6 billion for 1999.

Mask ROM Forecast Assumptions

The following assumptions guide Dataquest's mask ROM forecast:

- The eventual demise of the ROM-based video cartridge business will cause ROM suppliers to migrate to other applications or de-emphasize this product technology; however, Nintendo already successfully managed several times to resuscitate the ROM technology that appeared on the verge of a market decline.
- ROM PPB will remain less than that of flash memory through the forecast period; although a quick advance in Intel's multilevel cell flash technology could alter this scenario, current trends signal that flash likely will be unable to displace ROM if PPB is the major consideration.

Table 1
Factory Revenue from Shipments of Semiconductor Memory to the World, 1992-1999
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
DRAM	8,521	14,411	22,668	36,273	52,535	64,788	69,142	78,858	28.3
SRAM	2,990	3,471	4,093	5,757	6,713	7,418	7,840	8,860	16.7
EPROM	1,226	1,418	1,442	1,554	1,532	1,435	1,296	1,109	-5.1
Flash	257	725	992	1,489	2,086	2,908	3,836	4,640	36.1
ROM	1,445	1,732	2,172	2,351	2,427	2,568	2,604	2,558	3.3
EEPROM	369	488	559	751	1,011	1,185	1,319	1,454	21.1
Total	14,808	22,245	31,926	48,176	66,305	80,302	86,038	97,479	25.0
Percentage Change	18.7	50.2	43.5	50.9	37.6	21.1	7.1	13.3	

Source: Dataquest (October 1995)

Table 2
Shipments of Semiconductor Memory to the World, 1992-1999
(Millions of Units)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
DRAM	1,474	1,610	1,806	2,106	2,042	2,165	2,026	1,872	0.7
SRAM	842	906	881	1,008	916	897	947	1,014	2.9
EPROM	424	476	458	483	443	448	386	300	-8.1
Flash	28	74	124	168	237	384	556	814	45.8
ROM	418	445	456	422	350	322	320	371	-4.0
EEPROM	300	460	581	722	898	1,069	1,095	1,310	17.7
Total	3,487	3,971	4,305	4,909	4,886	5,286	5,329	5,682	5.7
Percentage Change	13.4	13.9	8.4	14.0	-0.5	8.2	.8	6.6	

Source: Dataquest (October 1995)

Table 3
Average Selling Price for Shipments of Semiconductor Memory to the World, 1992-1999 (U.S. Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999
DRAM	5.78	8.95	12.55	17.22	25.72	29.93	34.13	42.12
SRAM	3.55	3.83	4.65	5.71	7.33	8.27	8.28	8.74
EPROM	2.89	2.98	3.15	3.22	3.46	3.20	3.36	3.70
Flash	9.14	9.80	8.02	8.87	8.80	7.57	6.90	5.70
ROM	3.46	3.89	4.76	5.58	6.94	7.97	8.14	6.89
EEPROM	1.23	1.06	0.96	1.04	1.13	1.11	1.20	1.11
Average	4.2	5.6	7.4	9.8	13.6	15.2	16.1	17.16
Percentage Change	4.6	31.9	32.4	32.3	38.3	11.9	6.3	6.3

Source: Dataquest (October 1995)

Table 4
Bits from Shipments of Semiconductor Memory to the World, 1992-1999 (Trillions of Bits)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
DRAM	2,828	4,662	7,157	11,338	17,317	26,235	40,334	59,377	52.7
SRAM	186	270	309	443	829	1,289	2,303	3,507	62.5
EPROM	253	386	403	520	574	777	831	866	16.5
Flash	29	101	231	493	942	3,130	6,944	15,614	132.2
ROM	1,592	2,866	3,400	4,116	5,050	6,797	9,447	15,047	34.6
EEPROM	3	4	6	11	18	30	52	83	69.3
Total	4,892	8,290	11,507	16,920	24,730	38,257	59,911	94,496	52.4
Percentage Change	71.6	69.5	38.8	47.0	46.2	54.7	56.6	57.7	

Source: Dataquest (October 1995)

Table 5
Price per Bit for Shipments of Semiconductor Memory to the World, 1992-1999 (Micro Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
DRAM	3.0	3.1	3.2	3.2	3.0	2.5	1.7	1.3	-16.0
SRAM	16.0	12.8	13.2	13.0	8.1	5.8	3.4	2.5	-28.2
EPROM	4.9	3.7	3.6	3.0	2.7	1.8	1.6	1.3	-18.6
Flash	8.7	7.2	4.3	3.0	2.2	0.9	0.6	0.3	-41.4
ROM	0.9	0.6	0.6	0.6	0.5	0.4	0.3	0.2	-23.3
EEPROM	126.1	115.8	93.3	71.3	56.9	40.0	25.3	17.4	-28.5
Average	3.0	2.7	2.8	2.8	2.7	2.1	1.4	1.0	-18.0
Percentage Change	-30.9	-11.4	3.4	2.6	-5.8	-21.7	-31.6	-28.2	

Source: Dataquest (October 1995)

Table 6
Factory Revenue from Shipments of DRAMs to the World, 1992-1999 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
64K STAND	11	5	3	0	0	0	0	0	NM
256K STAND	189	109	57	53	23	2	0	0	NM
256K VRAM	156	103	76	49	22	21	7	7	-38.7
1Mb STAND	2,392	1,618	1,502	1,262	418	242	171	138	-37.9
1Mb VRAM	527	775	559	330	147	80	30	26	-46.0
2Mb VRAM	5	237	303	493	540	459	369	213	-6.8
4Mb STAND	5,031	9,949	14,346	17,371	13,795	8,485	3,364	1,450	-36.8
4Mb VRAM	1	15	110	523	911	1,426	1,276	1,143	59.7
16Mb STAND	208	1,601	5,712	16,152	35,440	39,349	30,572	21,114	29.9
64Mb STAND	0	0	0	39	1,239	14,723	32,999	49,013	NM
256Mb STAND	0	0	0	0	0	0	355	5,754	NM
Total	8,521	14,411	22,668	36,273	52,535	64,788	69,142	78,858	28.3
Percentage Change	23.4	69.1	57.3	60.0	44.8	23.3	6.7	14.1	

NM = Not meaningful

Source: Dataquest (October 1995)

Table 7
Shipments of DRAMs to the World, 1992-1999
(Millions of Units)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
64K STAND	8	5	3	0	0	0	0	0	NM
256K STAND	135	71	33	30	14	1	0	0	NM
256K VRAM	59	34	22	17	8	7	2	2	-37.3
1Mb STAND	743	479	376	310	107	56	39	31	-39.5
1Mb VRAM	79	123	93	55	27	15	5	5	-45.4
2Mb STAND	0	0	9	0	0	0	0	0	NM
2Mb VRAM	0	18	26	44	50	45	36	20	-5.5
4Mb STAND	449	859	1,131	1,315	1,062	812	434	209	-28.7
4Mb VRAM	0	0	4	22	47	79	85	83	84.1
16Mb STAND	2	22	108	312	724	1,090	1,145	918	53.4
64Mb STAND	0	0	0	0	4	60	279	596	NM
256Mb STAND	0	0	0	0	0	0	1	10	NM
Total	1,474	1,610	1,806	2,106	2,042	2,165	2,026	1,872	0.7
Percentage Change	14.6	9.2	12.1	16.6	-3.0	6.0	-6.4	-7.6	

NM = Not meaningful
Source: Dataquest (October 1995)

Table 8
Average Selling Price for Shipments of DRAMs to the World, 1992-1999
(U.S. Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999
64K STAND	1.34	1.12	1.20	0	0	0	0	NM
256K STAND	1.40	1.54	1.72	1.73	1.61	1.75	0	NM
256K VRAM	2.67	3.04	3.51	2.96	2.76	3.01	3.00	3.12
1Mb STAND	3.22	3.38	3.99	4.07	3.91	4.36	4.35	4.53
1Mb VRAM	6.71	6.31	6.03	5.97	5.55	5.36	5.50	5.72
2Mb VRAM	15.30	12.88	11.43	11.19	10.80	10.20	10.26	10.67
4Mb STAND	11.20	11.58	12.68	13.21	12.99	10.45	7.75	6.95
4Mb VRAM	60.00	33.88	28.12	23.45	19.42	18.03	15.01	13.84
16Mb STAND	114.85	74.26	52.84	51.77	48.95	36.10	26.70	23.00
64Mb STAND	0	0	0	394.65	309.85	244.57	118.49	82.25
256Mb STAND	0	0	0	0	0	0	710.94	575.38
Average	5.8	9.0	12.6	17.2	25.7	29.9	34.1	42.12
Percentage Change	7.6	54.8	40.3	37.2	49.3	16.3	14.0	23.4

NM = Not meaningful
Source: Dataquest (October 1995)

Table 9
Bits from Shipments of DRAMs to the World, 1992-1999
(Trillions of Bits)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
64K STAND	1	0	0	0	0	0	0	0	NM
256K STAND	35	19	9	8	4	0	0	0	NM
256K VRAM	15	9	6	4	2	2	1	1	-37.3
1Mb STAND	779	502	394	325	112	58	41	32	-39.5
1Mb VRAM	82	129	97	58	28	16	6	5	-45.4
2Mb STAND	0	0	20	0	0	0	0	0	NM
2Mb VRAM	1	39	56	92	105	94	75	42	-5.5
4Mb STAND	1,885	3,602	4,745	5,516	4,454	3,406	1,820	875	-28.7
4Mb VRAM	0	2	16	94	197	332	357	346	84.1
16Mb STAND	30	362	1,814	5,234	12,147	18,287	19,210	15,401	53.4
64Mb STAND	0	0	0	7	268	4,040	18,690	39,990	NM
256Mb STAND	0	0	0	0	0	0	134	2,684	NM
Total	2,828	4,662	7,157	11,338	17,317	26,235	40,334	59,377	52.7
Percentage Change	84.2	64.9	53.5	58.4	52.7	51.5	53.7	47.2	

NM = Not meaningful
Source: Dataquest (October 1995)

Table 10
Price per Bit for Shipments of DRAMs to the World, 1992-1999
(Micro Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
64K STAND	20.5	17.1	18.3	0	0	0	0	0	NM
256K STAND	5.4	5.9	6.6	6.6	6.1	6.7	0	0	NM
256K VRAM	10.2	11.6	13.4	11.3	10.5	11.5	11.4	11.9	-2.4
1Mb STAND	3.1	3.2	3.8	3.9	3.7	4.2	4.1	4.3	2.5
1Mb VRAM	6.4	6.0	5.7	5.7	5.3	5.1	5.2	5.5	-1.0
2Mb VRAM	7.3	6.1	5.5	5.3	5.1	4.9	4.9	5.1	-1.4
4Mb STAND	2.7	2.8	3.0	3.1	3.1	2.5	1.8	1.7	-11.3
4Mb VRAM	14.3	8.1	6.7	5.6	4.6	4.3	3.6	3.3	-13.2
16Mb STAND	6.8	4.4	3.1	3.1	2.9	2.2	1.6	1.4	-15.3
64Mb STAND	0	0	0	5.9	4.6	3.6	1.8	1.2	NM
256Mb STAND	0	0	0	0	0	0	2.6	2.1	NM
Average	3.0	3.1	3.2	3.2	3.0	2.5	1.7	1.3	-16.0
Percentage Change	-33.0	2.6	2.5	1.0	-5.2	-18.6	-30.6	-22.5	

NM = Not meaningful
Source: Dataquest (October 1995)

Table 11
Factory Revenue from Shipments of SRAMs to the World, 1992-1999
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
16K 10-19ns	6	3	4	3	2	1	1	0	-43.5
16K 20-44ns	35	13	16	11	6	4	2	1	-40.3
16K 45-70ns	9	4	5	3	2	1	1	0	-46.6
16K >70ns	77	101	81	46	20	13	9	4	-44.4
64K 0-9ns	3	25	9	4	2	1	1	1	-41.9
64K 10-19ns	40	24	47	159	68	32	17	9	-27.6
64K 20-44ns	190	119	98	126	78	44	32	19	-28.0
64K 45-70ns	50	28	24	25	14	7	5	5	-28.0
64K >70ns	380	438	273	274	62	39	22	12	-46.9
64K >70ns PSRAM	7	7	8	7	8	4	3	1	-28.6
256K 0-9ns	4	9	11	71	74	59	49	51	35.4
256K 10-19ns	66	66	302	794	520	397	48	33	-35.7
256K 20-44ns	395	394	429	554	348	202	125	63	-31.8
256K 45-70ns	90	91	157	164	118	61	36	37	-25.2
256K >70ns	706	813	676	473	323	244	155	112	-30.3
256K >70ns PSRAM	139	141	119	94	71	25	19	10	-38.9
512K 10-19ns	0	0	28	0	0	0	0	0	NM
1Mb 0-9ns	52	34	104	119	216	277	271	258	20.0
1Mb 10-19ns	149	197	328	552	862	916	806	665	15.2
1Mb 20-44ns	93	124	226	709	1,048	1,258	926	573	20.4
1Mb 45-70ns	86	100	81	149	155	131	94	84	0.8
1Mb >70ns	313	497	550	726	864	722	475	434	-4.6
1Mb >70ns PSRAM	52	73	72	80	100	80	60	44	-9.4
4Mb 0-9ns	0	0	0	0	38	45	87	52	NM
4Mb 10-19ns	0	5	5	12	238	241	569	506	150.0
4Mb 20-44ns	0	2	125	67	132	206	733	827	46.0
4Mb 45-70ns	0	10	0	7	185	283	662	643	NM
4Mb >70ns	2	50	190	391	789	808	994	1,241	45.5
4Mb >70ns PSRAM	45	104	124	137	356	275	394	297	19.1
16Mb 0-9ns	0	0	0	0	0	61	115	304	NM
16Mb 10-19ns	0	0	0	0	0	269	247	652	NM
16Mb 20-44ns	0	0	0	0	0	101	153	979	NM
16Mb 45-70ns	0	0	0	0	0	121	148	319	NM
16Mb >70ns	0	0	0	0	16	488	579	622	NM
Total	2,990	3,471	4,093	5,757	6,713	7,418	7,840	8,860	16.7
Percentage Change	16.4	16.1	17.9	40.7	16.6	10.5	5.7	13.0	

NM = Not meaningful

Source: Dataquest (October 1995)

Table 12
Shipments of SRAMs to the World, 1992-1999
(Millions of Units)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
16K 10-19ns	2	1	2	1	1	0	0	0	-43.5
16K 20-44ns	13	7	7	4	2	2	1	1	-41.0
16K 45-70ns	6	3	2	2	1	1	0	0	-47.1
16K >70ns	87	47	36	21	9	6	4	2	-44.4
64K 0-9ns	0	2	1	0	0	0	0	0	-31.3
64K 10-19ns	10	9	17	53	22	10	6	3	-30.0
64K 20-44ns	77	57	50	45	28	16	11	6	-34.0
64K 45-70ns	27	16	15	13	7	3	3	2	-31.3
64K >70ns	213	219	152	142	32	20	11	6	-48.1
64K >70ns PSRAM	4	5	5	3	2	1	1	0	-42.6
256K 0-9ns	0	1	1	10	14	12	10	10	71.8
256K 10-19ns	4	10	41	123	101	97	13	10	-25.5
256K 20-44ns	57	92	111	125	92	58	36	19	-29.9
256K 45-70ns	23	29	49	51	44	24	14	15	-21.3
256K >70ns	199	244	212	148	121	95	61	45	-26.8
256K >70ns PSRAM	59	63	52	41	33	12	9	5	-38.2
512K 0-9ns	0	0	1	0	0	0	0	0	NM
512K 10-19ns	0	0	4	0	0	0	0	0	NM
512K 20-44ns	0	0	0	0	0	0	0	0	NM
1Mb 0-9ns	0	0	1	4	10	25	29	52	140.3
1Mb 10-19ns	1	3	5	24	48	64	81	104	81.1
1Mb 20-44ns	3	8	16	46	84	135	150	114	48.2
1Mb 45-70ns	7	11	9	19	22	21	20	18	14.6
1Mb >70ns	31	55	62	95	128	116	101	94	8.5
1Mb >70ns PSRAM	12	18	18	20	25	20	15	11	-9.6
4Mb 0-9ns	0	0	0	0	0	1	4	4	NM
4Mb 10-19ns	0	0	0	0	4	11	36	41	332.1
4Mb 20-44ns	0	0	1	1	6	15	73	92	160.0
4Mb 45-70ns	0	0	0	0	8	22	69	76	NM
4Mb >70ns	0	0	2	7	44	70	114	164	143.3
4Mb >70ns PSRAM	4	8	9	11	29	32	54	45	36.5
16Mb 0-9ns	0	0	0	0	0	0	0	1	NM
16Mb 10-19ns	0	0	0	0	0	1	2	9	NM
16Mb 20-44ns	0	0	0	0	0	1	2	13	NM
16Mb 45-70ns	0	0	0	0	0	2	4	17	NM
16Mb >70ns	0	0	0	0	0	7	16	38	NM
Total	842	906	881	1,008	916	897	947	1,014	2.9
Percentage Change	19.7	7.6	-2.8	14.4	-9.1	-2.0	5.5	7.1	

NM = Not meaningful
Source: Dataquest (October 1995)

Table 13
Average Selling Price for Shipments of SRAMs to the World, 1992-1999 (U.S. Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999
16K 10-19ns	3.50	2.59	2.49	2.50	2.50	2.50	2.50	2.50
16K 20-44ns	2.67	1.81	2.35	2.50	2.50	2.50	2.50	2.50
16K 45-70ns	1.48	1.25	1.90	2.00	2.00	2.00	2.00	2.00
16K >70ns	0.88	2.14	2.25	2.25	2.25	2.25	2.25	2.25
64K 0-9ns	17.12	14.78	13.10	10.42	8.56	7.05	6.45	5.67
64K 10-19ns	3.84	2.56	2.80	3.02	3.05	3.07	3.12	3.31
64K 20-44ns	2.46	2.07	1.95	2.79	2.82	2.85	2.91	3.03
64K 45-70ns	1.84	1.70	1.60	1.93	1.93	1.95	1.97	2.03
64K >70ns	1.78	2.00	1.80	1.93	1.93	1.95	1.97	2.03
64K >70ns PSRAM	1.50	1.49	1.65	2.47	4.88	4.90	4.90	4.90
256K 0-9ns	138.12	13.52	16.61	7.34	5.23	5.14	5.10	5.05
256K 10-19ns	16.75	6.73	7.29	6.46	5.14	4.08	3.68	3.50
256K 20-44ns	6.93	4.29	3.86	4.42	3.80	3.50	3.49	3.35
256K 45-70ns	3.88	3.15	3.23	3.20	2.68	2.58	2.55	2.50
256K >70ns	3.54	3.33	3.19	3.20	2.68	2.58	2.55	2.50
256K >70ns PSRAM	2.34	2.25	2.29	2.30	2.17	2.15	2.15	2.15
512K 10-19ns	0	0	6.92	0	0	0	0	NM
1Mb 0-9ns	546.42	186.11	159.61	32.12	20.99	11.18	9.26	4.97
1Mb 10-19ns	165.01	73.50	61.42	22.64	18.15	14.24	9.95	6.39
1Mb 20-44ns	29.79	16.42	14.27	15.55	12.49	9.33	6.16	5.05
1Mb 45-70ns	13.27	8.74	8.89	7.81	7.01	6.25	4.77	4.69
1Mb >70ns	10.15	9.11	8.83	7.67	6.73	6.21	4.70	4.64
1Mb >70ns PSRAM	4.18	4.15	3.95	4.00	4.00	4.00	4.00	4.00
4Mb 0-9ns	0	0	0	0	93.77	41.02	24.81	13.24
4Mb 10-19ns	0	225.00	189.65	116.25	58.05	22.94	15.62	12.29
4Mb 20-44ns	0	134.00	160.73	74.40	23.22	13.93	10.11	8.98
4Mb 45-70ns	0	97.43	0	73.47	22.33	13.16	9.65	8.51
4Mb >70ns	120.00	103.87	98.92	55.80	17.86	11.61	8.73	7.56
4Mb >70ns PSRAM	11.54	13.16	13.05	13.02	12.50	8.60	7.35	6.62
16Mb 0-9ns	0	0	0	0	0	610.00	577.29	304.16
16Mb 10-19ns	0	0	0	0	0	335.84	137.45	72.42
16Mb 20-44ns	0	0	0	0	0	125.94	95.50	75.32
16Mb 45-70ns	0	0	0	0	0	71.37	41.23	19.31
16Mb >70ns	0	0	0	0	158.64	65.89	36.65	16.42
Average	3.6	3.8	4.6	5.7	7.3	8.3	8.3	8.74
Percentage Change	-2.7	7.8	21.4	22.9	28.3	12.8	0.1	5.6

NM = Not meaningful

Source: Dataquest (October 1995)

Table 14
Bits from Shipments of SRAMs to the World, 1992-1999
(Trillions of Bits)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
16K 10-19ns	0	0	0	0	0	0	0	0	-43.5
16K 20-44ns	0	0	0	0	0	0	0	0	-41.0
16K 45-70ns	0	0	0	0	0	0	0	0	-47.1
16K >70ns	1	1	1	0	0	0	0	0	-44.4
64K 0-9ns	0	0	0	0	0	0	0	0	-31.3
64K 10-19ns	1	1	1	3	1	1	0	0	-30.0
64K 20-44ns	5	4	3	3	2	1	1	0	-34.0
64K 45-70ns	2	1	1	1	0	0	0	0	-31.3
64K >70ns	14	14	10	9	2	1	1	0	-48.1
64K >70ns PSRAM	0	0	0	0	0	0	0	0	-42.6
256K 0-9ns	0	0	0	3	4	3	3	3	71.8
256K 10-19ns	1	3	11	32	27	26	3	2	-25.5
256K 20-44ns	15	24	29	33	24	15	9	5	-29.9
256K 45-70ns	6	8	13	13	12	6	4	4	-21.3
256K >70ns	52	64	55	39	32	25	16	12	-26.8
256K >70ns PSRAM	16	16	14	11	9	3	2	1	-38.2
512K 0-9ns	0	0	0	0	0	0	0	0	NM
512K 10-19ns	0	0	2	0	0	0	0	0	NM
512K 20-44ns	0	0	0	0	0	0	0	0	NM
1Mb 0-9ns	0	0	1	4	11	26	31	55	140.3
1Mb 10-19ns	1	3	6	26	50	67	85	109	81.1
1Mb 20-44ns	3	8	17	48	88	141	158	119	48.2
1Mb 45-70ns	7	12	10	20	23	22	21	19	14.6
1Mb >70ns	32	57	65	99	135	122	106	98	8.5
1Mb >70ns PSRAM	13	18	19	21	26	21	16	12	-9.6
4Mb 0-9ns	0	0	0	0	2	5	15	16	NM
4Mb 10-19ns	0	0	0	0	17	44	153	173	332.1
4Mb 20-44ns	0	0	3	4	24	62	304	386	160.0
4Mb 45-70ns	0	0	0	0	35	90	288	317	NM
4Mb >70ns	0	2	8	29	185	292	478	689	143.3
4Mb >70ns PSRAM	16	33	40	44	120	134	225	188	36.5
16Mb 0-9ns	0	0	0	0	0	2	3	17	NM
16Mb 10-19ns	0	0	0	0	0	13	30	151	NM
16Mb 20-44ns	0	0	0	0	0	13	27	218	NM
16Mb 45-70ns	0	0	0	0	0	29	60	277	NM
16Mb >70ns	0	0	0	0	2	124	265	636	NM
Total	186	270	309	443	829	1,289	2,303	3,507	62.5
Percentage Change	46.8	44.9	14.4	43.4	87.0	55.5	78.6	52.3	

NM = Not meaningful
Source: Dataquest (October 1995)

Table 15
Price per Bit for Shipments of SRAMs to the World, 1992-1999
(Micro Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
16K 10-19ns	213.6	158.2	151.8	152.6	152.6	152.6	152.6	152.6	0.1
16K 20-44ns	162.7	110.8	143.4	152.6	152.6	152.6	152.6	152.6	1.2
16K 45-70ns	90.4	76.3	116.0	122.1	122.1	122.1	122.1	122.1	1.0
16K >70ns	53.7	130.4	137.3	137.3	137.3	137.3	137.3	137.3	0
64K 0-9ns	261.2	225.5	199.9	159.0	130.6	107.6	98.4	86.5	-15.4
64K 10-19ns	58.5	39.0	42.7	46.1	46.5	46.8	47.6	50.5	3.4
64K 20-44ns	37.6	31.6	29.8	42.6	43.0	43.5	44.4	46.2	9.2
64K 45-70ns	28.0	26.0	24.4	29.4	29.4	29.8	30.1	31.0	4.9
64K >70ns	27.1	30.6	27.5	29.4	29.4	29.8	30.1	31.0	2.4
64K >70ns PSRAM	22.9	22.7	25.2	37.7	74.5	74.8	74.8	74.8	24.3
256K 0-9ns	526.9	51.6	63.3	28.0	20.0	19.6	19.5	19.3	-21.2
256K 10-19ns	63.9	25.7	27.8	24.6	19.6	15.6	14.0	13.4	-13.6
256K 20-44ns	26.4	16.4	14.7	16.9	14.5	13.4	13.3	12.8	-2.8
256K 45-70ns	14.8	12.0	12.3	12.2	10.2	9.8	9.7	9.5	-5.0
256K >70ns	13.5	12.7	12.2	12.2	10.2	9.8	9.7	9.5	-4.8
256K >70ns PSRAM	8.9	8.6	8.7	8.8	8.3	8.2	8.2	8.2	-1.2
512K 10-19ns	0	0	13.2	0	0	0	0	0	NM
1Mb 0-9ns	521.1	177.5	152.2	30.6	20.0	10.7	8.8	4.7	-50.0
1Mb 10-19ns	157.4	70.1	58.6	21.6	17.3	13.6	9.5	6.1	-36.4
1Mb 20-44ns	28.4	15.7	13.6	14.8	11.9	8.9	5.9	4.8	-18.8
1Mb 45-70ns	12.7	8.3	8.5	7.4	6.7	6.0	4.5	4.5	-12.0
1Mb >70ns	9.7	8.7	8.4	7.3	6.4	5.9	4.5	4.4	-12.1
1Mb >70ns PSRAM	4.0	4.0	3.8	3.8	3.8	3.8	3.8	3.8	0.3
4Mb 0-9ns	0	0	0	0	22.4	9.8	5.9	3.2	NM
4Mb 10-19ns	0	53.6	45.2	27.7	13.8	5.5	3.7	2.9	-42.1
4Mb 20-44ns	0	31.9	38.3	17.7	5.5	3.3	2.4	2.1	-43.8
4Mb 45-70ns	0	23.2	0	17.5	5.3	3.1	2.3	2.0	NM
4Mb >70ns	28.6	24.8	23.6	13.3	4.3	2.8	2.1	1.8	-40.2
4Mb >70ns PSRAM	2.8	3.1	3.1	3.1	3.0	2.1	1.8	1.6	-12.7
16Mb 0-9ns	0	0	0	0	0	36.4	34.4	18.1	NM
16Mb 10-19ns	0	0	0	0	0	20.0	8.2	4.3	NM
16Mb 20-44ns	0	0	0	0	0	7.5	5.7	4.5	NM
16Mb 45-70ns	0	0	0	0	0	4.3	2.5	1.2	NM
16Mb >70ns	0	0	0	0	9.5	3.9	2.2	1.0	NM
Average	16.0	12.8	13.2	13.0	8.1	5.8	3.4	2.5	-28.2
Percentage Change	-20.7	-19.9	3.1	-1.9	-37.6	-29.0	-40.8	-25.8	

NM = Not meaningful
Source: Dataquest (October 1995)

Table 16
Factory Revenue from Shipments of EPROMs to the World, 1992-1999
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
16K	12	12	9	8	6	4	4	3	-19.6
32K	23	17	8	10	9	6	5	4	-12.6
64K	71	50	41	46	33	18	10	10	-24.0
128K	44	37	26	25	19	14	8	8	-21.9
256K	331	258	277	275	235	190	142	81	-21.9
512K	226	294	284	328	275	234	186	113	-16.8
1Mb	229	304	276	231	196	163	151	107	-17.3
2Mb	111	118	132	145	119	92	59	47	-18.7
4Mb	178	328	389	440	564	532	515	484	4.5
8Mb	0	0	1	22	36	113	139	163	193.2
16Mb	0	0	0	24	40	69	77	90	355.8
Total	1,226	1,418	1,442	1,554	1,532	1,435	1,296	1,109	-5.1
Percentage Change	-10.0	15.7	1.7	7.8	-1.4	-6.3	-9.7	-14.4	

Source: Dataquest (October 1995)

Table 17
Shipments of EPROMs to the World, 1992-1999
(Millions of Units)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
16K	6	5	4	4	3	2	2	2	-19.0
32K	10	8	3	4	4	3	2	2	-10.6
64K	42	31	27	25	18	11	6	6	-25.1
128K	29	21	16	15	12	10	5	5	-20.1
256K	157	143	142	130	114	106	78	45	-20.5
512K	85	116	117	138	122	119	95	58	-13.0
1Mb	65	98	85	78	68	65	58	41	-13.5
2Mb	16	22	25	31	25	22	14	11	-14.6
4Mb	14	32	38	57	73	95	99	95	20.3
8Mb	0	0	0	2	4	15	21	25	266.1
16Mb	0	0	0	1	1	3	5	9	515.0
Total	424	476	458	483	443	448	386	300	-8.1
Percentage Change	-10.9	12.2	-3.8	5.6	-8.4	1.3	-14.0	-22.3	

Source: Dataquest (October 1995)

Table 18
Average Selling Price for Shipments of EPROMs to the World, 1992-1999
(U.S. Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999
16K	2.20	2.16	2.02	2.32	2.32	2.34	2.34	1.95
32K	2.30	2.26	2.32	2.47	2.47	2.49	2.49	2.08
64K	1.70	1.60	1.51	1.88	1.87	1.64	1.64	1.63
128K	1.50	1.74	1.60	1.68	1.64	1.44	1.44	1.43
256K	2.11	1.81	1.95	2.12	2.06	1.80	1.81	1.79
512K	2.66	2.54	2.43	2.37	2.25	1.97	1.97	1.95
1Mb	3.52	3.09	3.25	2.96	2.90	2.50	2.60	2.60
2Mb	6.80	5.31	5.25	4.74	4.70	4.30	4.10	4.10
4Mb	13.02	10.34	10.30	7.70	7.70	5.60	5.18	5.10
8Mb	0	0	19.75	11.56	10.36	7.54	6.61	6.50
16Mb	0	0	45.55	48.82	39.50	24.80	17.16	10.18
Average	2.9	3.0	3.1	3.2	3.5	3.2	3.4	3.70
Percentage Change	1.0	3.1	5.7	2.1	7.7	-7.5	5.0	10.1

Source: Dataquest (October 1995)

Table 19
Bits from Shipments of EPROMs to the World, 1992-1999
(Trillions of Bits)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
16K	0	0	0	0	0	0	0	0	-19.0
32K	0	0	0	0	0	0	0	0	-10.6
64K	3	2	2	2	1	1	0	0	-25.1
128K	4	3	2	2	2	1	1	1	-20.1
256K	41	37	37	34	30	28	21	12	-20.5
512K	45	61	61	73	64	62	50	31	-13.0
1Mb	68	103	89	82	71	68	61	43	-13.5
2Mb	34	47	53	64	53	45	30	24	-14.6
4Mb	57	133	158	239	307	398	417	398	20.3
8Mb	0	0	0	16	29	126	176	210	266.1
16Mb	0	0	0	8	17	47	75	148	515.0
Total	253	386	403	520	574	777	831	866	16.5
Percentage Change	14.3	52.8	4.4	29.0	10.5	35.2	7.0	4.3	

Source: Dataquest (October 1995)

Table 20
Price per Bit for Shipments of EPROMs to the World, 1992-1999
(Micro Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
16K	134.3	132.0	123.5	141.6	141.6	142.8	142.8	119.0	-0.7
32K	70.2	69.0	70.8	75.4	75.4	76.0	76.0	63.5	-2.2
64K	25.9	24.4	23.1	28.7	28.5	25.0	25.0	24.9	1.5
128K	11.4	13.3	12.2	12.8	12.5	11.0	11.0	10.9	-2.2
256K	8.0	6.9	7.5	8.1	7.9	6.9	6.9	6.8	-1.7
512K	5.1	4.8	4.6	4.5	4.3	3.8	3.8	3.7	-4.3
1Mb	3.4	3.0	3.1	2.8	2.8	2.4	2.5	2.5	-4.4
2Mb	3.2	2.5	2.5	2.3	2.2	2.1	2.0	2.0	-4.8
4Mb	3.1	2.5	2.5	1.8	1.8	1.3	1.2	1.2	-13.1
8Mb	0	0	2.4	1.4	1.2	0.9	0.8	0.8	-19.9
16Mb	0	0	2.7	2.9	2.4	1.5	1.0	0.6	-25.9
Average	4.9	3.7	3.6	3.0	2.7	1.8	1.6	1.3	-18.6
Percentage Change	-21.3	-24.3	-2.6	-16.4	-10.7	-30.7	-15.7	-17.9	

Source: Dataquest (October 1995)

Table 21
Factory Revenue from Shipments of Flash Memory to the World, 1992-1999
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
256K	26	50	50	20	15	13	11	7	-32.0
512K	28	39	42	40	31	26	19	14	-19.2
1Mb	117	279	337	344	374	269	192	144	-15.7
2Mb	76	209	183	270	420	307	182	105	-10.5
4Mb	4	110	132	336	500	508	487	479	29.5
8Mb	6	38	159	162	180	350	407	440	22.7
16Mb	0	0	90	266	480	934	1,334	1,280	70.0
32Mb	0	0	0	52	80	422	601	590	NM
64Mb	0	0	0	0	7	79	463	1,047	NM
128Mb	0	0	0	0	0	0	139	534	NM
Total	257	725	992	1,489	2,086	2,908	3,836	4,640	36.1
Percentage Change	114.5	182.5	36.9	50.1	40.1	39.4	31.9	21.0	

NM = Not meaningful

Source: Dataquest (October 1995)

Table 22
Shipments of Flash Memory to the World, 1992-1999
(Millions of Units)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
256K	5	11	11	7	6	5	5	4	-19.0
512K	4	7	9	12	11	10	9	8	-3.0
1Mb	15	38	68	74	85	90	77	70	0.5
2Mb	4	14	18	30	48	58	48	38	15.5
4Mb	0	4	8	28	50	72	111	133	74.2
8Mb	0	1	6	9	15	43	72	98	72.7
16Mb	0	0	1	7	20	83	171	295	188.8
32Mb	0	0	0	1	2	21	44	78	NM
64Mb	0	0	0	0	0	2	18	83	NM
128Mb	0	0	0	0	0	0	1	7	NM
Total	28	74	124	168	237	384	556	814	45.8
Percentage Change	137.9	163.5	67.2	35.8	41.1	62.0	44.6	46.5	

NM = Not meaningful
Source: Dataquest (October 1995)

Table 23
Average Selling Price for Shipments of Flash Memory to the World, 1992-1999
(U.S. Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999
256K	5.22	4.67	4.34	2.82	2.46	2.36	2.41	1.81
512K	6.69	5.76	4.52	3.30	2.81	2.59	2.15	1.81
1Mb	7.99	7.43	4.93	4.65	4.40	3.00	2.49	2.05
2Mb	18.90	15.39	9.91	9.00	8.75	5.30	3.80	2.76
4Mb	29.00	26.89	15.89	12.00	10.00	7.05	4.39	3.60
8Mb	32.00	31.58	24.85	18.00	12.00	8.15	5.65	4.49
16Mb	0	0	61.41	38.00	24.00	11.25	7.80	4.34
32Mb	0	0	0	51.93	40.00	20.10	13.66	7.57
64Mb	0	0	0	0	65.91	35.88	25.72	12.61
128Mb	0	0	0	0	0	0	139.20	76.30
Average	9.1	9.8	8.0	8.9	8.8	7.6	6.9	5.70
Percentage Change	-9.8	7.2	-18.2	10.6	-0.7	-14.0	-8.8	-17.4

Source: Dataquest (October 1995)

Table 24
Bits from Shipments of Flash Memory to the World, 1992-1999
(Trillions of Bits)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
256K	1	3	3	2	2	1	1	1	-19.0
512K	2	4	5	6	6	5	5	4	-3.0
1Mb	15	39	72	78	89	94	81	73	0.5
2Mb	8	28	39	63	101	122	101	80	15.5
4Mb	1	17	35	117	210	302	466	558	74.2
8Mb	2	10	54	75	126	361	604	822	72.7
16Mb	0	0	25	117	336	1,393	2,869	4,949	188.8
32Mb	0	0	0	34	67	705	1,476	2,617	NM
64Mb	0	0	0	0	7	148	1,208	5,570	NM
128Mb	0	0	0	0	0	0	134	940	NM
Total	29	101	231	493	942	3,130	6,944	15,614	132.2
Percentage Change	182.8	243.7	128.1	113.1	91.3	232.2	121.9	124.8	

NM = Not meaningful
Source: Dataquest (October 1995)

Table 25
Price per Bit for Shipments of Flash Memory to the World, 1992-1999
(Micro Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
256K	19.9	17.8	16.6	10.8	9.4	9.0	9.2	6.9	-16.1
512K	12.8	11.0	8.6	6.3	5.4	4.9	4.1	3.5	-16.7
1Mb	7.6	7.1	4.7	4.4	4.2	2.9	2.4	2.0	-16.1
2Mb	9.0	7.3	4.7	4.3	4.2	2.5	1.8	1.3	-22.6
4Mb	6.9	6.4	3.8	2.9	2.4	1.7	1.0	0.9	-25.7
8Mb	3.8	3.8	3.0	2.1	1.4	1.0	0.7	0.5	-29.0
16Mb	0	0	3.7	2.3	1.4	0.7	0.5	0.3	-41.1
32Mb	0	0	0	1.5	1.2	0.6	0.4	0.2	NM
64Mb	0	0	0	0	1.0	0.5	0.4	0.2	NM
128Mb	0	0	0	0	0	0	1.0	0.6	NM
Average	8.7	7.2	4.3	3.0	2.2	0.9	0.6	0.3	-41.4
Percentage Change	-24.2	-17.8	-40.0	-29.5	-26.8	-58.0	-40.5	-46.2	

NM = Not meaningful
Source: Dataquest (October 1995)

Table 26
Factory Revenue from Shipments of ROMs to the World, 1992-1999
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
64K	4	1	0	0	0	0	0	0	NM
128K	4	2	0	0	0	0	0	0	NM
256K	42	18	12	0	0	0	0	0	NM
512K	36	14	8	5	2	1	1	0	NM
1Mb	237	82	80	48	18	7	3	1	-58.2
2Mb	157	99	130	92	27	12	4	1	-60.2
4Mb	350	357	439	334	206	123	71	40	-38.2
8Mb	433	593	587	530	318	242	193	125	-26.6
16Mb	182	565	792	936	836	507	298	192	-24.7
32Mb	0	1	122	354	641	682	666	721	42.6
64Mb	0	0	0	53	380	933	1,173	1,013	NM
128Mb	0	0	0	0	0	60	196	376	NM
256Mb	0	0	0	0	0	0	0	88	NM
Total	1,445	1,732	2,172	2,351	2,427	2,568	2,604	2,558	3.3
Percentage Change	20.7	19.8	25.4	8.2	3.2	5.8	1.4	-1.8	

NM = Not meaningful

Source: Dataquest (October 1995)

Table 27
Shipments of ROMs to the World, 1992-1999
(Millions of Units)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
64K	2	1	0	0	0	0	0	0	NM
128K	3	2	0	0	0	0	0	0	NM
256K	28	16	11	0	0	0	0	0	NM
512K	19	12	6	3	1	1	0	0	NM
1Mb	113	55	39	24	10	5	2	1	-52.0
2Mb	59	43	51	41	14	7	3	1	-54.5
4Mb	102	125	130	100	70	54	35	24	-28.6
8Mb	77	123	124	118	79	64	57	45	-18.3
16Mb	16	69	90	120	131	95	73	55	-9.4
32Mb	0	0	4	15	36	63	84	123	94.7
64Mb	0	0	0	1	10	32	61	105	NM
128Mb	0	0	0	0	0	1	5	16	NM
256Mb	0	0	0	0	0	0	0	1	NM
Total	418	445	456	422	350	322	320	371	**-4.0**
Percentage Change	9.1	6.4	2.6	-7.6	-17.1	-7.9	-0.6	16.0	

NM = Not meaningful

Source: Dataquest (October 1995)

Table 28
Average Selling Price for Shipments of ROMs to the World, 1992-1999
(U.S. Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999
64K	1.55	0.86	0.86	0	0	0	0	NM
128K	1.45	0.95	0.96	0	0	0	0	NM
256K	1.50	1.12	1.10	0	0	0	0	NM
512K	1.95	1.23	1.40	1.51	1.51	1.51	1.40	NM
1Mb	2.10	1.49	2.03	1.99	1.79	1.41	1.26	1.02
2Mb	2.66	2.33	2.55	2.25	1.99	1.78	1.41	1.30
4Mb	3.45	2.85	3.39	3.35	2.93	2.27	2.03	1.65
8Mb	5.64	4.83	4.74	4.50	4.05	3.78	3.39	2.78
16Mb	11.66	8.22	8.77	7.80	6.40	5.34	4.11	3.49
32Mb	0	27.50	27.83	23.00	18.00	10.81	7.93	5.86
64Mb	0	0	0	52.50	38.00	28.90	19.16	9.65
128Mb	0	0	0	0	0	59.92	39.22	22.95
256Mb	0	0	0	0	0	0	0	88.32
Average	3.5	3.9	4.8	5.6	6.9	8.0	8.1	6.89
Percentage Change	10.7	12.6	22.3	17.1	24.5	14.9	2.0	-15.4

NM = Not meaningful
Source: Dataquest (October 1995)

Table 29
Bits from Shipments of ROMs to the World, 1992-1999
(Trillions of Bits)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
64K	0	0	0	0	0	0	0	0	NM
128K	0	0	0	0	0	0	0	0	NM
256K	7	4	3	0	0	0	0	0	NM
512K	10	6	3	2	1	0	0	0	NM
1Mb	119	58	41	25	10	5	2	1	-52.0
2Mb	124	89	107	86	28	14	6	2	-54.5
4Mb	426	526	544	418	294	228	147	101	-28.6
8Mb	644	1,029	1,039	988	659	536	478	377	-18.3
16Mb	262	1,153	1,515	2,013	2,191	1,594	1,216	923	-9.4
32Mb	0	1	148	517	1,195	2,117	2,819	4,127	94.7
64Mb	0	0	0	67	671	2,168	4,107	7,046	NM
128Mb	0	0	0	0	0	134	671	2,201	NM
256Mb	0	0	0	0	0	0	0	268	NM
Total	1,592	2,866	3,400	4,116	5,050	6,797	9,447	15,047	34.6
Percentage Change	66.8	80.0	18.6	21.0	22.7	34.6	39.0	59.3	

NM = Not meaningful
Source: Dataquest (October 1995)

Table 30
Price per Bit for Shipments of ROMs to the World, 1992-1999
(Micro Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
64K	23.7	13.1	13.1	0	0	0	0	0	NM
128K	11.1	7.2	7.3	0	0	0	0	0	NM
256K	5.7	4.3	4.2	0	0	0	0	0	NM
512K	3.7	2.3	2.7	2.9	2.9	2.9	2.7	0	NM
1Mb	2.0	1.4	1.9	1.9	1.7	1.3	1.2	1.0	-12.8
2Mb	1.3	1.1	1.2	1.1	0.9	0.8	0.7	0.6	-12.6
4Mb	0.8	0.7	0.8	0.8	0.7	0.5	0.5	0.4	-13.4
8Mb	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.3	-10.1
16Mb	0.7	0.5	0.5	0.5	0.4	0.3	0.2	0.2	-16.8
32Mb	0	0.8	0.8	0.7	0.5	0.3	0.2	0.2	-26.8
64Mb	0	0	0	0.8	0.6	0.4	0.3	0.1	NM
128Mb	0	0	0	0	0	0.4	0.3	0.2	NM
256Mb	0	0	0	0	0	0	0	0.3	NM
Average	0.9	0.6	0.6	0.6	0.5	0.4	0.3	0.2	-23.3
Percentage Change	-27.6	-33.4	5.7	-10.6	-15.9	-21.4	-27.0	-38.3	

NM = Not meaningful
Source: Dataquest (October 1995)

Table 31
Factory Revenue from Shipments of EEPROMs to the World, 1992-1999
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
256b	23	33	15	7	6	5	3	3	-26.6
512b	7	4	5	9	12	7	5	6	3.9
1K	69	87	116	88	54	27	13	9	-39.4
2K	41	83	81	103	96	76	63	65	-4.3
4K	41	67	67	88	135	177	158	143	16.4
8K	4	7	10	13	22	38	45	63	44.1
16K	33	44	55	76	94	113	149	162	24.2
32K	0	0	1	0	0	0	0	0	NM
64K	81	102	122	146	187	211	196	206	11.1
256K	61	48	54	82	115	157	164	132	19.6
512K	1	1	8	25	65	133	119	119	72.7
1Mb	8	11	26	67	128	127	226	289	62.3
4Mb	0	0	0	48	96	114	178	256	NM
Total	369	488	559	751	1,011	1,185	1,319	1,454	21.1
Percentage Change	13.0	32.4	14.6	34.4	34.5	17.3	11.3	10.2	

NM = Not meaningful
Source: Dataquest (October 1995)

Table 32
Shipments of EEPROMs to the World, 1992-1999
(Millions of Units)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
256b	40	66	29	18	20	16	13	12	-16.3
512b	10	6	9	19	28	26	19	24	22.0
1K	144	195	258	221	165	108	51	36	-32.5
2K	47	101	133	205	253	271	218	211	9.7
4K	21	39	67	119	210	286	293	311	36.0
8K	2	4	9	17	35	58	72	116	67.7
16K	15	22	34	53	76	119	164	246	48.8
32K	0	0	1	0	0	0	0	0	NM
64K	18	22	36	58	91	149	192	248	47.4
256K	4	4	5	10	14	26	46	54	58.7
512K	0	0	0	1	3	8	17	34	171.0
1Mb	0	0	0	1	3	3	10	15	107.8
4Mb	0	0	0	0	0	0	1	3	118.7
Total	300	460	581	722	898	1,069	1,095	1,310	17.7
Percentage Change	41.0	53.2	26.3	24.3	24.3	19.0	2.5	19.6	

NM = Not meaningful
Source: Dataquest (October 1995)

Table 33
Average Selling Price for Shipments of EEPROMs to the World, 1992-1999
(U.S. Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999
256b	0.57	0.51	0.50	0.38	0.33	0.28	0.25	0.26
512b	0.75	0.66	0.58	0.45	0.43	0.28	0.25	0.26
1K	0.48	0.45	0.45	0.40	0.33	0.25	0.25	0.26
2K	0.87	0.82	0.61	0.50	0.38	0.28	0.29	0.31
4K	1.93	1.71	1.00	0.74	0.64	0.62	0.54	0.46
8K	2.24	2.11	1.15	0.77	0.63	0.66	0.62	0.54
16K	2.26	1.99	1.63	1.43	1.24	0.95	0.91	0.66
32K	0	0	2.09	0	0	0	0	NM
64K	4.64	4.68	3.40	2.50	2.05	1.42	1.02	0.83
256K	14.99	11.17	10.05	8.40	8.00	6.17	3.57	2.45
512K	38.61	38.53	33.09	25.36	23.11	17.09	7.18	3.48
1Mb	77.38	73.10	66.22	56.16	51.36	37.25	23.74	19.25
4Mb	0	0	0	950.00	480.00	380.00	198.00	85.20
Average	1.2	1.1	1.0	1.0	1.1	1.1	1.2	1.11
Percentage Change	-19.9	-13.6	-9.3	8.1	8.2	-1.5	8.6	-7.9

NM = Not meaningful
Source: Dataquest (October 1995)

Table 34
Bits from Shipments of EEPROMs to the World, 1992-1999
(Trillions of Bits)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
256b	0	0	0	0	0	0	0	0	-16.3
512b	0	0	0	0	0	0	0	0	22.0
1K	0	0	0	0	0	0	0	0	-32.5
2K	0	0	0	0	1	1	0	0	9.7
4K	0	0	0	0	1	1	1	1	36.0
8K	0	0	0	0	0	0	1	1	67.7
16K	0	0	1	1	1	2	3	4	48.8
32K	0	0	0	0	0	0	0	0	NM
64K	1	1	2	4	6	10	13	16	47.4
256K	1	1	1	3	4	7	12	14	58.7
512K	0	0	0	1	1	4	9	18	171.0
1Mb	0	0	0	1	3	4	10	16	107.8
4Mb	0	1	0	0	1	1	4	13	118.7
Total	3	4	6	11	18	30	52	83	69.3
Percentage Change	37.8	44.2	42.2	75.8	68.6	66.7	75.8	60.2	

NM = Not meaningful
Source: Dataquest (October 1995)

Table 35
Price per Bit for Shipments of EEPROMs to the World, 1992-1999 (Micro Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
256b	2,226.7	1,973.6	1,953.1	1,484.4	1,289.1	1,093.8	976.6	1,015.6	-12.3
512b	1,464.4	1,283.8	1,133.1	878.9	839.8	546.9	488.3	507.8	-14.8
1K	470.1	435.8	436.8	390.6	322.3	244.1	244.1	253.9	-10.3
2K	423.5	399.6	299.1	244.1	185.5	136.7	141.6	151.4	-12.7
4K	470.1	416.7	245.2	180.7	156.3	151.4	131.8	112.3	-14.5
8K	273.1	257.3	140.8	94.0	76.9	80.6	75.7	65.9	-14.1
16K	137.7	121.4	99.4	87.3	75.7	58.0	55.5	40.3	-16.5
32K	0	0	63.7	0	0	0	0	0	NM
64K	70.8	71.5	51.9	38.1	31.3	21.7	15.6	12.7	-24.6
256K	57.2	42.6	38.3	32.0	30.5	23.5	13.6	9.3	-24.6
512K	73.6	73.5	63.1	48.4	44.1	32.6	13.7	6.6	-36.3
1Mb	73.8	69.7	63.2	53.6	49.0	35.5	22.6	18.4	-21.9
4Mb	0	0	0	226.5	114.4	90.6	47.2	20.3	NM
Average	126.1	115.8	93.3	71.3	56.9	40.0	25.3	17.4	-28.5
Percentage Change	-18.0	-8.2	-19.5	-23.5	-20.2	-29.7	-36.7	-31.2	

NM = Not meaningful
Source: Dataquest (October 1995)

For More Information...

Jim Handy, Director/Principal Analyst ..... (408) 468-8228
Internet address ..... jhandy@dataquest.com
Ron Bohn, Principal Analyst ..... (408) 468-8542
Internet address ..... rbohn@dataquest.com
Via fax ..... (408) 954-1780

Dataquest®

a company of The Dun & Bradstreet Corporation

DATAQUEST WORLDWIDE OFFICES

NORTH AMERICA
Worldwide Headquarters
Dataquest Incorporated
251 River Oaks Parkway
San Jose, California 95134-1913
United States
Phone: 1-408-468-8000
Facsimile: 1-408-954-1780

Dataquest Incorporated
Nine Technology Drive
P.O. Box 5093
Westborough, Massachusetts 01581-5093
United States
Phone: 1-508-871-5555
Facsimile: 1-508-871-6262

Dataquest Global Events
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: 1-714-476-9117
Facsimile: 1-714-476-9969

Sales Offices:
Washington, DC (Federal)
New York, NY (Financial)
Dallas, TX

LATIN AMERICA
Research Affiliates and Sales Offices:
Buenos Aires, Argentina
Sao Paulo, Brazil
Santiago, Chile
Mexico City, Mexico

EUROPE
European Headquarters
Dataquest Europe Limited
Holmers Farm Way
High Wycombe, Bucks HP12 4XH
United Kingdom
Phone: +44 1494 422 722
Facsimile: +44 1494 422 742

Dataquest Europe SA
Immeuble Défense Bergères
345, avenue Georges Clémenceau
TSA 40002
92882 - Nanterre CTC Cedex 9
France
Phone: +33 1 41 35 13 00
Facsimile: +33 1 41 35 13 13

Dataquest GmbH
Kronstadter Strasse 9
81677 München
Germany
Phone: +49 89 93 09 09 0
Facsimile: +49 89 93 03 27 7

Sales Offices:
Brussels, Belgium
Kfar Saba, Israel
Milan, Italy
Randburg, South Africa
Madrid, Spain

JAPAN
Japan Headquarters
Dataquest Japan K.K.
Shinkawa Sanko Building
6th Floor
1-3-17, Shinkawa
Chuo-ku, Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

ASIA/PACIFIC
Asia/Pacific Headquarters
7/F China Underwriters Centre
88 Gloucester Road
Wan Chai
Hong Kong
Phone: 852-2824-6168
Facsimile: 852-2824-6138

Dataquest Korea
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: 822-551-1331
Facsimile: 822-551-1330

Dataquest Taiwan
11F-2, No. 188, Section 5
Nan King East Road
Taipei
Taiwan, R.O.C.
Phone: 8862-756-0389
Facsimile: 8862-756-2663

Dataquest Singapore
105 Cecil Street
#06-01/02 The Octagon
Singapore 0106
Phone: 65-227-1213
Facsimile: 65-227-4607

Dataquest Thailand
12/F, Vanissa Building
29 Soi Chidlom
Ploenchit Road
Patumwan, Bangkok 10330
Thailand
Phone: 662-655-0577
Facsimile: 662-655-0576

Research Affiliates and Sales Offices:
Melbourne, Australia
Beijing, China

Dataquest®

a company of
The Dun & Bradstreet Corporation

Market Analysis

Memories Worldwide

Quarterly Industry Review

Q1/95 Quarterly MOS Memory Regional Shipment Forecast: Continued Growth Expected

Abstract: *This is the second issue of a new MOS Memories Worldwide deliverable that illustrates North American unit shipment estimates for 11 important MOS memory devices. This quarterly report contains a rolling four quarters of history and four quarters of forecast data, with top-five North American market vendor rankings for each device.*
By Jim Handy and Mario Morales

MOS Memory Forecast

Table 1 shows Dataquest's first-quarter 1995 North American unit shipment estimates for 11 important MOS memory devices.

DRAM

There is little change between last quarter's estimates of 2Mb VRAM sales and those for the first quarter of 1995. Although 1995 annual use will be above overall 1994 unit shipments, Dataquest continues to anticipate a mild downturn late in 1995 as these new DRAM architectures move to displace this device. North American market 2Mb supplier rankings are as follows:

1. Mosel-Vitelic
2. NEC
3. Toshiba
4. Fujitsu
5. Hitachi

Dataquest

Program: Memories Worldwide
Product Code: MMRY-WW-QR-9502
Publication Date: July 17, 1995
Filing: Market Analysis

Table 1
MOS Quarterly Memory Shipments into North America, 1994 to Q1/96
(Thousands of Units)

		1994			1995				1996
Device Type	Density	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
DRAM	2Mb	3,706	5,003	5,812	5,748	5,685	5,623	5,561	5,500
DRAM	4Mb	112,961	121,047	128,917	136,198	143,890	152,016	160,601	164,671
DRAM	16Mb	8,486	11,090	17,017	22,184	28,921	37,703	49,152	64,079
SRAM	256K ≤35ns	18,567	20,133	23,834	30,489	39,929	51,681	66,893	86,582
SRAM	256K ≥45ns	18,934	18,641	18,096	14,439	11,835	9,571	7,740	6,259
SRAM	1Mb ≥45ns	6,592	6,949	7,286	9,428	12,200	15,786	20,426	26,431
EPROM	1Mb	7,264	7,422	7,719	8,155	8,616	9,102	9,616	10,159
EPROM	4Mb	2,980	3,044	3,362	3,699	4,069	4,477	4,925	5,418
Flash	1Mb	8,768	9,936	11,221	10,892	10,688	10,431	9,962	9,670
Flash	4Mb	710	1,399	1,925	1,846	3,166	4,061	5,207	6,678
ROM	16Mb	2,167	2,344	2,440	3,262	4,361	5,831	7,797	10,425

Source: Dataquest (July 1995)

There is continuing strength in the personal computer market, and Dataquest anticipates a mild upturn in our next PC forecast. As a result, the popular 4Mb DRAM, sold mainly to the PC market, is being increased slightly from last quarter's estimate. This does not come at the expense of any other devices, therefore it is not incongruous for us to also raise our estimates for shipments of the 16Mb DRAM. 4Mb DRAM shipments in 1995 now are expected be higher than those of 1995. Rankings for 4Mb suppliers to the North American market are as follows:

1. Micron
2. Hitachi
3. Samsung
4. Texas Instruments
5. NEC

Rankings for 16Mb suppliers to the North American market are as follows:

1. Samsung
2. NEC
3. Toshiba
4. Hyundai
5. Hitachi

SRAM

We still expect the 35ns and faster 256Kb SRAM to grow in North America throughout 1995. Intel's rapid ramp of the Pentium CPU is driving this in two ways: First, the 64-bit bus of the Pentium processor requires twice as many 32Kx8 SRAMs as does the 32-bit bus of the 486; second, the fact that this is a leading-edge processor dictates that users pay for additional performance-related features in their new systems. Whether right or wrong, cache memory is perceived by most PC purchasers to be an important performance-enhancing feature. These phenomena combine to cause a very large demand for high-speed 32Kx8 SRAMs. Intel has estimated that its Pentium processor shipments for 1995 should reach nearly 30 million units, each of which could consume eight 32Kx8s. Rankings for suppliers to North America are as follows:

1. Cypress
2. IDT
3. Alliance
4. Motorola
5. Toshiba

The North American market for slower versions of the 32Kx8 continues to convert to the 1Mb density. As we anticipated in the last edition of this report, the third quarter of 1994 seems to have been the peak shipments quarter, and a ramp-down is in process. North American supplier rankings are as follows:

1. Hitachi
2. Samsung
3. NEC
4. Sony
5. Mitsubishi

Our Market Analysis newsletter titled *1994 SRAM Regional Markets in Review* (MMRY-WW-MA-9501, dated June 26, 1995) discussed how the slower-speed 1Mb SRAM should be approaching the peak market share point in its life cycle. This appears not yet to have occurred, and we now expect it not to lose market share to the 4Mb density until 1996. Sales should continue to rise through 1995. Rankings for suppliers to North America are as follows:

1. Hitachi
2. Samsung
3. Toshiba
4. NEC
5. Sony

To restate the speed splits used in this report, as we did last quarter, the 0ns to 9ns category has been combined with the 10ns, 12ns, 15ns and 20ns, 25ns, and 35ns categories to produce a 35ns-and-faster grade, which, in the case

of the 256Kb SRAM, is made up largely of the 20ns 32Kx8 used in PC caches. The 45ns, 55ns, and 70ns speed range and the "slow" speed range of the 256K and 1Mb densities have been combined in this report to produce the 45ns-and-slower line, a range that represents today's slow market for these two devices.

EPROM

The 4Mb EPROM is used in strong growth applications, including digital cellular handsets; therefore, the device should maintain its current strong growth in 1995. However, wider availability of the 1Mb flash memory continues to erode the 1Mb EPROM market in PC BIOS applications.

North American market rankings for suppliers of the 1Mb EPROM are as follows:

1. Texas Instruments
2. Atmel
3. AMD
4. SGS-Thomson
5. Macronix

North American market rankings for suppliers of the 4Mb density are as follows:

1. Texas Instruments
2. SGS-Thomson
3. AMD
4. Toshiba
5. Hitachi

Flash

As discussed in the last issue of this report, unit shipments of the 1Mb flash memory are forecast to be flat in 1995. We expect sales of the 1Mb flash in 1995 to be about equal to sales in 1994, with the peak having occurred in the last quarter of 1994. Applications are undergoing a conversion this year from the 1Mb to the 2Mb density. Dataquest still expects the 4Mb flash's high growth to last through the year, despite a short-term drop in unit shipments in the first quarter. The 4Mb flash memory is found in a wide array of telecommunications systems, ranging from LAN routers to cellular handsets.

Intel and AMD are the leaders in the flash memory market, accounting for a combined market share of 80 percent, so Dataquest does not produce a quarterly ranking table for 1Mb and 4Mb flash memories.

Mask ROM

Dataquest continues to expect the strong recent growth of the 16Mb mask ROM to continue into 1996. However, shipments of this device into the North American market amount to only about a tenth of the worldwide market. Because the bulk of the market for mask ROMs is in Japan, the

North American market rankings are of less significance than the worldwide ranking given in Dataquest's April 17, 1995, Market Statistics document titled *Worldwide Memory Market Share, 1992-1994* (MMRY-WW-MS-9501):

1. Samsung
2. Sharp
3. Macronix
4. Goldstar
5. Mitsubishi

Dataquest Perspective

The 1995 North American memory market is showing strong signs of continuing the strength of the 1994 market. Sales of the 4Mb DRAM continue to rise above last year's levels, in the face of a conversion from the 1Mx4 device to the 1Mx16. The 2Mb VRAM is at the mercy of less-costly alternatives.

Fast 32Kx8 SRAM sales are being driven to new highs in two ways by the rapid ramp of Intel's Pentium processor. Slow SRAMs are not anywhere near as rapid in growth, with the 256K in a slow decline, the 1Mb at its peak, and the 4Mb density moving to replace the 1Mb part. Although both 4Mb EPROM and flash memories are growing well, EPROMs and flash memories both are expected to cool off at the 1Mb density, with 1Mb EPROMs being displaced in certain applications by the 1Mb and 2Mb flash. North American sales of the 16Mb mask ROM, although growing quickly, are still a relatively insignificant portion of the overall market.

Qty: 1

MMRY-WW-QR-9502
Mr. Joe Grenier
Dataquest Incorporated
1-1100

--INTERNAL DIST.--

For More Information...

Jim Handy, Director/Principal Analyst ..... (408) 437-8228
Internet address ..... jhandy@dataquest.com
Via fax ..... (408) 437-0292

Market Analysis

Memories Worldwide

Quarterly Industry Review

Density Shifts Drive the Quarterly MOS Memory Regional Shipment Forecast

Abstract: *The following Quarterly Industry Review contains a rolling four quarters of history, four quarters of forecast data, and top-five vendor rankings for North America for each device. Dataquest is bullish on the 1995 memory market; however, we are anticipating certain changes to have a profound impact. This report looks at the memory market and provides the North American unit shipment estimates for 11 important MOS memory devices.*

By Jim Handy

The MOS Memory Market

Dataquest is bullish on the 1995 memory market; however, we are anticipating certain changes to have a profound impact. The following newsletter provides an overview of the memory market and estimates of North American unit shipments for 11 important MOS memory devices (see Table 1).

DRAM

The 2Mb VRAM is showing a lot of strength, despite widespread alternative solutions including synchronous 4Mb DRAMs and the conversion of high-end graphics controllers to 64-bit data buses. We anticipate a mild downturn in use in 1995 as these new approaches move to displace the

Dataquest

Program: Memories Worldwide
Product Code: MMRY-WW-QR-9501
Publication Date: June 12, 1995
Filing: Market Analysis

Table 1
MOS Quarterly Memory Shipments into North America, 1994 to 1995
(Thousands of Units)

		1994				1995			
Device Type	Density	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
DRAM	2Mb	2,397	3,706	5,003	5,812	5,652	5,496	5,345	5,198
DRAM	4Mb	101,718	112,961	121,047	128,917	125,694	122,552	119,488	116,501
DRAM	16Mb	6,417	8,486	11,090	17,017	21,628	27,489	34,939	44,407
SRAM	256Kb ≤35ns	16,808	18,567	20,133	23,834	25,455	27,185	29,034	31,008
SRAM	256Kb ≥45ns	18,685	18,934	18,641	18,096	14,929	12,316	10,161	8,383
SRAM	1Mb ≥45ns	6,016	6,592	6,949	7,286	7,235	7,184	7,134	7,084
EPROM	1Mb	7,503	7,264	7,422	7,719	7,063	6,463	5,913	5,411
EPROM	4Mb	2,624	2,980	3,044	3,362	3,631	3,922	4,236	4,574
Flash	1Mb	7,307	8,768	9,936	11,221	10,716	10,234	9,773	9,333
Flash	4Mb	460	710	1,399	1,925	2,445	3,105	3,944	5,008
ROM	16Mb	2,103	2,167	2,344	2,440	2,623	2,819	3,031	3,258

Source: Dataquest (June 1995)

2Mb VRAM. Still, 1995 annual usage will be above the overall 1994 figure. Rankings for 2Mb VRAM shipments into North America are as follows:

1. Mosel-Vitelic
2. NEC
3. Micron
4. Toshiba
5. Samsung

There continue to be record shipments of the 4Mb DRAM; however, Dataquest believes that the peak has been reached and that the industry is poised for conversion to the 16Mb density primarily in the 1Mx16 organization. The steady rise through the fourth quarter of 1994 is expected to turn back down in the first quarter of 1995, and the total for 1995 should approach that of 1994. This will be a result of the conversion of "convertible" 4Mb/16Mb fabs to the 16Mb density as suppliers gain experience in yielding the 1Mx16 organization. Rankings for suppliers of 4Mb DRAMs into North America are as follows:

1. Micron
2. Samsung
3. Hitachi
4. NEC
5. Texas Instruments

Rankings for suppliers of 16Mb DRAMs into North America are as follows:

1. Samsung
2. Toshiba
3. NEC
4. Mitsubishi
5. Hitachi

SRAM

For the purposes of this report, we have combined certain of our speed grades into two categories. The 0-9ns category is added to the 10, 12, 15ns and 20, 25, 35ns categories to produce a "35ns and faster" grade, which, in the case of the 256Kb SRAM in this report, consists largely of the 20ns 32Kx8 used in PC caches. For the 256Kb and 1Mb densities, we have combined the 45, 55, 70ns category with the "slow" category to produce the "45ns and slower" line. Most manufacturers are satisfied that this represents today's slow market for these two devices.

The 35ns and faster 256Kb SRAM is expected to experience healthy growth in North America throughout 1995, as it did in 1994. Most of this growth stems from Intel's rapid ramp of the Pentium CPU with its 64-bit bus. The 64-bit bus requires twice as many 32Kx8 SRAMs as does the 32-bit bus of the 486, so the potential for high-speed 32Kx8 SRAM consumption is extremely high. Rankings for suppliers in North America for 35ns and faster 256Kb SRAM are as follows:

1. Cypress
2. IDT
3. Alliance
4. Motorola
5. Paradigm

The slower versions of the 32Kx8 are used in widespread applications such as telecommunications, industrial control, and consumer. In North America, interest in this density has been waning for one major application, hard disk drive cache. With this loss of interest and with the conversion of systems from the 256Kb to the 1Mb density (fostered by low prices), we believe that the third-quarter of 1994 will prove to be the peak quarter for shipments and that a ramp-down will occur. Rankings for suppliers in North America for the slower versions of 256Kb SRAM are as follows:

1. Hitachi
2. Samsung
3. Sony
4. NEC
5. Mitsubishi

The 1Mb slow SRAM has been a disappointment. The life cycle of this density of SRAM has not developed along the lines followed by all prior generations of SRAM. As opposed to the 256Kb device—less than one-quarter of whose market is in North America—almost one-third of all slow 1Mb SRAMs are used in North America, at a point in the life cycle where a far smaller percentage should be in this region. This can be blamed on the extremely slow acceptance of this part in Japan for the consumer electronics market, which, in turn, appears to be stifled by difficulties in the Japanese economy.

The 1Mb density is at a point in its life cycle where we expect it to lose market share to the 4Mb density, and this appears to be happening. For this reason, we expect sales to remain flat through 1995 at a quarterly world-wide rate of 24 million units. Conversions from the 256Kb to the 1Mb appear to be offset by conversions from the 1Mb density to the 4Mb density. Rankings for suppliers in North America are as follows:

1. Samsung
2. Mitsubishi
3. Hitachi
4. Toshiba
5. Sony

EPROM

Although wider availability of the 1Mb flash memory is ready to take its toll on the 1Mb EPROM density, especially in PC BIOS applications, Dataquest expects the 4Mb density to continue to grow substantially in 1995. Demand for the 1Mb EPROM was flat in 1994, and 1995 will be the start of a gradual decline in demand for this part. On the other hand, 1994 and 1995 will both be strong growth years for the 4Mb EPROM density, which is used in far-flung applications, including strong growth areas like digital cellular handsets.

Rankings for suppliers in North America for the 1Mb EPROM are as follows:

1. AMD
2. Texas Instruments
3. SGS-Thomson
4. National
5. Macronix

Rankings for suppliers in North America for the 4Mb density are as follows:

1. Texas Instruments
2. AMD
3. SGS-Thomson
4. Toshiba
5. Hitachi

Flash

Despite flash's inroads to the PC BIOS market, the 1Mb density is forecast to be flat in 1995. The reason behind this is that Dataquest anticipates a level of conversion from the 1Mb to the 2Mb density in 1995. We anticipate that sales of the 1Mb flash in 1995 will be roughly equal to sales in 1994, with the peak having occurred in the last quarter of 1994.

The 4Mb flash is undergoing high growth, which is expected to last throughout the year. These devices are found in telecommunications systems ranging from LAN routers to cellular handsets (where applications appear to be poised to use either EPROM or flash technology).

AMD and Intel are the leaders in this market, and Dataquest is not currently producing a ranking table for these vendors for the 1Mb and 4Mb flash devices.

Mask ROM

The 16Mb mask ROM experienced strong growth in 1994, and Dataquest expects this growth to continue through 1995. North American shipments of this device are small, accounting for only about one-tenth of the worldwide market. Because the bulk of the market for mask ROMs is in Japan, regional ROM supplier rankings differ from worldwide rankings for every region other than Japan. Rankings for suppliers in North America are as follows:

1. Samsung
2. Sharp
3. Macronix
4. Mitsubishi
5. Goldstar

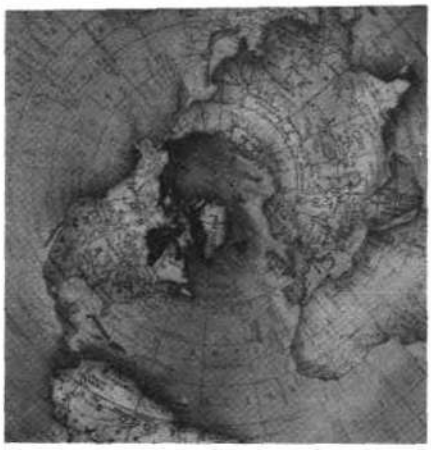
Dataquest Perspective

Dataquest is bullish on the 1995 memory market; however, we are anticipating certain changes to have a profound impact. The conversion from the 1Mx4 DRAM to the 1Mx16 will begin in earnest this year. The 2Mb VRAM will begin to lose market to less costly alternatives. The Pentium will drive high consumption of the fast 32Kx8 SRAM, while the slow version of this device will cool off. The 1Mb SRAM will continue to dawdle until replaced by the 4Mb density. 1Mb EPROMs and flash memories are both expected to cool off, but the EPROMs will reduce at a faster rate because they are being displaced in certain applications by the 1Mb and 2Mb flash. Both 4Mb EPROM and flash memories are in a heady growth phase. The 16Mb mask ROM is also in a growth phase, but little of this market is in the North American region.

MMRY-WW-QR-9501 Qty: 1
Mr. Joe Grenier
Dataquest Incorporated
1-1100
--INTERNAL DIST.--

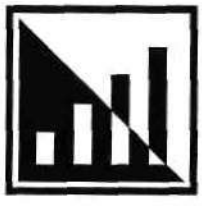
For More Information...
Jim Handy, Director/Principal Analyst ..... (408) 437-8228
Internet address ..... jhandy@dataquest.com
Via fax ..... (408) 437-0292

Dataquest
a company of The Dun & Bradstreet Corporation



Dataquest

Trends in the MOS Memory Market



Market Trends

Program: Memories Worldwide
Product Code: MMRY-WW-MT-9501
Publication Date: July 31, 1995
Filing: Market Analysis

Trends in the MOS Memory Market

Market Trends

Program: Memories Worldwide
Product Code: MMRY-WW-MT-9501
Publication Date: July 31, 1995
Filing: Market Analysis

Table of Contents

List of Figures

Chapter 1
Executive Summary

This report reviews trends in all MOS memory types over the years for which Dataquest has been collecting data. It is meant to update the following Dataquest Market Trends documents: *Trends in the DRAM Market* (MMRY-WW-MT-9301), *Trends in the SRAM Market* (MMRY-WW-MT-9302), and *Flash Memory Drives Trends in the Nonvolatile Memory Market* (MMRY-WW-MT-9401).

DRAMs are the most important of these markets, and this report examines the DRAM market in detail, providing rationale for today's events and comparing them to past cycles, with a look at what the future holds.

SRAMs are examined next, with a focus on the past four years' speed information used to illustrate new trends that have not previously been tracked in this level of detail.

Finally, each type of nonvolatile memory is examined, because each falls into a different market and each of these markets has its own dynamic.

Chapter 2
Trends in the DRAM Market

DRAMs have been enjoying explosive growth in recent years. This stems from a number of factors. First and foremost, there has been unheralded growth in PC use in the already developed PC markets of North America and Europe. This has been counterbalanced by an undersupply that has lasted for three years at the writing of this report. The effect of the undersupply has been, surprisingly, not to limit the per-system use of DRAM but instead to increase the DRAM portion of the overall system cost. We will look at the effect this has had on overall DRAM prices in a later section.

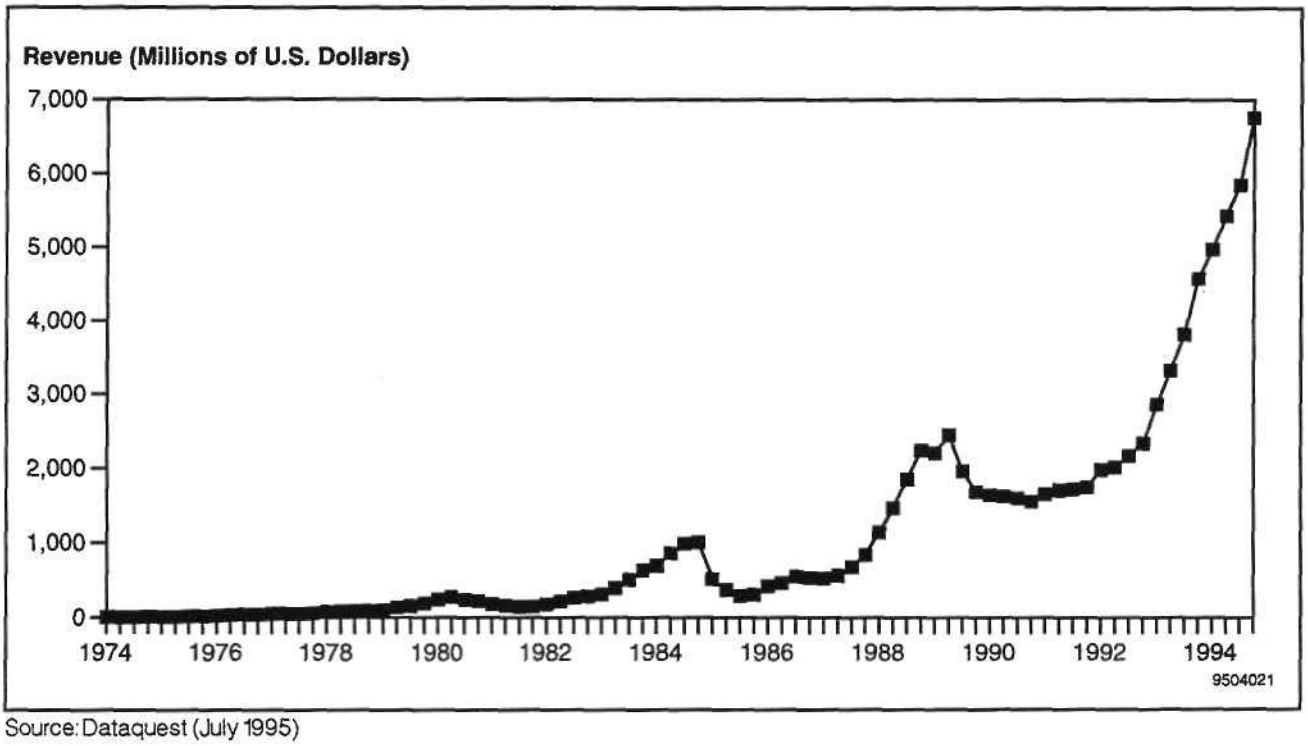
The net result—increased DRAM prices x increased usage—is a skyrocketing market (see Figure 2-1). Figure 2-1 shows quarterly worldwide DRAM revenue for the entire market, about 75 percent of which is accounted for by consumption within the PC. Mid-1992 marked the point at which the price for the 1Mx4 DRAM, the most popular organization during this cycle, stopped its downward trend and leveled off at ¥1,200, where it has stayed ever since. Figure 2-2 shows the ASP of the 4Mb DRAM in North America plotted against the yen-to-dollar conversion rate from first quarter 1992 through first quarter 1995. The two lines track because of the fixed ¥1,200 commanded for this part by its Japanese manufacturers. This price has been held as much for cultural reasons as for the firmness of the market. Because almost 50 percent of the DRAM market is controlled by Japan-based companies, the Japanese way of doing business has an overwhelming effect on DRAM pricing policies. It appears that, although DRAM manufacturers have the opportunity to raise prices high enough to test what the market will bear, doing so is not considered fair within Japanese business practices. What is considered fair, however, is to keep charging the same yen amount for the parts and to adjust foreign pricing to compensate for devaluation of foreign currencies against the yen. This explains the mild increases seen in North American DRAM prices over the past three years (see Figure 2-2).

Unit Shipments

Figure 2-3 shows historical DRAM unit shipments by density since 1974. Dataquest has used this chart to debunk the once-popular theory that the DRAM market is undergoing radical changes.

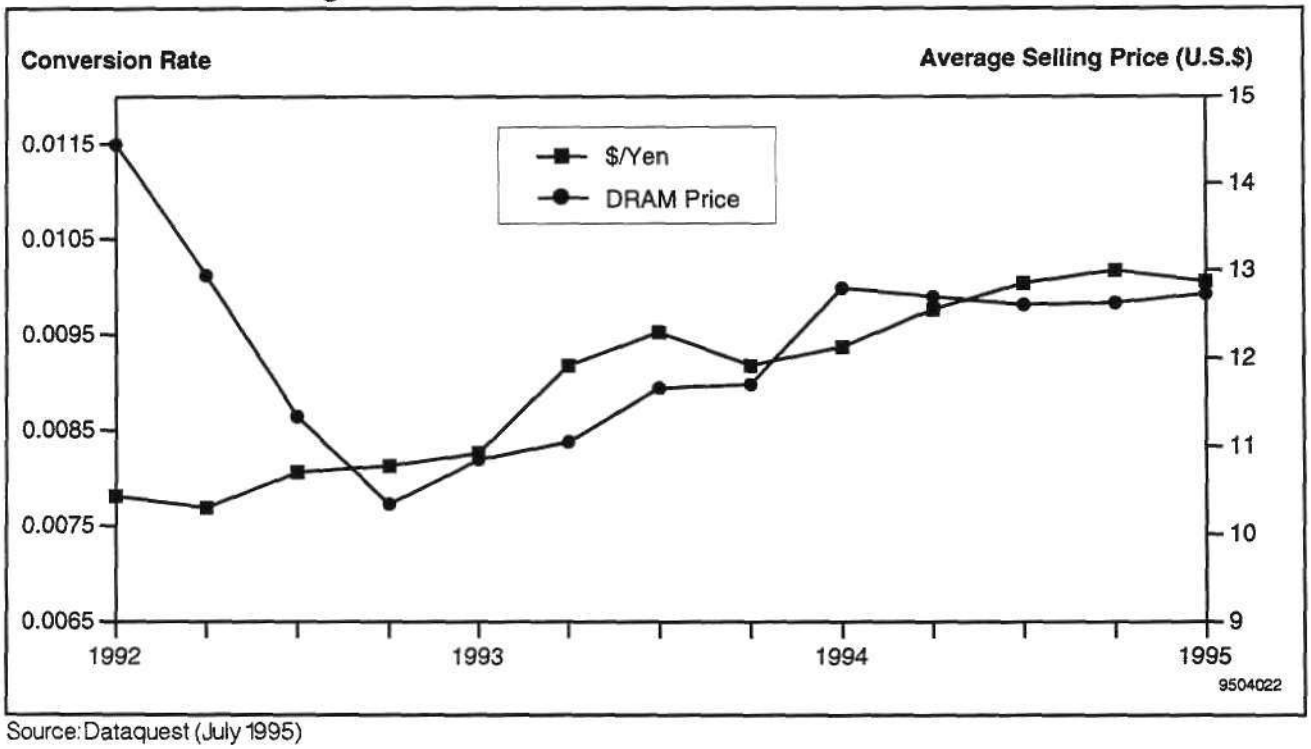
The arrow in Figure 2-3 points to an emerging trend for the peak quarterly unit shipments to drop from the high held in 1984 by the 64K density. Although the peaks were lower for each of the two successive generations, there appeared to be a widening of the curve. This apparent trend was used to forecast fewer peak unit shipments over a longer time for all DRAM generations (a phenomenon tied to the spiraling costs of DRAM wafer fabs); this trends would in turn raise minimum ASPs. The decrease in shipments was also said to be driven by a shift away from the "Pi Rule" toward the "Bi Rule," wherein the long-maintained cycle of a quadrupling density at a fixed price every three (Pi) years would slow, and prices would begin to eventually double in the same period. This conversion has been long anticipated, but because it seems annually to be pushed back by one year, it is always anticipated but it never actually happens.

Figure 2-1
Quarterly DRAM Worldwide Revenue, 1974 to 1994



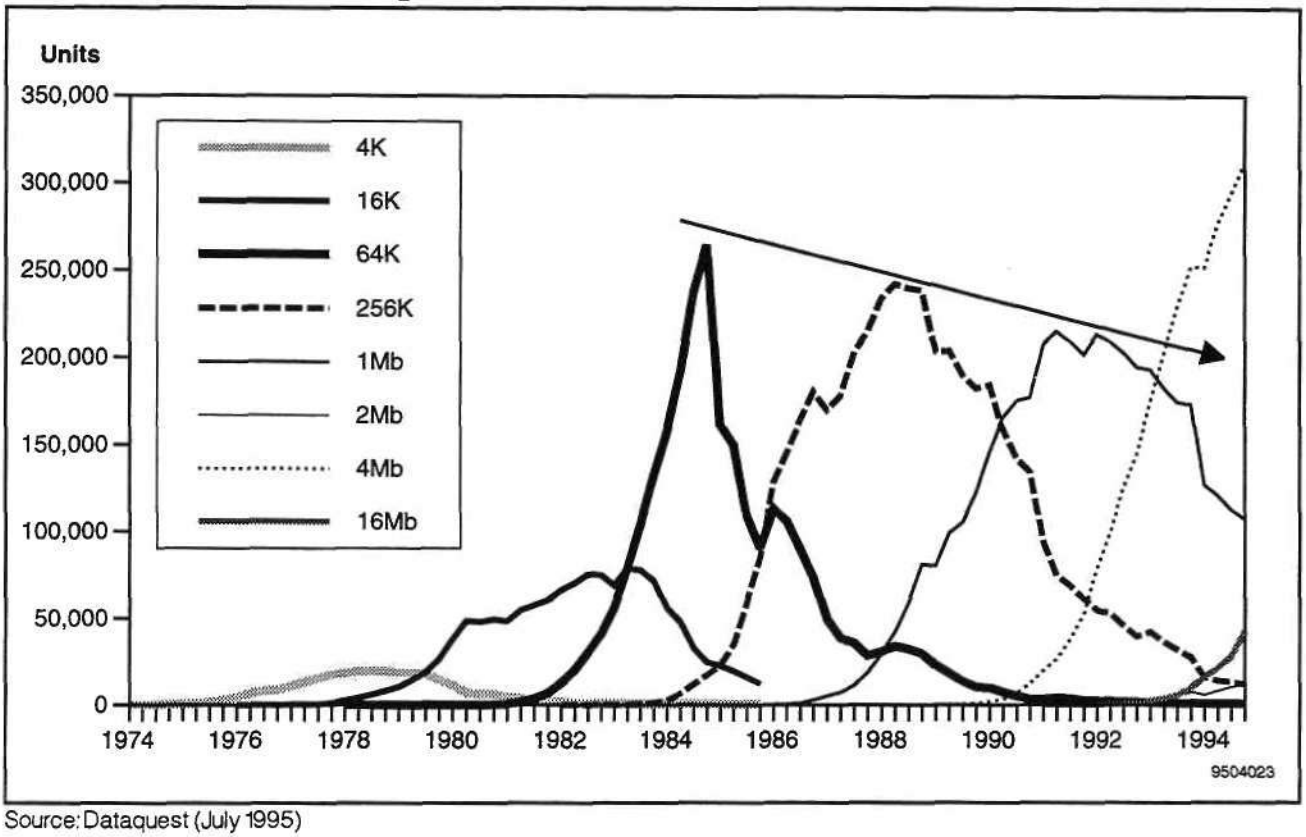
Source: Dataquest (July 1995)

Figure 2-2
Yen-to-Dollar Exchange Rate versus 1Mx4 DRAM Prices in North America



Source: Dataquest (July 1995)

Figure 2-3
DRAM Quarterly Unit Shipments, 1974 to 1994

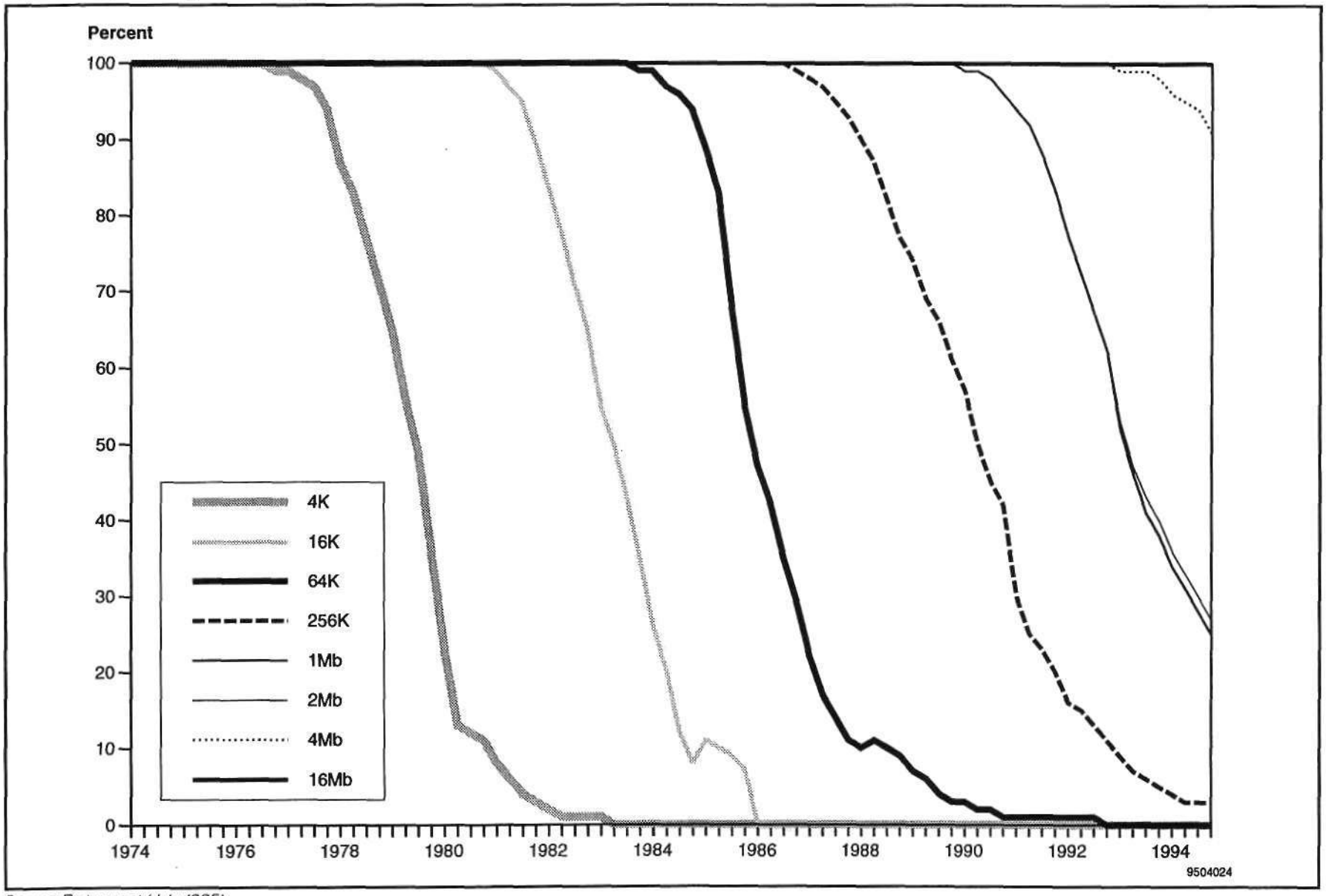


Source: Dataquest (July 1995)

We see the trend completely eradicated with the 4Mb density, with 4Mb units outshipping those of the 64K density in the second quarter. Although this can be partially attributed to increases in PC consumption and to the growth in per-PC memory usage, it is equally driven by the failure of DRAM manufacturers to anticipate PC manufacturers' need for the 16-bit-wide DRAM and by the difficulties that DRAM manufacturers have encountered in bringing this organization into the manufacturing stage. As a result, for every 1Mx16 version of the 16Mb DRAM not produced, four 1Mx4 versions of the 4Mb DRAM must ship. This radically increases shipments of the 1Mx4 DRAM. Dataquest anticipates that this is a one-time phenomenon and that the extremely high unit shipments of the 4Mb density and the postponed acceptance of the next density will not be repeated in future generations. Unit shipments over the life of a DRAM generation usually double from one generation to the next, as happened with the 64K and 256K generations, and it appears likely to happen with the 1Mb generation. Dataquest expects the 4Mb generation to ship about two and one-half times as many units as the 1Mb generation, once the 1Mb generation's life has ended.

Figure 2-4 gives a little indication of the acceptance of the 16Mb DRAM as compared with prior generations. The chart illustrates market share by density for all DRAM densities from 1974 through 1994. It can be seen that only three generations of DRAM ever ship in appreciable quantities at any one time. The rate at which the 16Mb DRAM is biting into the 4Mb

Figure 2-4
DRAM Quarterly Unit Shipments, 1974 to 1994



Source: Dataquest (July 1995)

DRAM's market is a little softer of a curve than that seen in other generations. In terms of the curves at the beginning of the market for each density, the rate appears most aggressive for the 64K and 256K densities and least aggressive for the 16Mb and 1Mb densities.

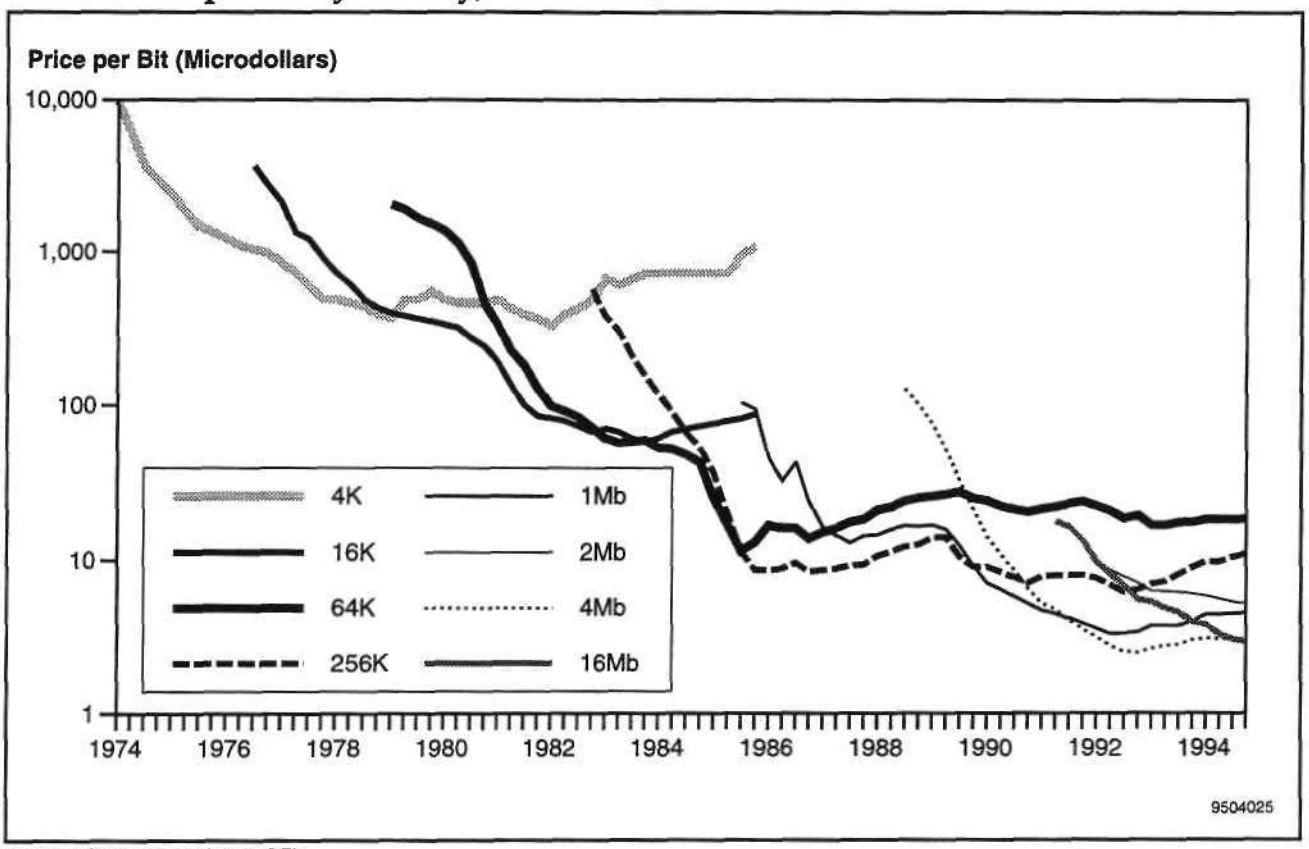
Pricing

Figure 2-5 shows price per bit of different DRAM densities. Although it is widely believed that clean crossovers have happened in the past, this appears to only be true for the crossover from the 4K to the 16K DRAM. All succeeding densities have anywhere from two quarters to nine quarters in which the price of two competing densities track. The nine-quarter instance is the crossover from the 16K to the 64K density, from 1982 to 1984, during the tremendous rise in sales for DRAMs that was driven by the sudden acceptance of the new PC. Such a drawn-out crossover is partly the result of a very high ASP for the lower-density product. Crossovers occur when two densities compete for market share, and the crossover is complete when the price of the lower-density part goes low enough to deter manufacturers from taking orders for the part. Dataquest refers to this price as the "floor" price. When the floor price is substantially lower than the going price for a device, which is an indication of an undersupply, the price per bit of the lower-density device can move for quite a distance before the floor is reached. In the case of the 16K DRAM, the ASP at the beginning of the crossover was double the floor price. We see the same phenomenon today, with the 4Mb DRAM selling for $13.00, or about double its floor price of approximately $6.50. For this and other reasons, Dataquest is forecasting the price per bit of the 16Mb and 4Mb DRAMs to track for as long as six quarters.

The DRAM price-per-bit learning curve is very telling (see Figure 2-6). Figure 2-6 compares, on a logarithmic scale, the cumulative bits shipped of all DRAMs over history versus the price per bit for DRAMs. Each dot represents a calendar quarter. The rises in price match the DRAM boom markets in years such as 1984 and 1988. Although price per bit did not rise in the current phase nearly as much as it did in 1988, there is still a departure from the trend. The trend actually indicates manufacturing cost, and the vascillations are in the direction above the trend line, where the market is more profitable than simply cost driven. The trend shows that somehow DRAM manufacturers continue to find ways to get the costs out of ever-increasing DRAM densities. If we take the estimated floor price of today's 4Mb density of $6.50, then the last point on the curve would lie along the trend. The flattening of the latest part of the line is more reflective of the constant yen price of the 4Mb density since 1992 than it is of the magnitude of today's supply/demand mismatch.

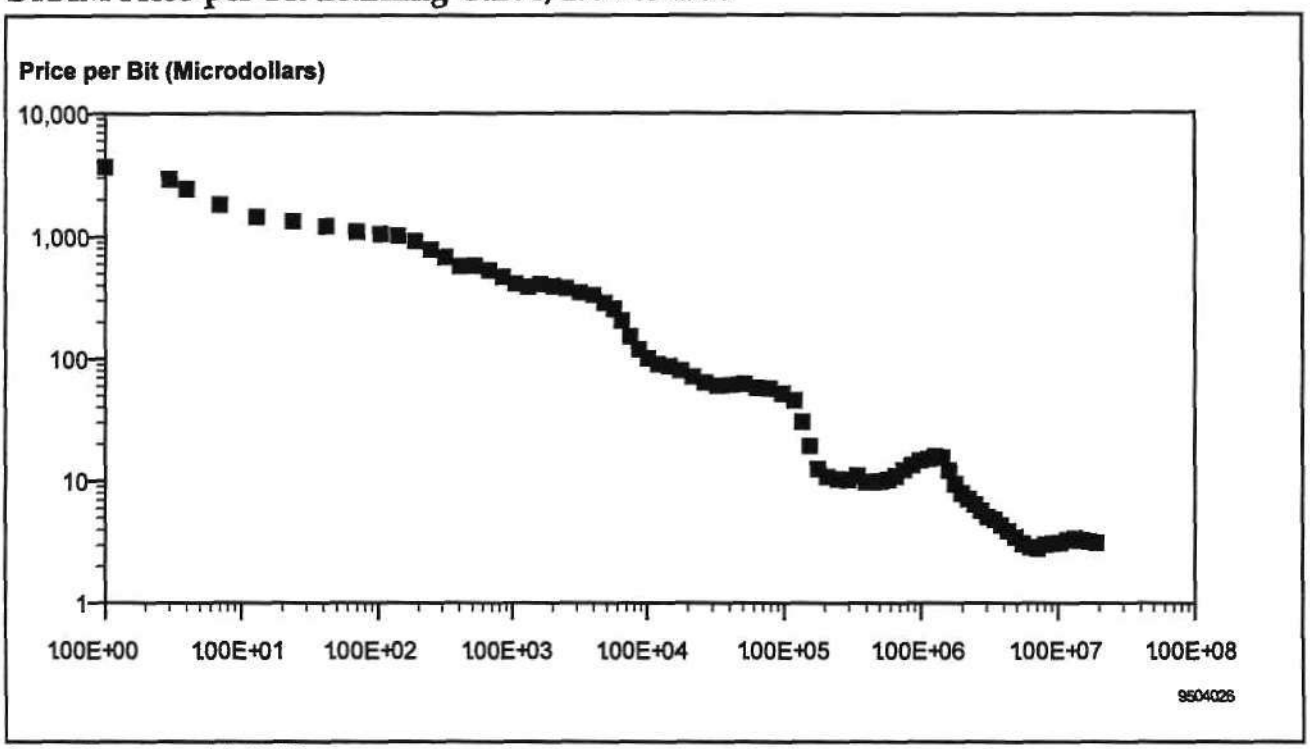
Figure 2-7 is another look at the same ASP data, here showing quarterly ASPs for all DRAMs combined since 1974. This data can be easily derived for the first quarter of this year from the WSTS DRAM statistics. The same bumps during the boom years seen in Figure 2-6 can be observed in Figure 2-7. Although many argue that DRAM ASPs are on an irreversible upward climb, the data appears to indicate that the pricing trend is flat and that there are peaks in boom times. Dataquest expects the ASP of DRAMs to drop significantly once an oversupply has been reached, which we expect to occur in 1997. The effect of this would be to cut the last column's height in half, bringing the ASP once again to a level point.

Figure 2-5
DRAM Price per Bit by Density, 1974 to 1994



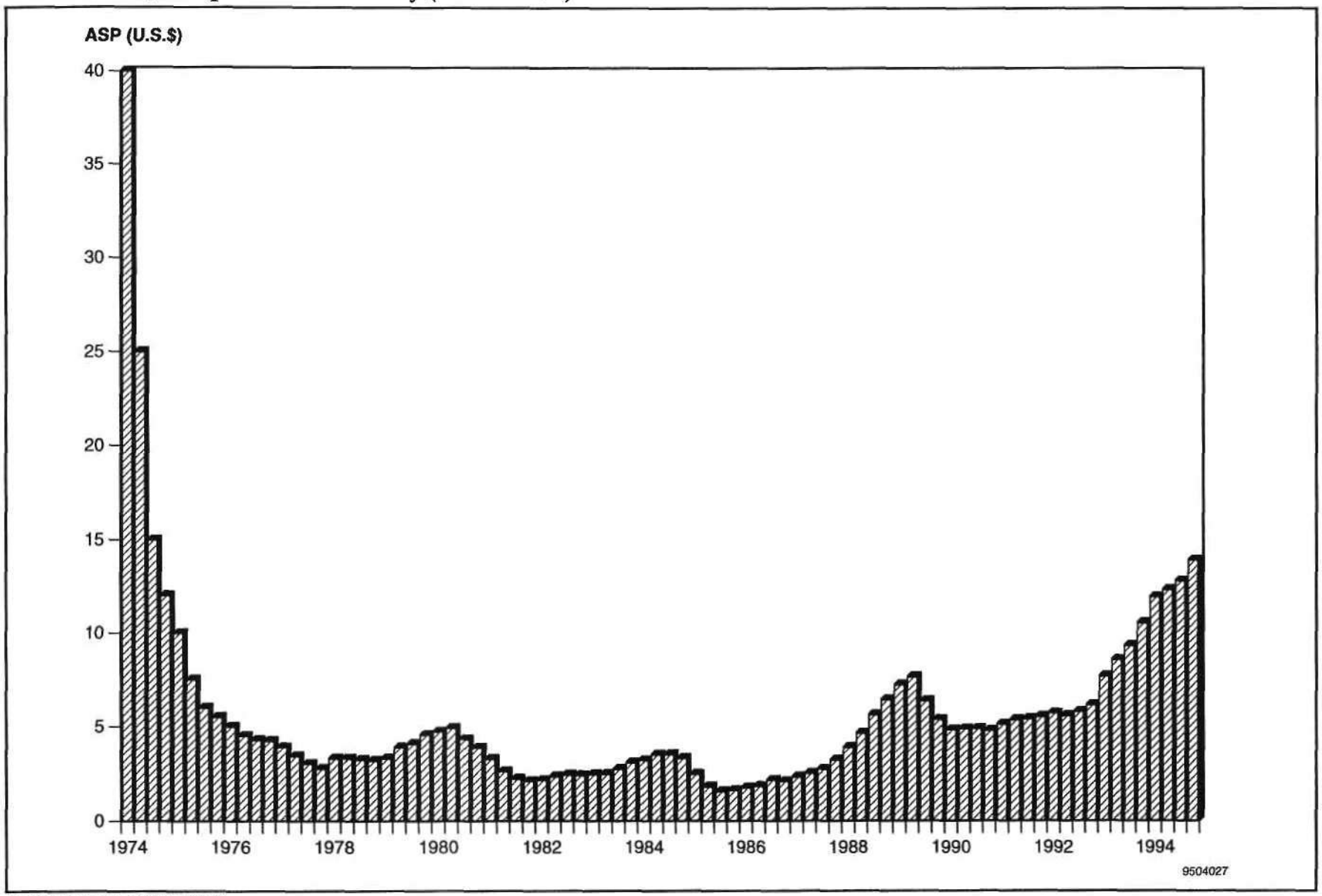
Source: Dataquest (July 1995)

Figure 2-6
DRAM Price-per-Bit Learning Curve, 1974 to 1994



Source: Dataquest (July 1995)

Figure 2-7
DRAM ASPs, Independent of Density (1974 to 1994)



Source: Dataquest (July 1995)

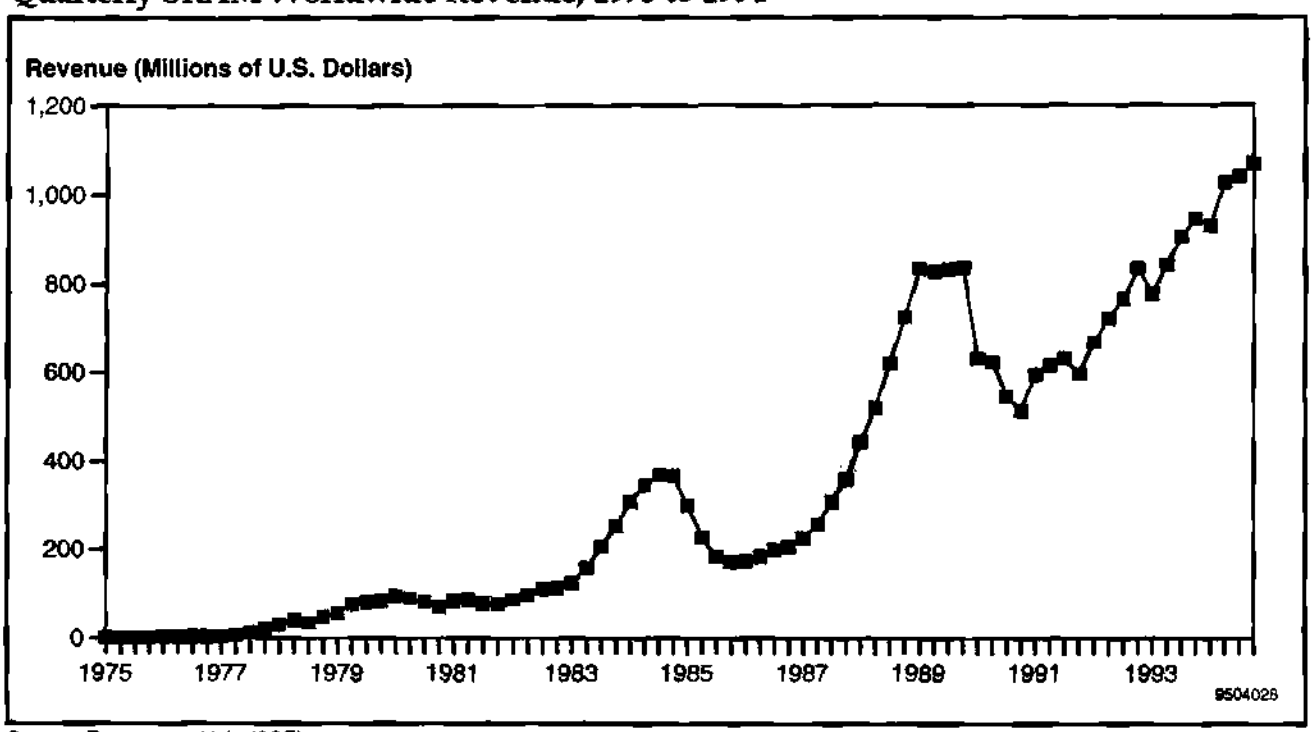
Chapter 3
Trends in the SRAM Market

Static RAMs show somewhat similar characteristics to the DRAM market; however, the SRAM market is still earlier in its evolution, in that new applications are being continually found, and SRAMs are found in a broader range of applications than are DRAMs. The result is that the growth does not always follow that of the DRAM market, which can be seen by comparing Figure 3-1 with Figure 2-1. Figure 3-1 shows the size of the SRAM market from 1975 to 1994. The same peaks occur in 1984 and 1988, but their shapes are different: in 1988, the peak for SRAMs is much flatter than for DRAMs, and the rise in recent years is much less smooth for SRAMs than it is for DRAMs. This phenomenon is partially attributed to the fact that SRAMs are more often found in consumer products than are DRAMs, and these consumer products have cyclical seasonal sales patterns, driving a similar cyclicality in the demand for their component parts. Slow SRAMs still account for about two-thirds of the entire market, and these devices are widely used in high-end consumer electronics products.

Unit Shipments

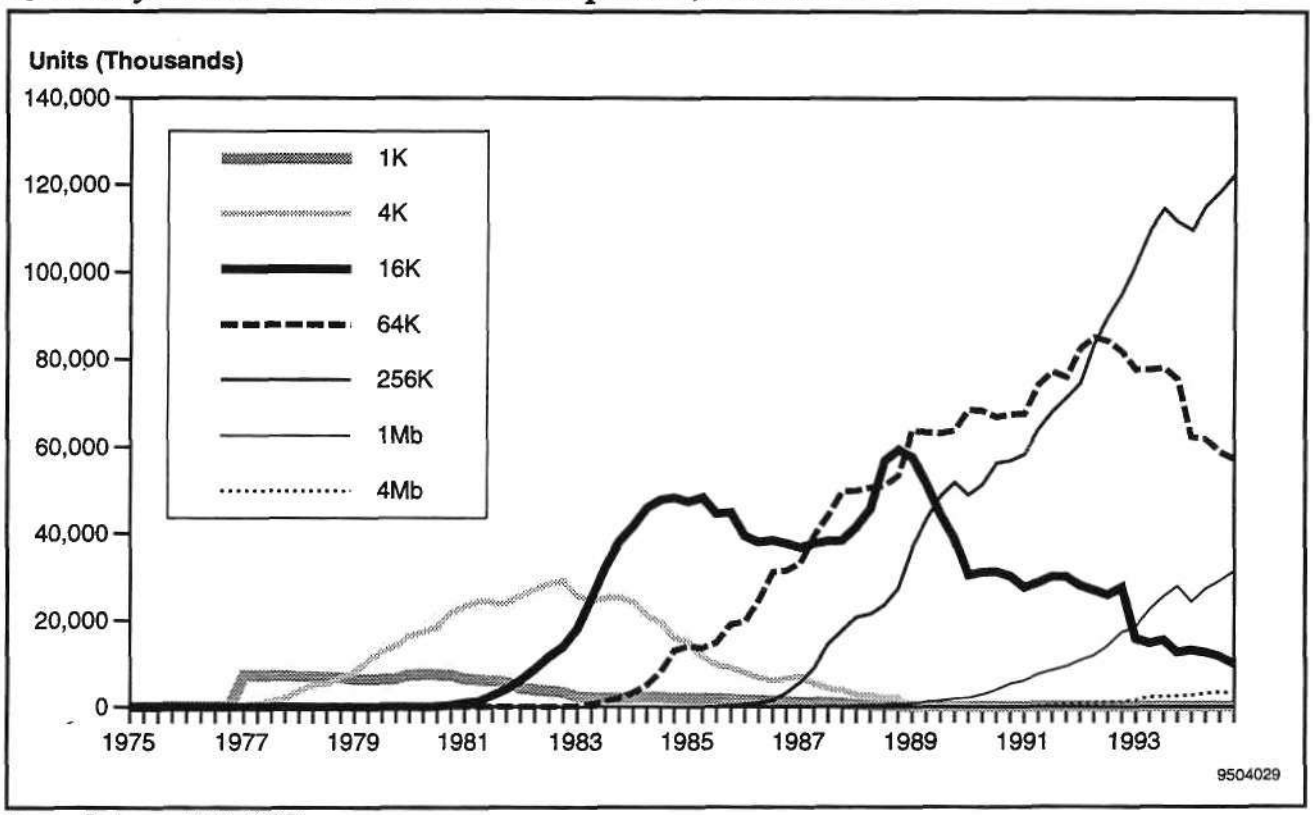
Figure 3-2 shows quarterly unit shipments by density for SRAMs from 1975 through 1994. The 256K device is showing quite strong sales growth quite late in its career, and the 1Mb density, while not growing as strongly as the 256K part, is the only other SRAM whose unit shipments are both significant and increasing. The 4Mb density is just starting to ship in appreciable volumes. An odd phenomenon of this somewhat difficult

Figure 3-1
Quarterly SRAM Worldwide Revenue, 1975 to 1994



Source: Dataquest (July 1995)

Figure 3-2
Quarterly SRAM Worldwide Units Shipments, 1975 to 1994



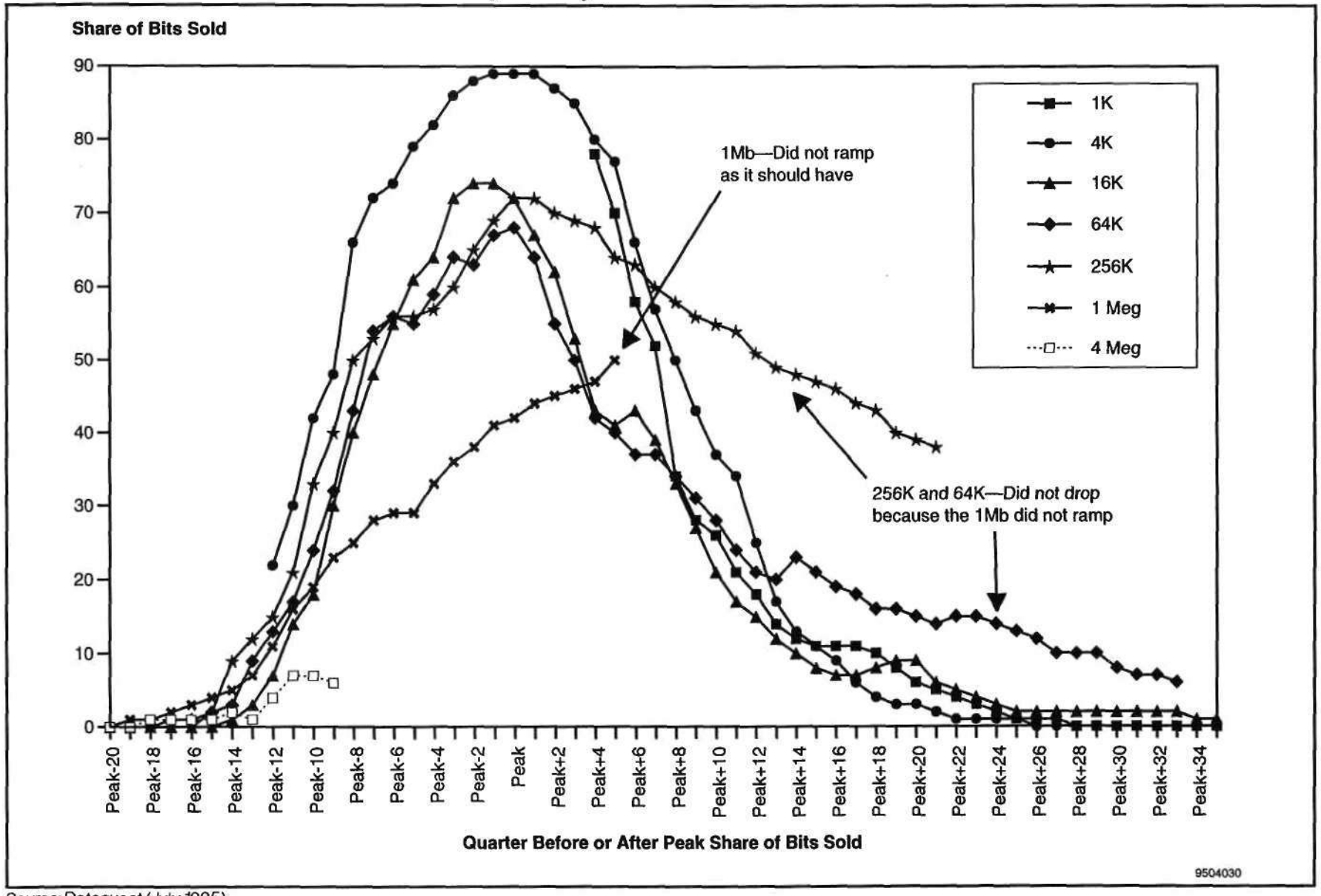
Source: Dataquest (July 1995)

chart is that the slope of the 256K SRAM is still greater than the slope of the 1Mb SRAM. This is not in line with past trends and needs to be explained. Why would the 256K device be outgrowing a more cost-effective alternative? To better understand this, see Figure 3-3.

We disclosed the derivation of charts like Figure 3-3 in the prior edition of our SRAM Market Trends report (MMRY-WW-MT-9302). The approach used to generate this chart is the only way to produce reasonable life-cycle charts for SRAMs. The unit of measure is the percentage of total bits shipped in the market. When the data in Figure 3-2 is turned into bits shipped—by multiplying the units of Figure 3-2 by the density of the SRAM—and when these bits are plotted as a percentage of the entire market—to take out market fluctuations and leave only the simple balance of bits from each density of part—highly repetitive life cycles appear. These life cycles have been laid over each other in Figure 3-3, and they all look the same with the exception of the curves for the 64K, 256K, and 1Mb densities within the last 12 quarters.

Although it is a bit of a departure, we should note that the major market during the first half of the rising curve of this life cycle usually represents the early adopters of the more expensive technology in North America and Europe. As the technology matures, it is adopted in high-end consumer goods in Japan and Asia/Pacific, where it reaches its peak. After the peak, the device starts to appear in low-end consumer electronics, where it resides for the duration of its life.

Figure 3-3
Slow SRAM Normalized Bit Market Share by Density



Source: Dataquest (July 1995)

Because Figure 3-3 is presented as share of total bit shipments, if one device languishes in market share, other devices reflect this by an increase in bit market share. The curves have all been laid on top of each other according to their peak bit market share, these peaks being separated by varying numbers of quarters, from 10 to 14.

As Figure 3-3 shows, the 1Mb density is way off track in achieving market share, and the resultant sales of the 256K and 64K density are not dropping in share as would normally be expected. What is driving this trend? In 1991, North America and Europe were suffering from a recession, and this recession postponed acceptance of the new density. This shows as a leveling of growth for a part of the curve we refer to as the "Front Porch." In early 1992, things reversed themselves, and there was a very sudden demand for the 1Mb SRAM in North America and Europe. Meanwhile, Japan slipped into a recession that has yet to end. Why did the demand in North America and Europe take off so suddenly? Dataquest found that system manufacturers had postponed putting new designs using the 1Mb density into production until the end of the recession. Because the recession ended at the same time for all of these manufacturers, they all phased-in their new designs simultaneously, causing a lurch in demand.

The second half of the rising edge of the curve should have been fueled by growth in Japan and Asia/Pacific (mostly controlled by Japanese manufacturers). Because Japan is still in a recession, Dataquest believes that Japanese manufacturers have 1Mb SRAM-based designs waiting to be put into manufacture and that when the Japanese recession ends, all of these designs will be moved into production at the same time. It is getting pretty late in the life cycle of the 1Mb density for this to happen, however, so it is very likely that manufacturers will start to design using the 4Mb SRAM; when this happens, the shift at the end of the Japanese recession could be a lurch from the 256K to the 4Mb density all at once, without the more typical conversion to the 1Mb device. This could relegate the 1Mb density to the annals of history as "the density that never realized its market." Oddly enough, SRAM manufacturers that have not seen the 1Mb SRAM take off as they had hoped have tried to create a market by continually lowering the price, with today's prices falling below $7.00. Compare this to the $13.00 ASP of a 4Mb DRAM, a device of the same complexity and die size and which is often manufactured on the same production line. It is a little odd that most SRAM manufacturers, those who also manufacture DRAMs, have not decided to trim their production of 1Mb SRAMs to allow themselves to build more of the highly profitable 4Mb DRAM.

The lowest curve represents the 4Mb density, a density whose downturn leaves us with a question: Why is it not headed up? There are several possible reasons. One possibility is that SRAM manufacturers have driven the price of the 1Mb SRAM so low, in an effort to jump-start the market, that the early adopters in North America and Europe have found it uneconomical to produce systems based on the 4Mb SRAM. Another possibility is that the device is just in a slight down cycle because of normal market dynamics ("noise"). Whatever the reason, we do not see this as an important phenomenon.

Pricing

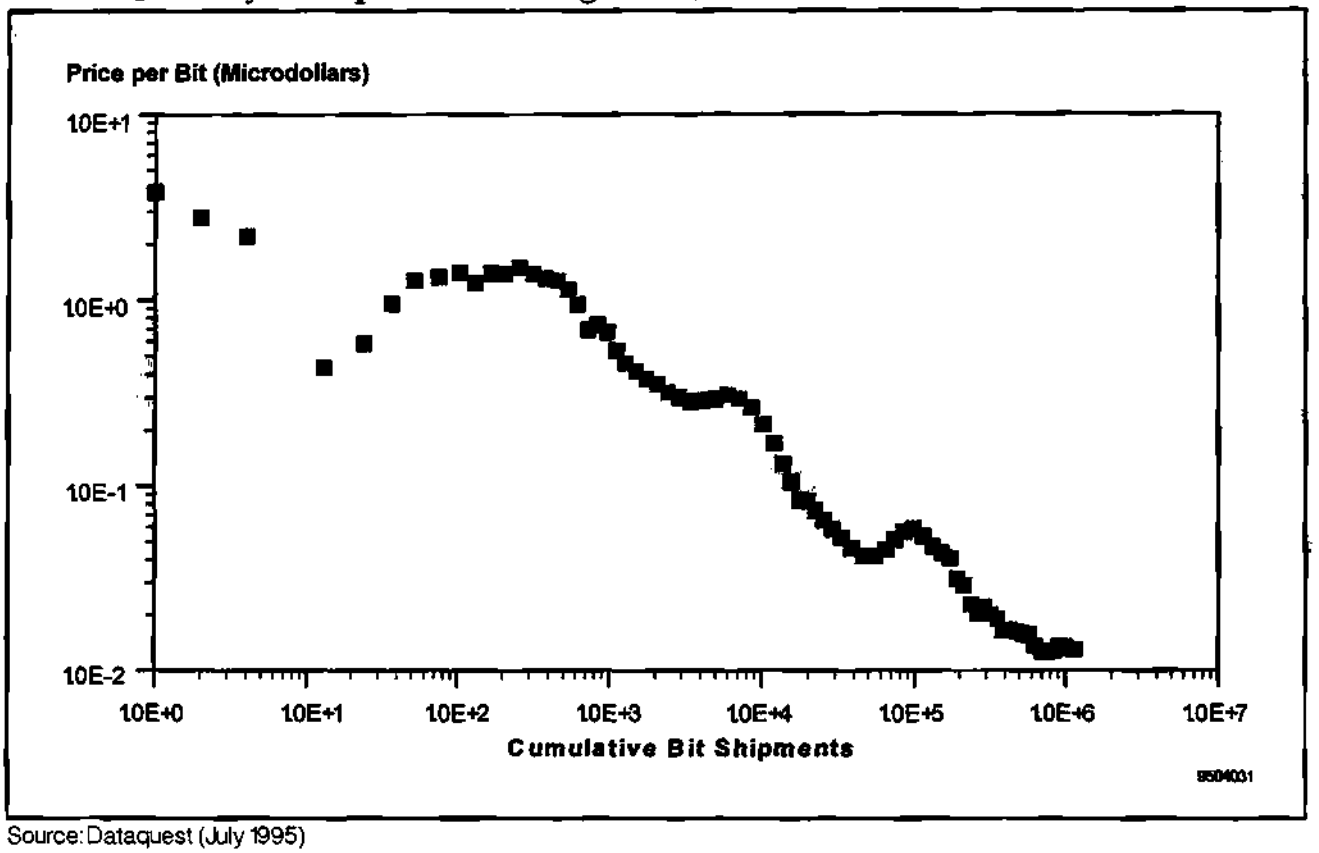
Figure 3-4 shows the SRAM price-per-bit learning curve, which is derived the same way as is the DRAM learning curve in Figure 2-6. Although the curve wanders far more than its DRAM counterpart, it still follows the same trend, of about a five-times price decline per decade of increase in bits shipped. As with the DRAM curve, peaks and valleys align with times of good or bad overall semiconductor sales, which in turn are roughly aligned with the good and bad times in the world economy.

Price per bit tends to be far less of a driver in the acceptance of an SRAM density than of a DRAM density, and SRAM life cycles are considerably longer than those of DRAMs, so we will not go into SRAM pricing as deeply as we did for DRAMs.

Shipments by Speed

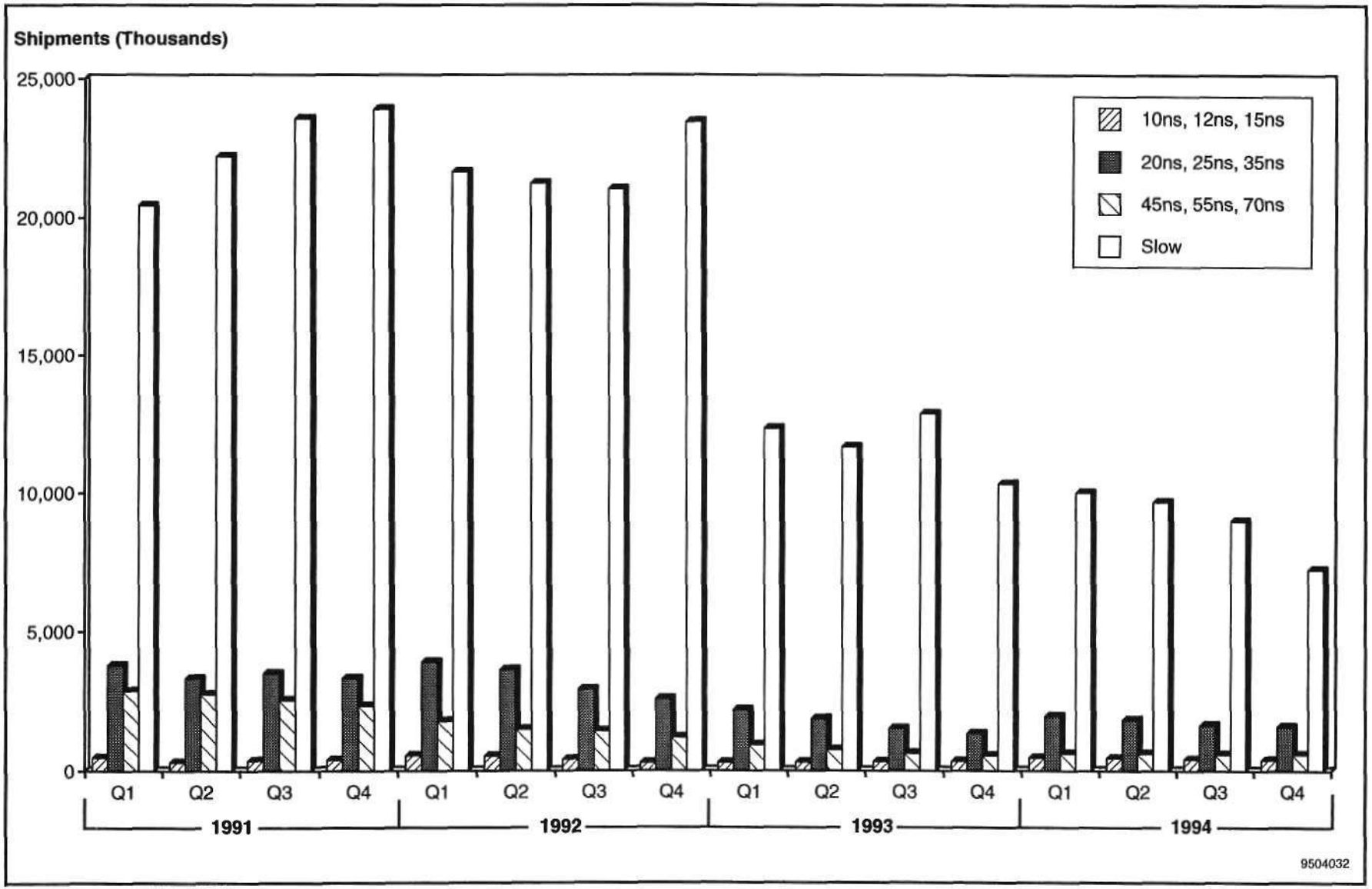
Dataquest has been tracking SRAM shipments by speed to a high degree of detail since 1991. Figures 3-5 through 3-9 show the quarterly worldwide shipments of SRAMs by density and speed. The shipments of the slower-than-70ns speed ("slow") tower over those of the faster speed grades in every case except for the 4Mb SRAM, which is early in its life cycle, causing the pseudo SRAM (PSRAM) to be a more manufacturable and cost-effective alternative. The slower devices always have made up the bulk of the SRAM market, a phenomenon that appears destined to continue into the foreseeable future.

Figure 3-4
SRAM Quarterly Price-per-Bit Learning Curve, 1975 to 1994



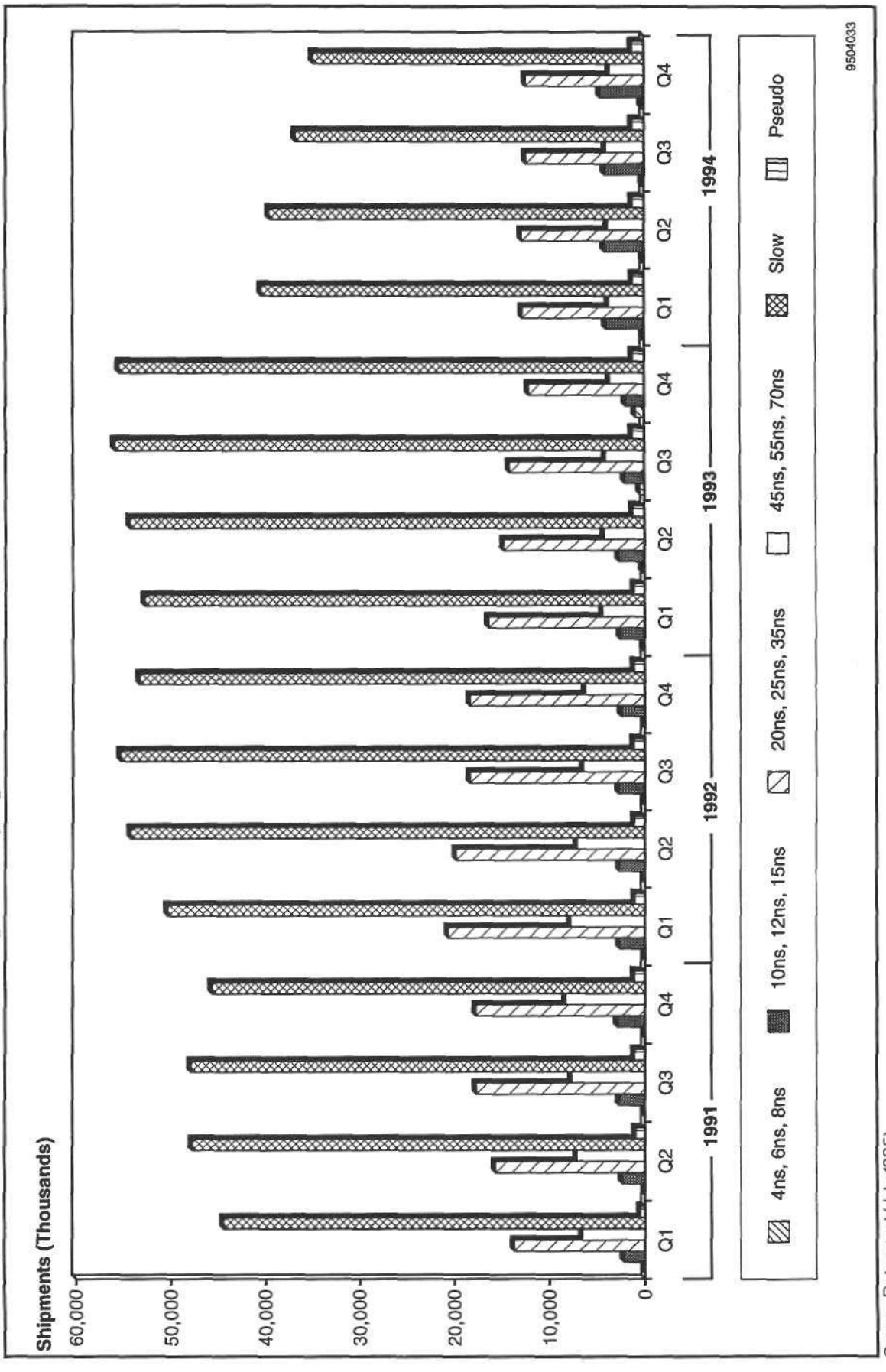
Source: Dataquest (July 1995)

Figure 3-5
Quarterly Worldwide 16K SRAM Shipments by Speed, 1991 to 1994



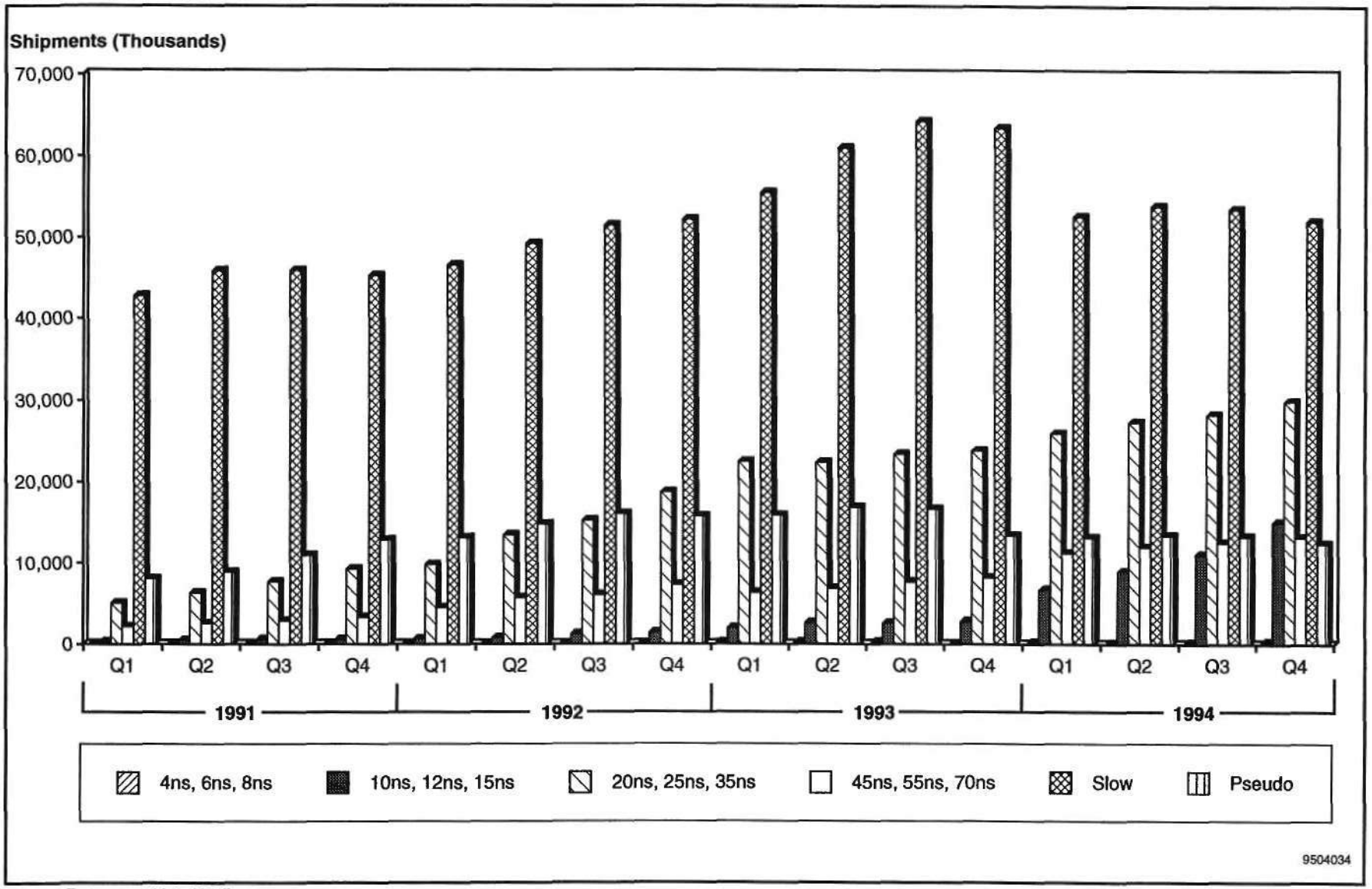
Source: Dataquest (July 1995)

Figure 3-6
Quarterly Worldwide 64K SRAM Shipments by Speed, 1991 to 1994



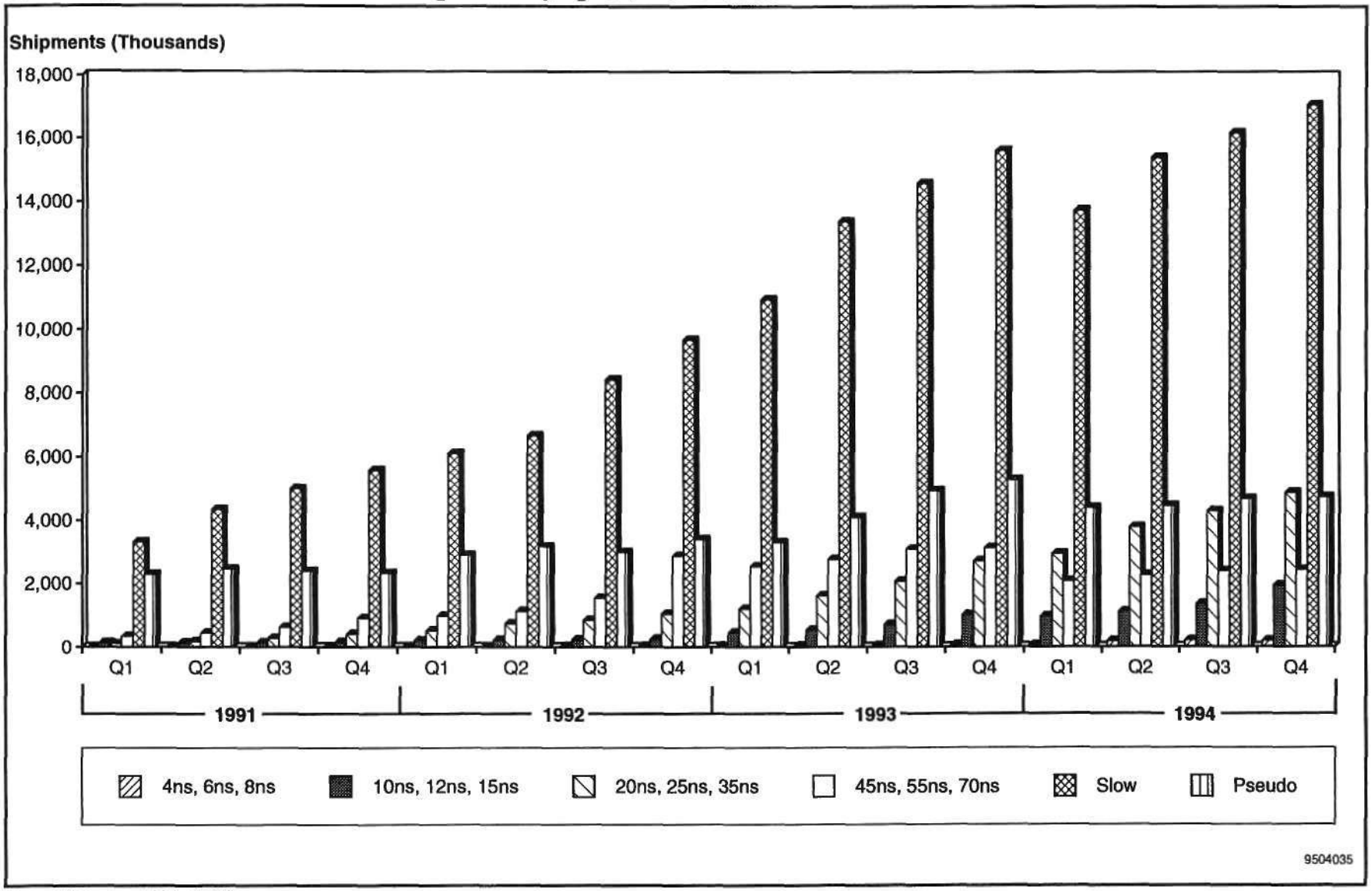
Source: Dataquest (July 1995)

Figure 3-7
Quarterly Worldwide 256K SRAM Shipments by Speed, 1991 to 1994



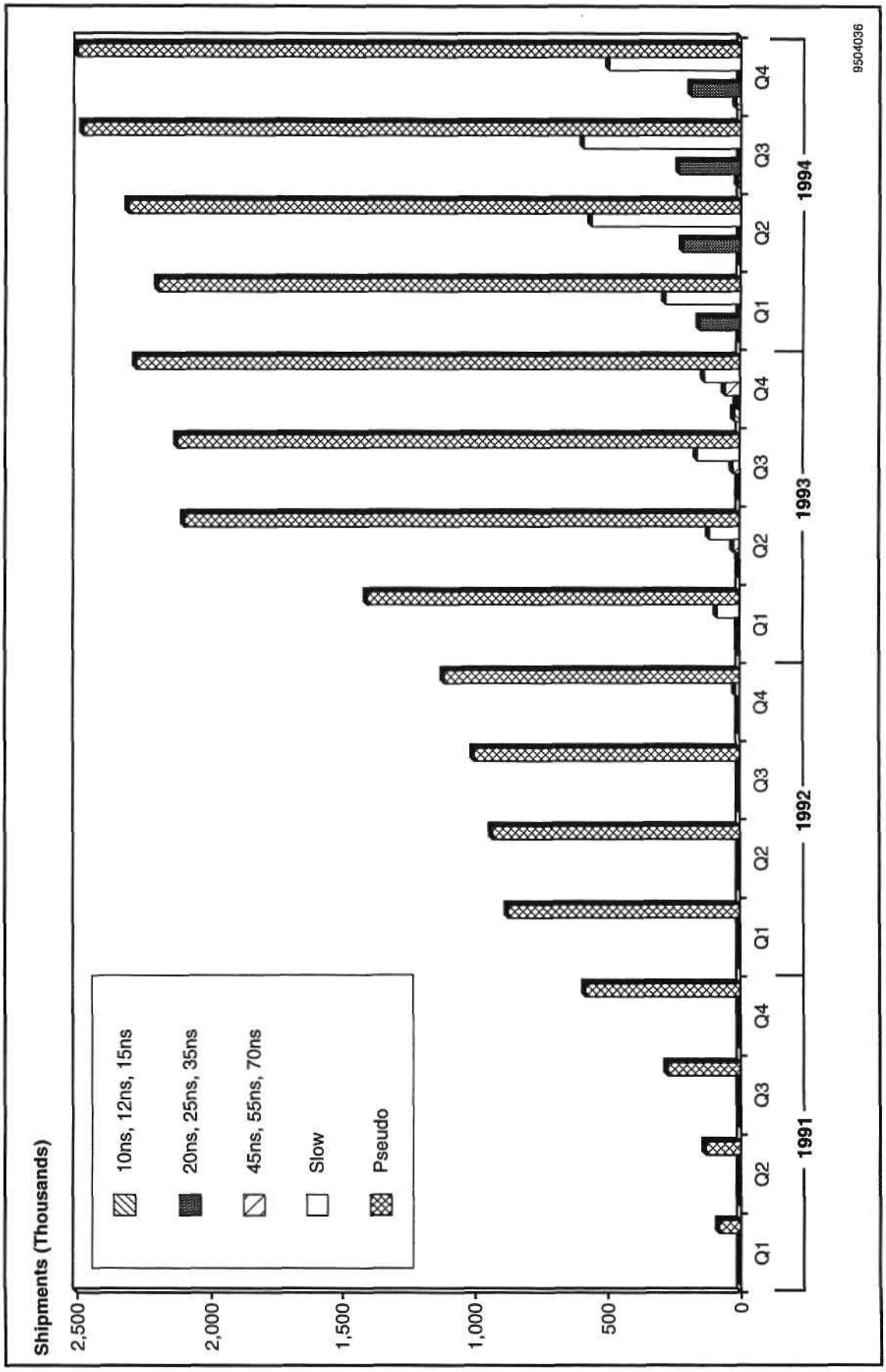
Source: Dataquest (July 1995)

Figure 3-8
Quarterly Worldwide 1Mb SRAM Shipments by Speed, 1991 to 1994



Source: Dataquest (July 1995)

Figure 3-9
Quarterly Worldwide 4Mb SRAM Shipments by Speed, 1991 to 1994



Source: Dataquest (July 1995)

There are some changes in methodology that show up in the curves as steps from year to year, but the trends do not vary despite these interruptions.

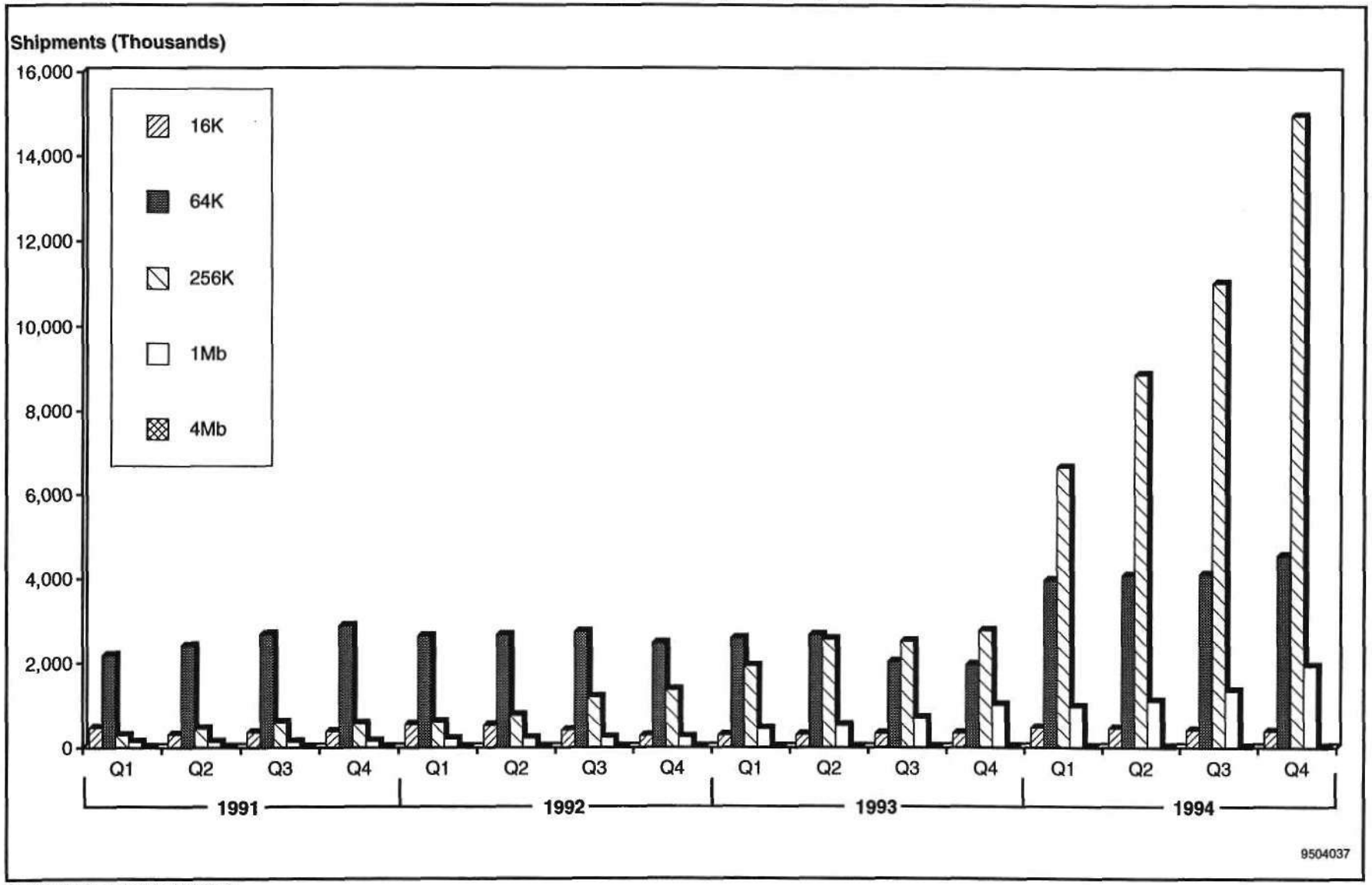
For the 16K, 64K, and 256K densities, unit shipments of the 20ns, 25ns, and 35ns speed range are second to those of the slow parts. These parts tend to be used in PC caches and are manufactured at about the same ASP as the slow part. There have even been parts in this speed range that have maintained markets at lower ASPs than their slower counterparts. At the 1Mb and 4Mb densities, PSRAMs have held a much more important position, mostly owing to the newness of each of these densities. PSRAMs tend to be available in volume at competitive prices far earlier than are standard SRAMs of the same densities.

The 20ns, 25ns, and 35ns speed range is the second most significant speed for the 16K and 64K densities; however, sales are flattening out. This is occurring as these devices are removed from use as cache data memories and are used more as cache-tag memories in PC and other cache memory designs. At the 256K density (see Figure 3-7), there is a steady climb in unit shipments at the 20ns, 25ns, and 35ns speed, which fits with what is happening in the market for PC caches. This rise has fueled the success of companies aligned toward this market, companies such as Alliance, Cypress, IDT, ISSI, UMC, and Winbond. A similar rise is taking place in the 1Mb density, although the comparison of this speed to the slow and pseudo speeds is nowhere near as significant.

It is a little easier to see what is happening with the different speed grades if we look at a specific speed range and compare the density shifts. There are five basic speed categories for SRAMs: pseudo, slow, a "gap" of speeds that do not ship, PC cache-speed devices, and premium-speed devices. These ranges roughly correspond to the numerical speed ranges shown in the charts, but there is not a clean division. There have been some anomalies in the reporting of the 4ns, 6ns, and 8ns speed range, owing to reporting errors, to the thinness of this market, or to the importance of single orders to the overall size of the market. Whatever the reason for these anomalies, we have chosen not to chart this speed split by density in this report because it is too erratic to be used to draw any conclusions. The data in Figure 3-10 shows the shipments of 10ns, 12ns, and 15ns parts by density. These fall into the premium-speed and a bit into the PC cache-speed portions of the market. The phenomenal rise of 256K SRAM shipments owes much to the conversion of PC cache designs from 25ns and 20ns SRAMs over to the 15ns speed, driven mainly by price reductions in this speed range. There is steady demand for 64K SRAMs at this speed, driven by demand for cache-tag RAMs, and there is growing use of the 1Mb, primarily for high-end caches.

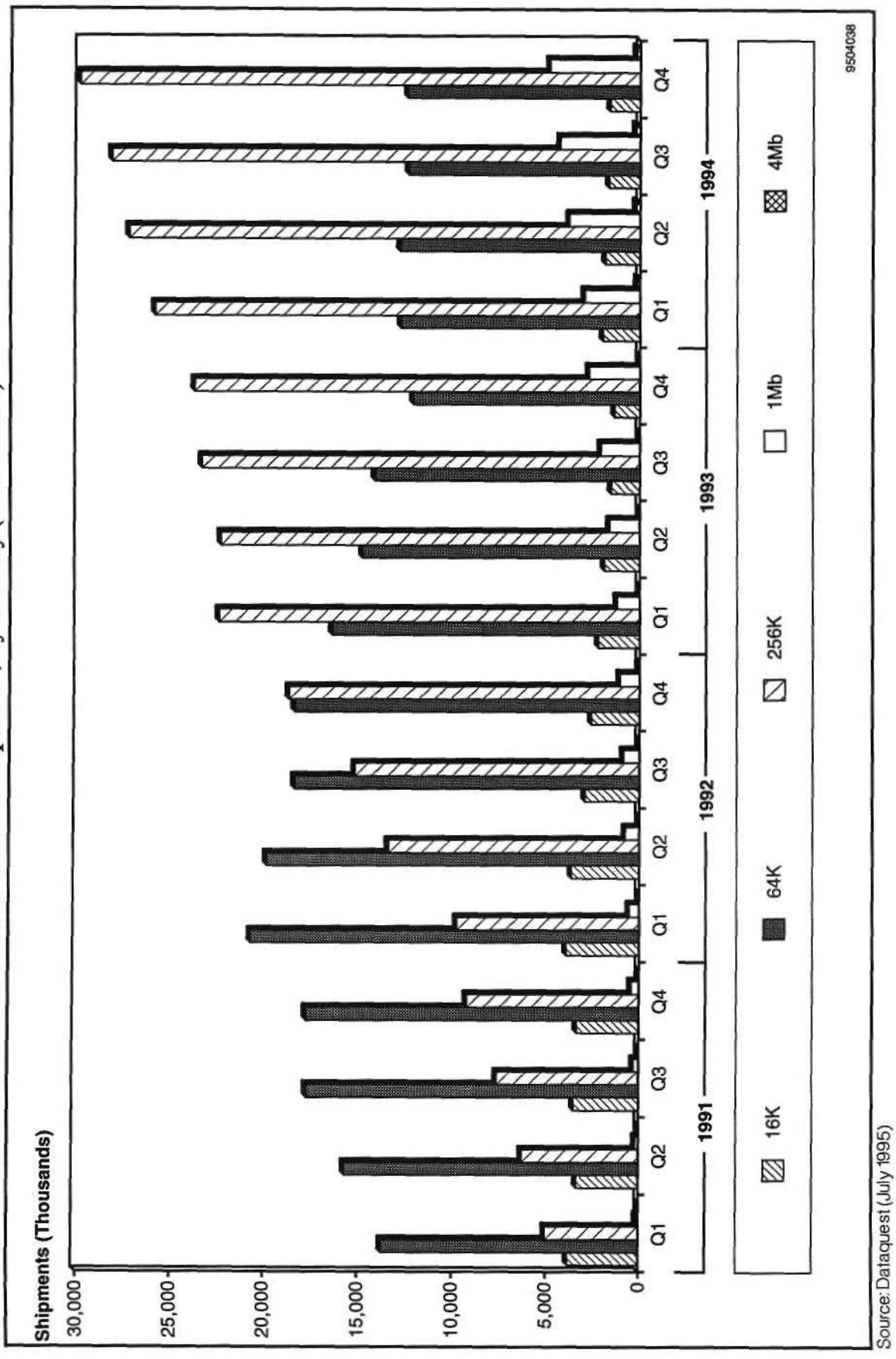
At the 20ns, 25ns, and 35ns speed, the PC phenomenon is seen better than in any other instance (see Figure 3-11). The 256K has a heavy ramp as it increases in use in PC caches. The 64K density crests in first quarter 1992, then slacks off as it is replaced by the 256K density. The 16K density is small and shrinking at this speed, and the 1Mb density is roughly the same size and is growing. The 4Mb density hardly even registers.

Figure 3-10
Quarterly Worldwide 10ns, 12ns, and 15ns SRAM Shipments, by Density (1991 to 1994)



Source: Dataquest (July 1995)

Figure 3-11
Quarterly Worldwide 20ns, 25ns, and 35ns SRAM Shipments, by Density (1991 to 1994)



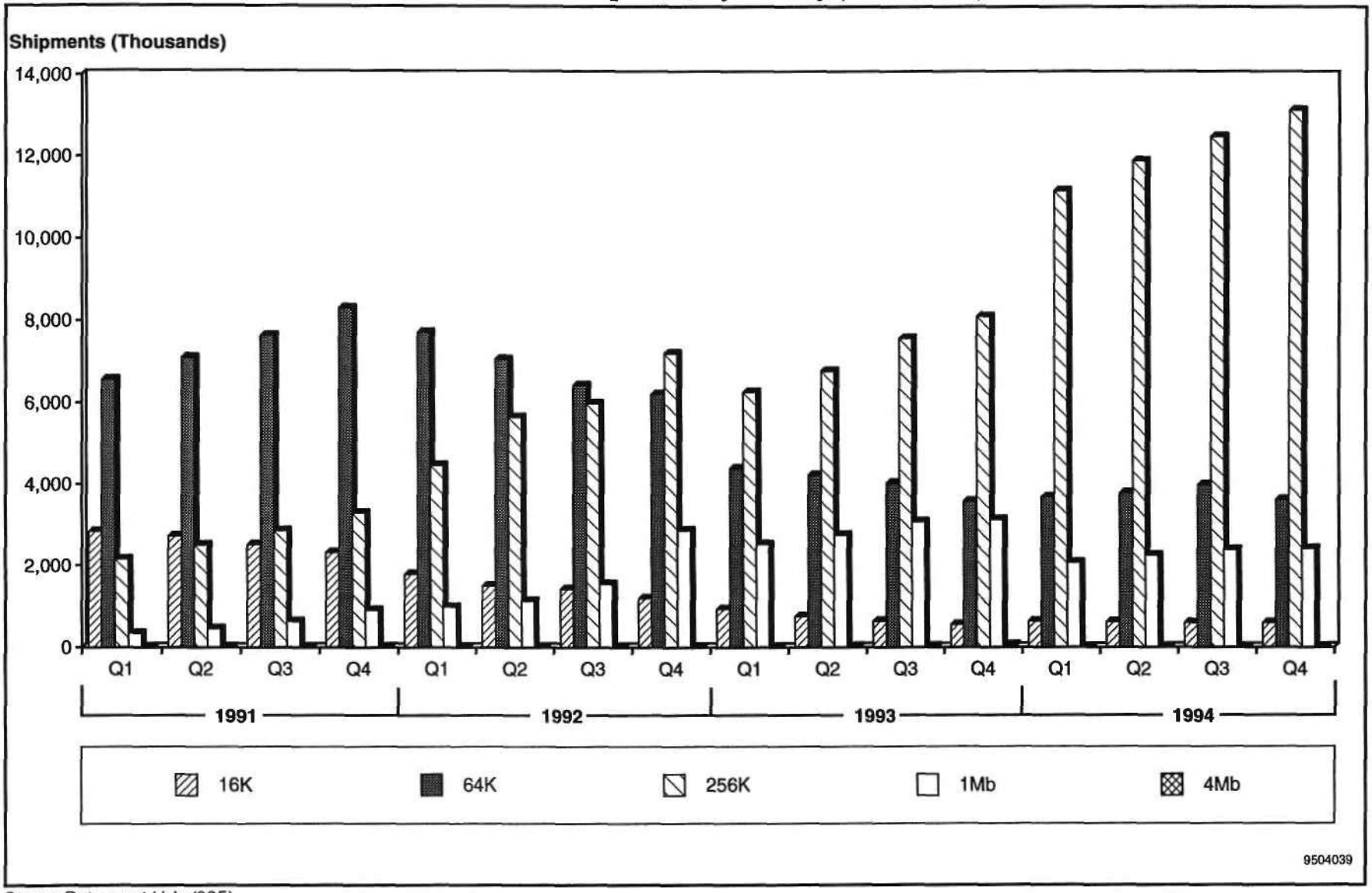
Source: Dataquest (July 1995)

There are some strange patterns at the 35ns, 45ns, and 70ns speed owing to the fact that the "gap" for most densities fits within this range (see Figure 3-12). At this gap, there are nearly no sales. The speed that does not sell is usually only one speed-range wide and is at a different speed for each device; it is at a higher speed for devices of increasing density. Still, there are some obvious patterns. The sales of the 16K and 64K densities at this speed are diminishing. Sales of the 256K and 1Mb are increasing; however, like the slow devices profiled in Figure 3-3, the 256K is enjoying more growth than is the 1Mb SRAM. The 4Mb part shows up on this chart (barely) in 1993, then is absent in 1994. This is because there is a market gap in this range and because the slow and fast versions of today's 4Mb SRAMs are manufactured using two different technologies, making parts within this speed range difficult to purchase.

At the "slower than 70ns" speed range, the 256K density is the leader, as it has been since 1993, with the 1Mb density not yet making an important contribution (see Figure 3-13). Before 1993, the 64K density was still the top-selling SRAM, owing largely to its use in consumer electronics devices. Surprisingly, business for the 16K SRAM in this speed range has been relatively steady. The 4Mb density is just beginning to show up.

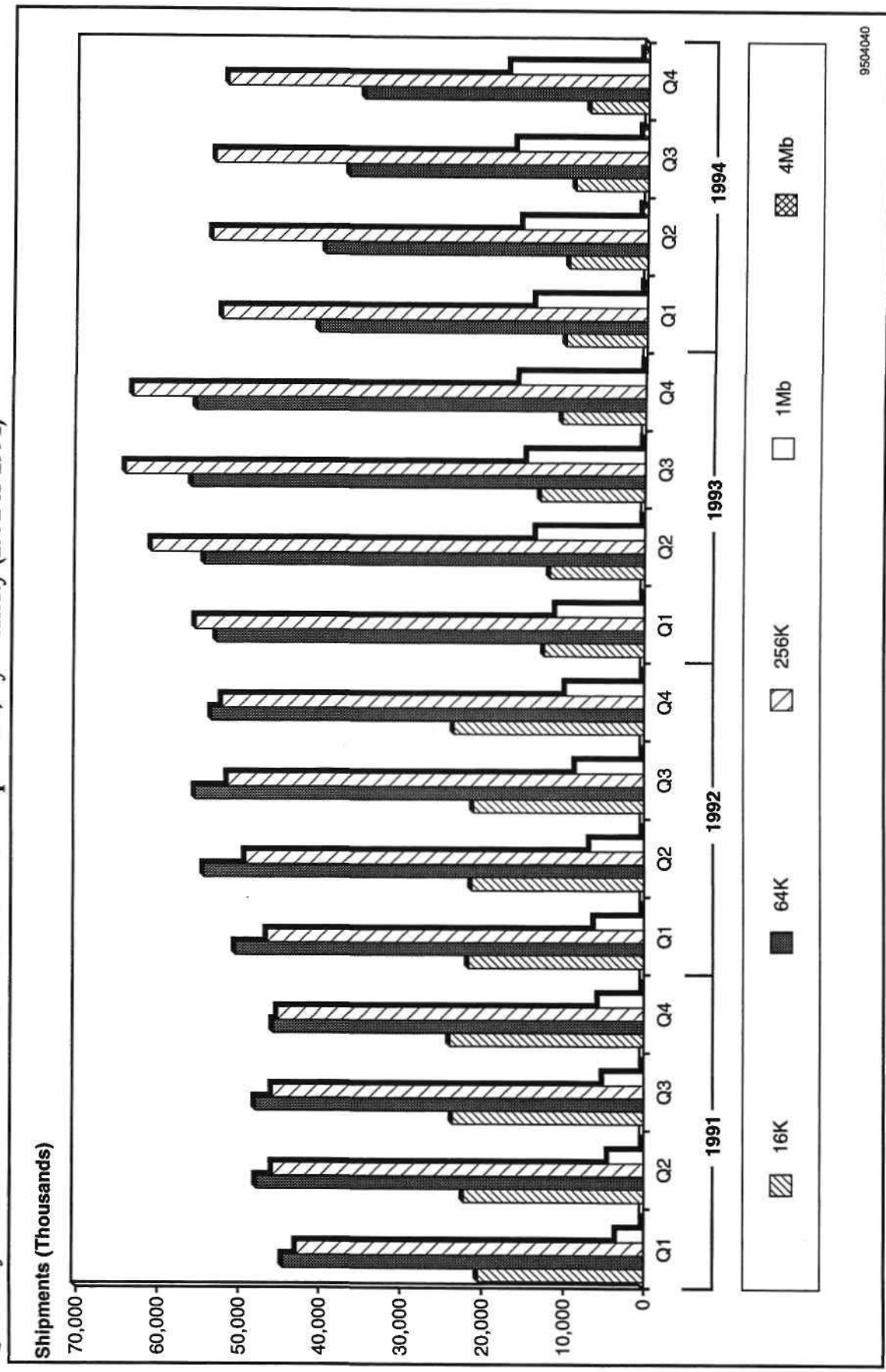
Figure 3-14 shows trends for PSRAMs. The market for these devices is highly limited, with only two high-volume suppliers and a similarly few number of users. Although the 256K density is, surprisingly enough, at the top, where it has been since 1991, there is a lot of growth at the 1Mb and 4Mb densities. Sales of the 64K density have stayed flat.

Figure 3-12
Quarterly Worldwide 35ns, 45ns, and 70ns SRAM Shipments, by Density (1991 to 1994)



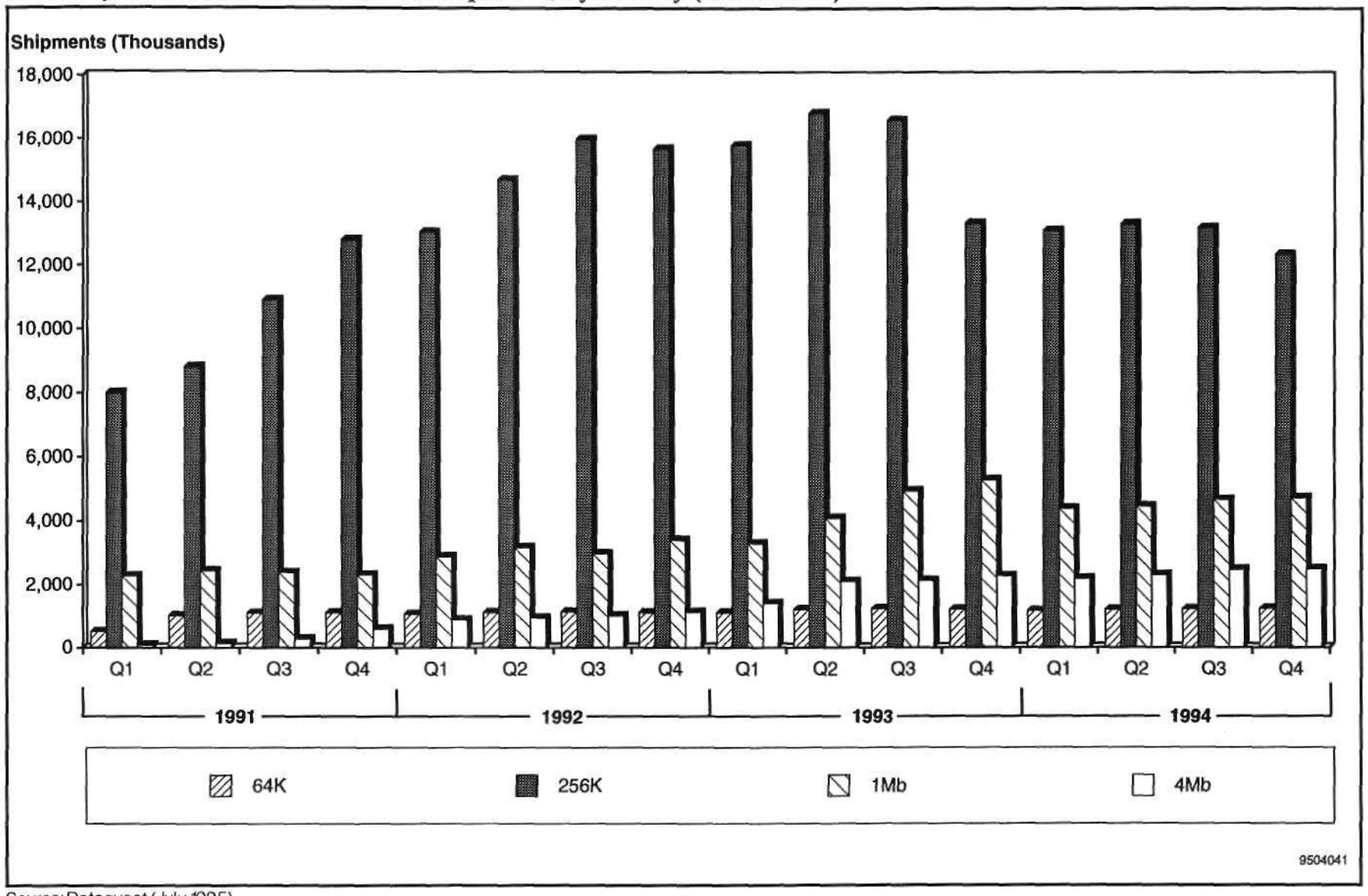
Source: Dataquest (July 1995)

Figure 3-13
Quarterly Worldwide Slower than 70ns SRAM Shipments, by Density (1991 to 1994)



Source: Dataquest (July 1995)

Figure 3-14
Quarterly Worldwide Pseudo-SRAM Shipments, by Density (1991 to 1994)



Source: Dataquest (July 1995)

Chapter 4
Trends in the Nonvolatile Memory Market

Nonvolatile memories consist of EPROM, EEPROM, flash memory, and mask ROM. Figure 4-1 shows the nonvolatile market as a whole, with adjacent columns representing each technology. Flash is obviously expected to grow the fastest, outstripping even mask ROM, the biggest market, by 1997. Growth is expected in the small EEPROM market, yet the market is expected to stay small. The EPROM market is expected to be level at an annual sales rate of between $1.5 billion and $2.0 billion.

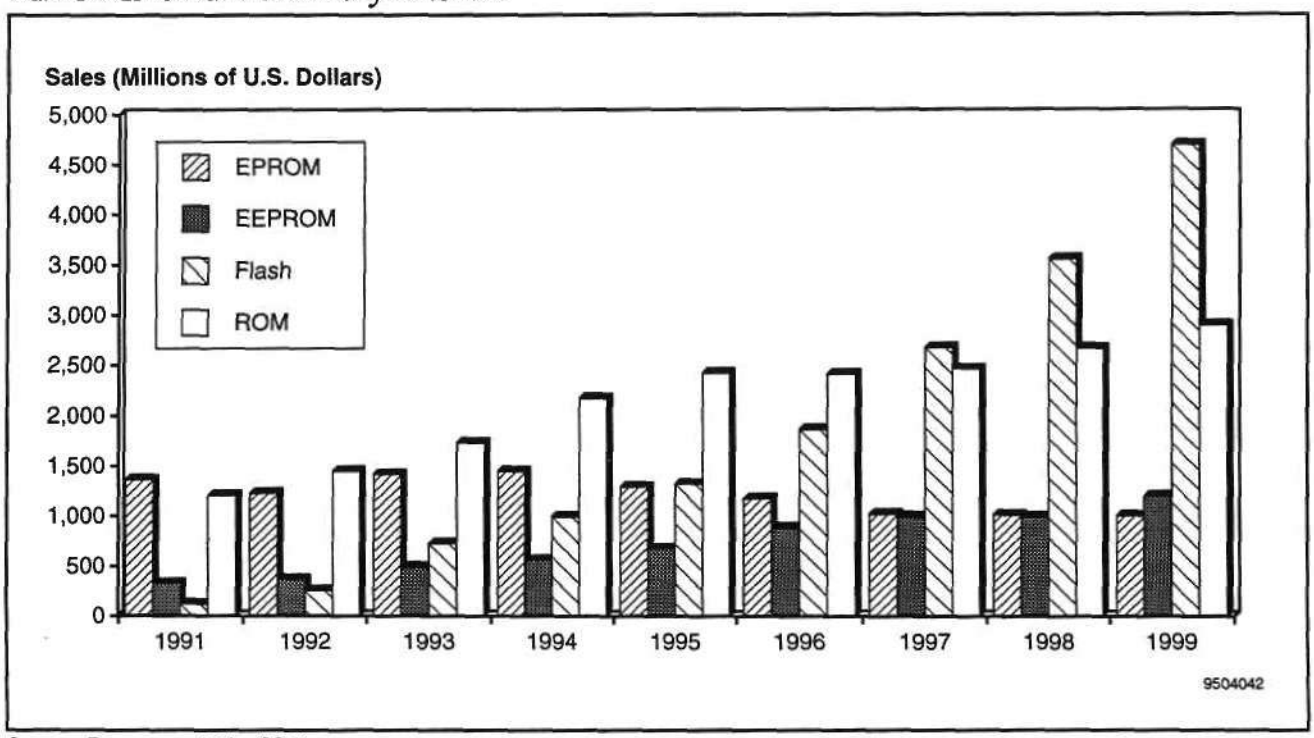
Dataquest has not been tracking each of these markets to any great degree of resolution until relatively recently. As a result, the data used to drive our forecasts is less trend driven than driven by analysis of the markets served by the products. Nonetheless, each technology will be explored in turn.

EPROM

One of the oldest technologies, EPROM is used to store code in applications both in embedded systems and in computers as the bootstrap or basic input/output subsystem (BIOS) in PCs. Figure 4-2 shows historical EPROM revenue, which has not fallen off despite the aggressive introduction of the flash memory.

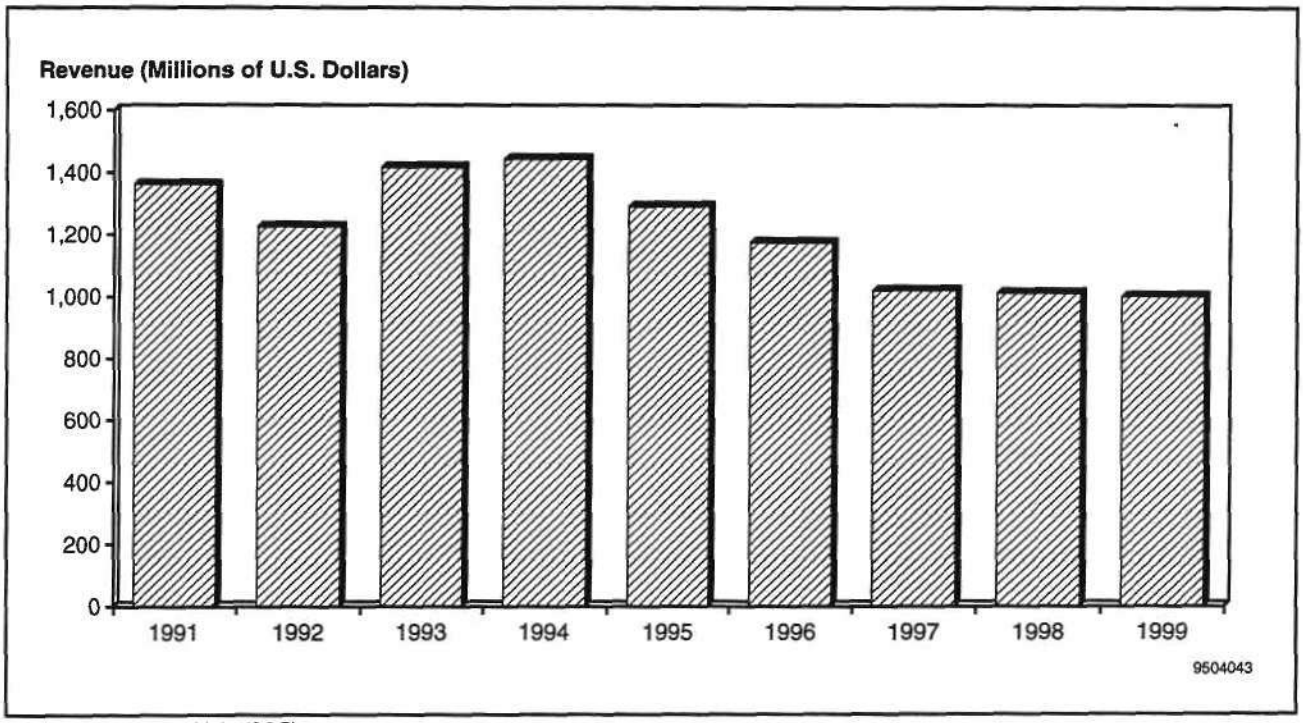
Unit shipments by density are shown in Figure 4-3. It is apparent that, over the term of the chart, there are certain erratic tendencies in the adoption of different densities. As a general rule, half-densities (512K, 2Mb, 8Mb) are not as popular as the standard devices.

Figure 4-1
The Nonvolatile Memory Market



Source: Dataquest (July 1995)

Figure 4-2
EPROM Revenue Forecast



Source: Dataquest (July 1995)

EEPROM

EEPROMs fill a need for a memory device with minimum storage to a set price point, usually less than $1. Revenue, while small in comparison with other memories tracked by Dataquest, is continually growing (see Figure 4-4). Dataquest expects this market to continue to be a small but respectable portion of the MOS memories market for a long time to come.

Unit shipments by density do not show any interrelationship between densities; rather, each density follows a unique dynamic, propelled by its own market (see Figure 4-5).

Flash

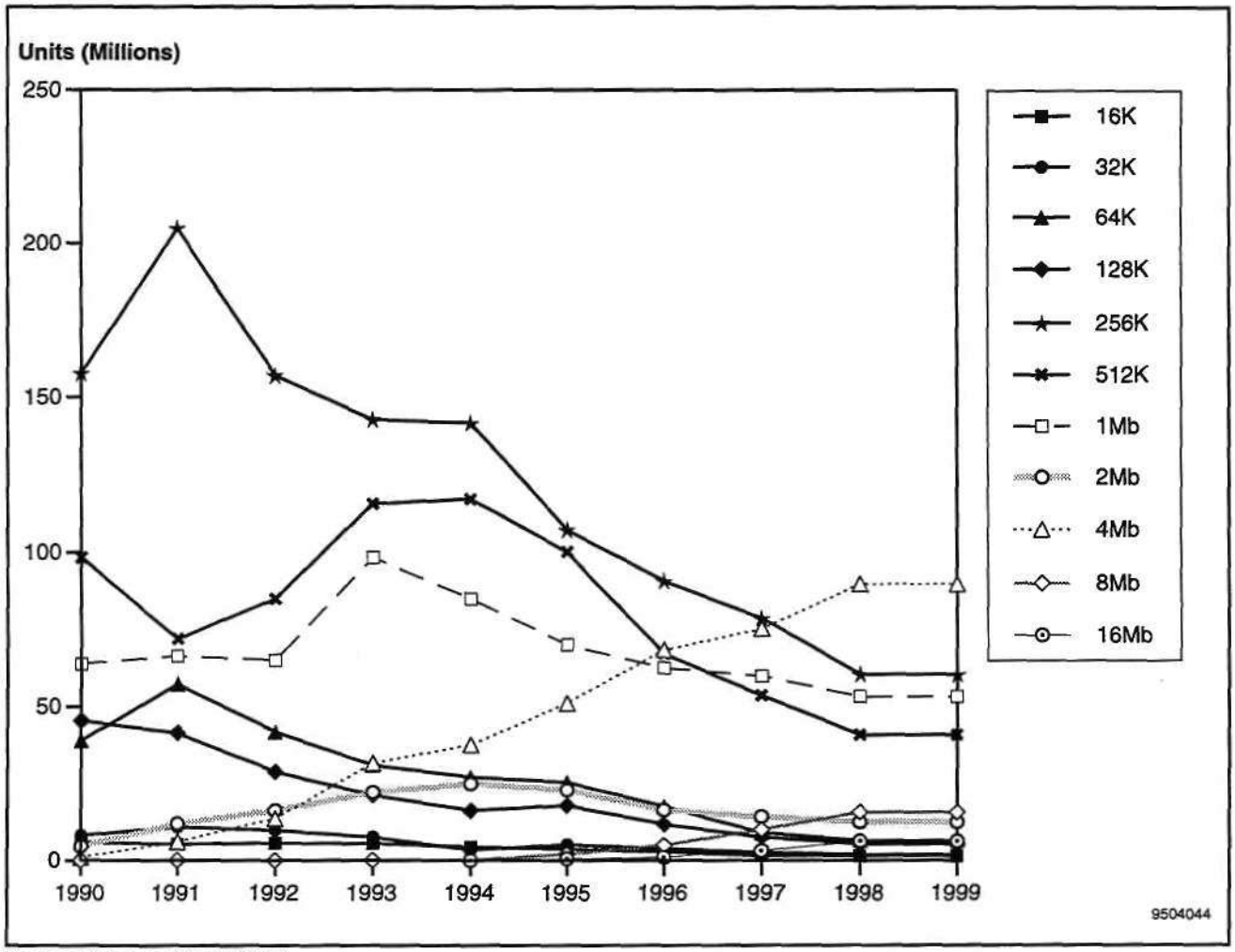
Flash memories are a new technology with a broad acceptance, and for this reason alone, all of Dataquest's charts for flash go up and to the right. Figure 4-6 shows flash revenue, the fastest-growing market of any MOS memory device.

In Figure 4-7 we see the market in units for each different flash memory device. Because all flash memory devices are new, all are on the increase, and none has reached an end-of-life stage. This situation will rectify itself as the market matures.

Mask ROM

The final type of MOS memory device, mask ROM, continues to be the cheapest device on a price-per-bit basis. Revenue for the mask ROM is shown in Figure 4-8. Dataquest has seen continued, even growth in this market despite threats from technologies ranging from CD-ROMs in games to flash memory in embedded applications.

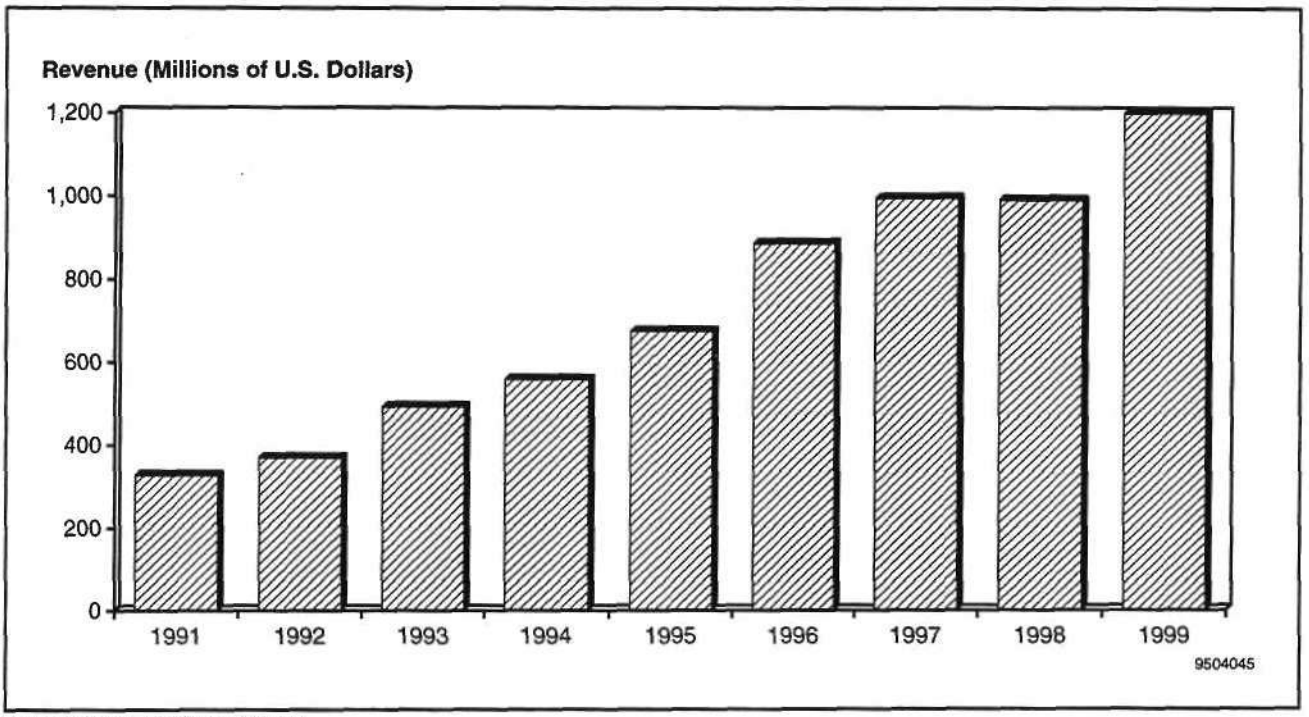
Figure 4-3
EPROM Unit Shipments, 1990 to 1999



Source: Dataquest (July 1995)

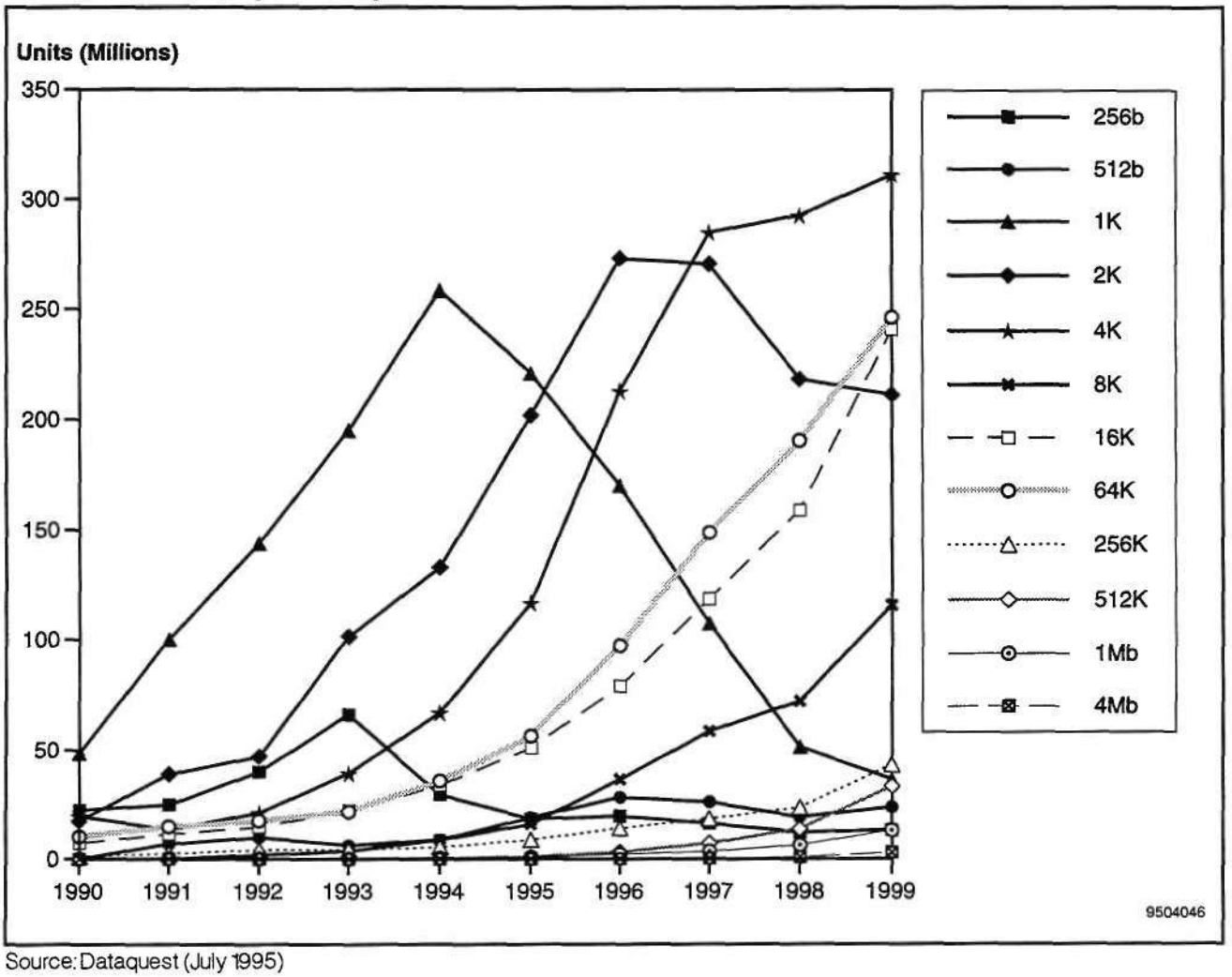
Figure 4-9 shows mask ROM unit shipments by density. There has been a recent phenomenon wherein new densities displace older ones faster than they have in the past. This phenomenon can be attributed to the massive growth of the video game market over the past decade. Life cycles of mask ROMs used to be relatively lengthy, but new generations are being massively accepted almost as soon as semiconductor manufacturers can put them into production. What is done with all of this capacity? Most of it is being used as storage for more and more detailed video effects, which consume more memory the more detailed they are in resolution and the smoother the animation is with which characters are portrayed.

Figure 4-4
EEPROM Revenue Forecast



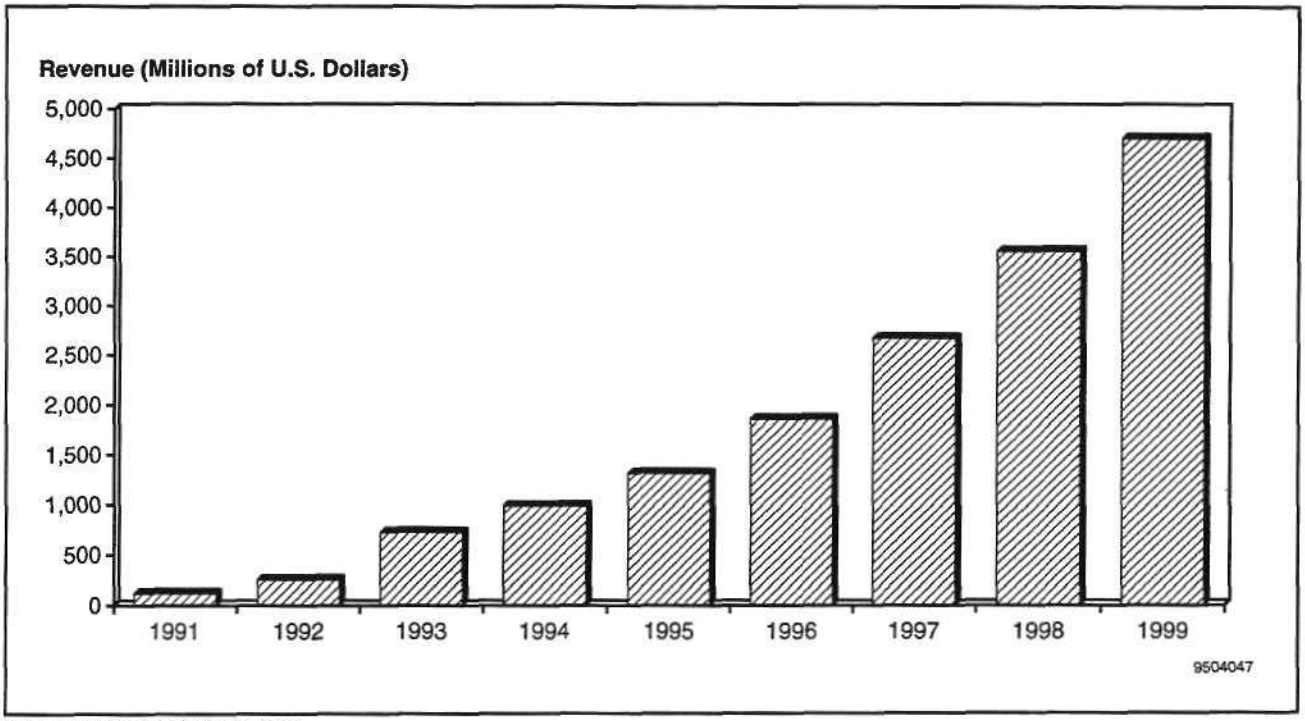
Source: Dataquest (July 1995)

Figure 4-5
EEPROM Units, by Density



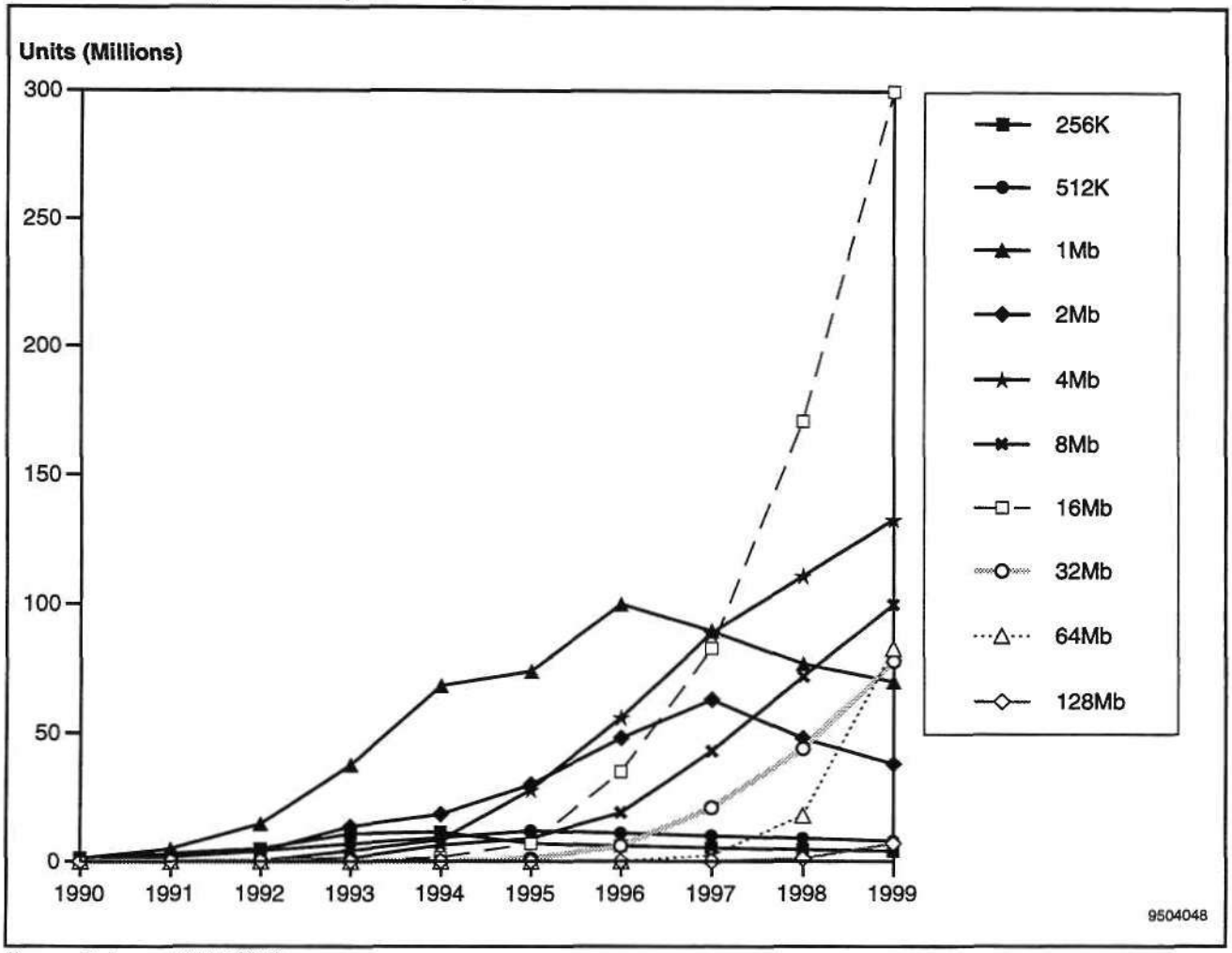
Source: Dataquest (July 1995)

Figure 4-6
Flash Memory Forecast



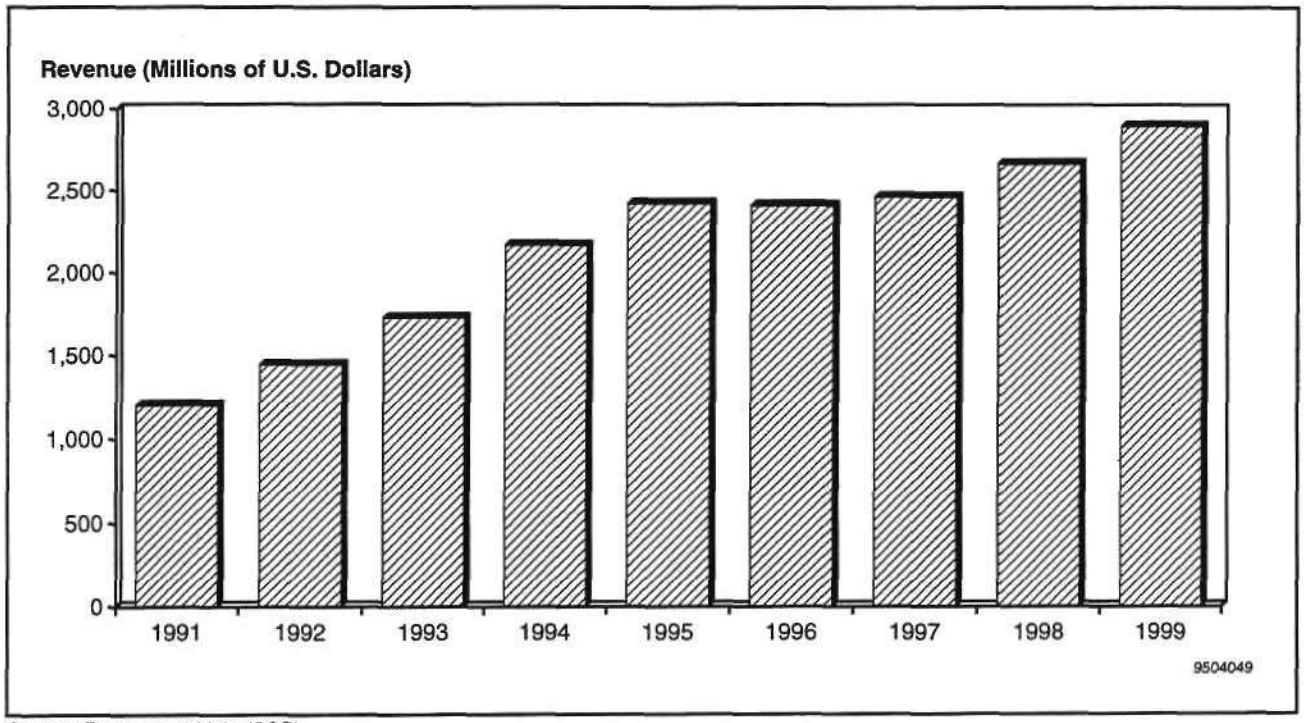
Source: Dataquest (July 1995)

Figure 4-7
Flash Unit Shipments, by Density



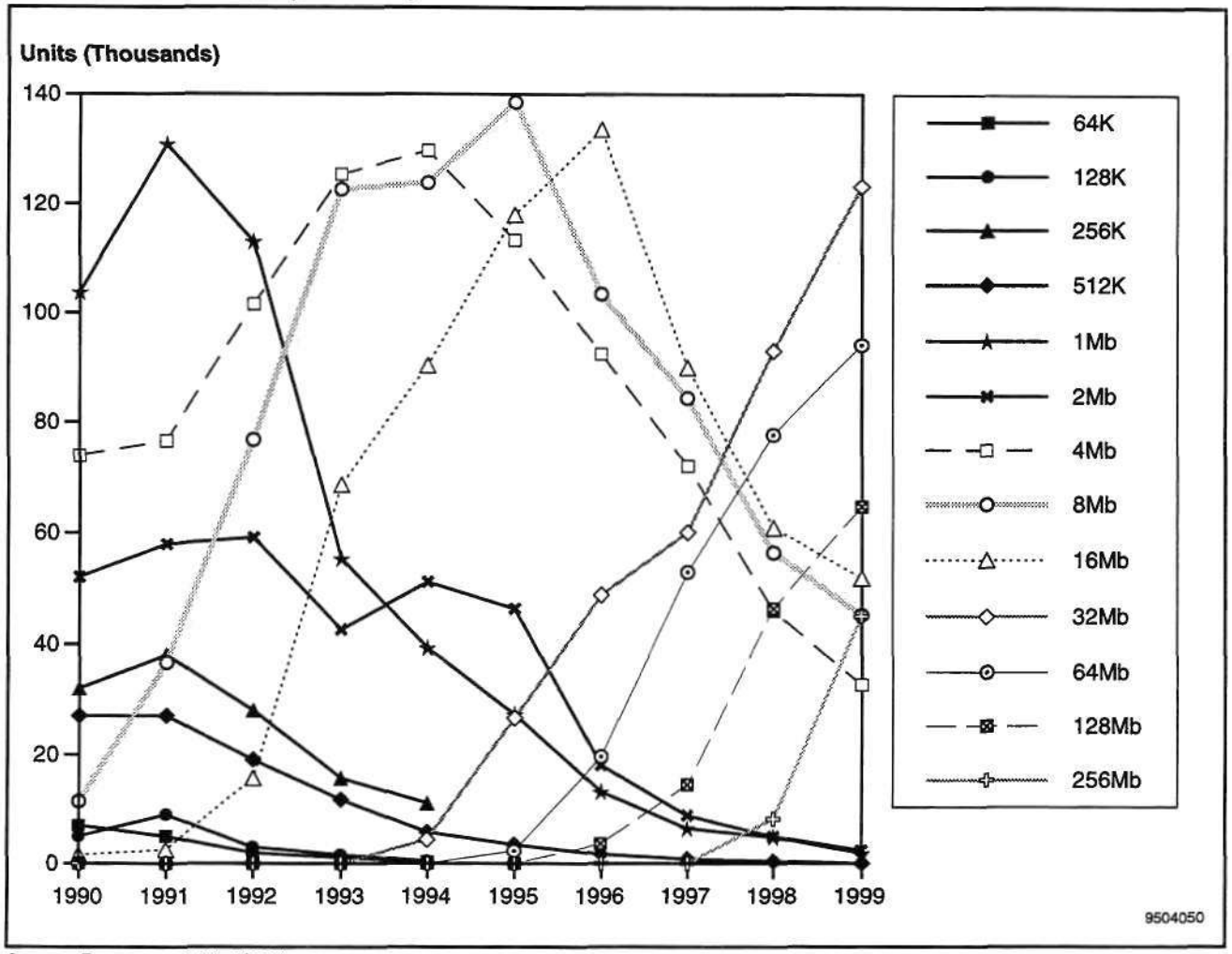
Source: Dataquest (July 1995)

Figure 4-8
Mask ROM Revenue



Source: Dataquest (July 1995)

Figure 4-9
Mask ROM Units, by Density



Source: Dataquest (July 1995)

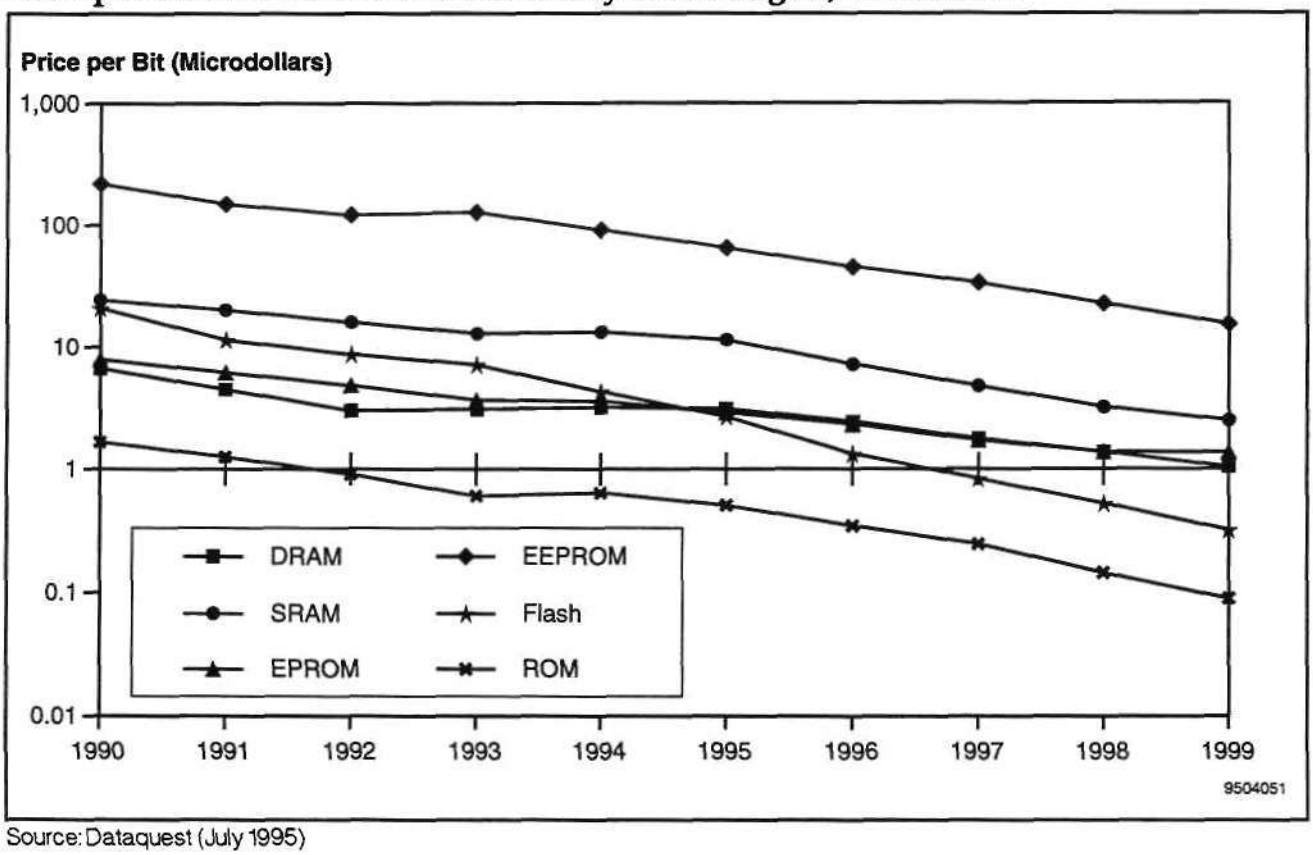
Chapter 5
Comparison of Technologies

To compare all of these technologies, we have drawn a historical and forecast average price-per-bit curve (see Figure 5-1). EEPROM is at the top, where price per bit is unimportant, as this device sells based upon the absolute ASP. EEPROM memory technology is used in applications where minimal memory is required and the price of this memory must be kept below $1.

Next comes SRAM. SRAM has been crossed over at a price-per-bit level by flash, yet this appears to have had no effect on overall SRAM sales. For this and for other reasons, Dataquest does not expect price-per-bit crossovers between flash and other technologies to be a driving factor in the conversion from other memory technologies to flash. The sales of flash have not been adequately high to have caused the strange effect on 1Mb SRAM shipments illustrated in Figure 3-3.

Flash, after SRAM, is the most aggressively falling price curve. Dataquest believes that the aggregate price per bit for flash fell below that of EPROM last year and will cross that of DRAM this year. If Intel is successful in putting multiple bits on a flash cell, this could further accelerate the fall. This will be an important technology to watch because it will eventually enable applications unheard of today.

Figure 5-1
Price-per-Bit Curve for All MOS Memory Technologies, 1990 to 1999



Source: Dataquest (July 1995)

Next in line is the EPROM, which Dataquest expects to decline less slowly than the other curves on the chart, simply because it is being supported by a shrinking supplier base, something that allows prices to firm up, and because these suppliers are not pushing as aggressively to get to the next density as are the suppliers in nearly all other technologies.

DRAM comes next, with a plateau in recent years, going once again to a steady descent as today's undersupply balances out. Mask ROM is expected to maintain the lowest price per bit of any MOS memory technology for the duration of Dataquest's forecast cycle.

Dataquest Perspective

There are a few exceptions to the trends that the MOS memory market has been following over the course of its history. The Japanese recession and other phenomena have caused a supply/demand imbalance for DRAMs as well as a lack of acceptance of the 1Mb slow SRAM. Fast SRAMs and DRAMs are being driven in consumption mainly by a PC market stronger than any seen before. Nonvolatile memories, while undergoing changes, are not being disrupted by the addition of flash memory to the portfolio.

In the long run, Dataquest anticipates that the market will correct its current anomalies and that the flash technology will find its own market as an enabling technology, leaving the balance of the market to other devices, as it has in the past.

For More Information...

Jim Handy, Director/Principal Analyst ..... (408) 437-8228
Internet address ..... jhandy@dataquest.com
Via fax ..... (408) 437-0292

Dataquest

a company of The Dun & Bradstreet Corporation

DATAQUEST WORLDWIDE OFFICES

NORTH AMERICA
Worldwide Headquarters
Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 1-408-437-8000
Facsimile: 1-408-437-0292

Dataquest Incorporated
Nine Technology Drive
P.O. Box 5093
Westborough, Massachusetts 01581-5093
United States
Phone: 1-508-871-5555
Facsimile: 1-508-871-6180

Dataquest Global Events
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: 1-714-476-9117
Facsimile: 1-714-476-9969

Sales Offices:
Washington, DC (Federal)
New York, NY (Financial)
Dallas, TX

LATIN AMERICA
Research Affiliates and Sales Offices:
Buenos Aires, Argentina
Sao Paulo, Brazil
Santiago, Chile
Mexico City, Mexico

EUROPE
European Headquarters
Dataquest Europe Limited
Holmers Farm Way
High Wycombe, Bucks HP12 4XH
United Kingdom
Phone: +44 1494 422 722
Facsimile: +44 1494 422 742

Dataquest Europe SA
Immeuble Défense Bergères
345, avenue Georges Clémenceau
TSA 40002
92882 - Nanterre CTC Cedex 9
France
Phone: +33 1 41 35 13 00
Facsimile: +33 1 41 35 13 13

Dataquest GmbH
Kronstadter Strasse 9
81677 München
Germany
Phone: +49 89 93 09 09 0
Facsimile: +49 89 93 03 27 7

Sales Offices:
Brussels, Belgium
Kfar Saba, Israel
Milan, Italy
Randburg, South Africa
Madrid, Spain

JAPAN
Japan Headquarters
Dataquest Japan K.K.
Shinkawa Sanko Building
6th Floor
1-3-17, Shinkawa
Chuo-ku, Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

ASIA/PACIFIC
Asia/Pacific Headquarters
7/F China Underwriters Centre
88 Gloucester Road
Wan Chai
Hong Kong
Phone: 852-2824-6168
Facsimile: 852-2824-6138

Dataquest Korea
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: 822-551-1331
Facsimile: 822-551-1330

Dataquest Taiwan
11F-2, No. 188, Section 5
Nan King East Road
Taipei
Taiwan, R.O.C.
Phone: 8862-756-0389
Facsimile: 8862-756-2663

Dataquest Singapore
105 Cecil Street
#06-01/02 The Octagon
Singapore 0106
Phone: 65-227-1213
Facsimile: 65-227-4607

Dataquest Thailand
12/F, Vanissa Building
19 Soi Chidlom
Ploenchit Road
Patumwan, Bangkok 10330
Thailand
Phone: 662-655-0577
Facsimile: 662-655-0576

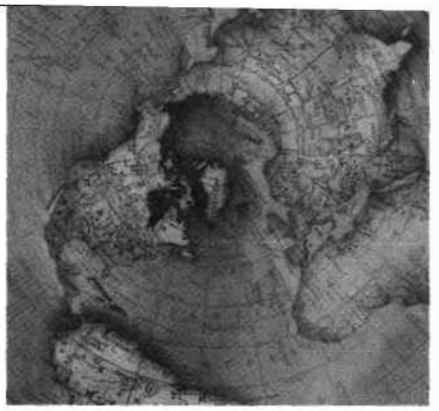
Research Affiliates and Sales Offices:
Melbourne, Australia
Beijing, China

Dataquest

a company of
The Dun & Bradstreet Corporation

MMRY-WW-MT-9501
Mr. Joe Grenier
Dataquest Incorporated
1-1100
.,
--INTERNAL DIST.--

Qty: 1



Dataquest

Worldwide Memory Market Share, 1992-1994

Market Statistics

Program: Memories Worldwide
Product Code: MMRY-WW-MS-9501
Publication Date: April 17, 1995
Filing: Market Analysis

Worldwide Memory Market Share, 1992-1994

Market Statistics

Program: Memories Worldwide
Product Code: MMRY-WW-MS-9501
Publication Date: April 17, 1995
Filing: Market Analysis

Table of Contents

List of Tables

Note: All tables show estimated data.

List of Tables (Continued)

Note: All tables show estimated data.

List of Tables (Continued)

Note: All tables show estimated data.

Worldwide Memory Market Share, 1992-1994

Introduction

This document contains detailed information on Dataquest's view of the MOS and bipolar memory IC markets. Included in this document is the following:

- 1992-1994 market share estimates

Analyses of the MOS and bipolar memory markets by company provide insight into high-technology markets and reinforce estimates of consumption, production, and company revenue.

Worldwide market share estimates combine data from many countries, each of which has different and fluctuating exchange rates. Estimates of non-U.S. market consumption or revenue are based upon the average exchange rate for the given year. Refer to the section entitled "Exchange Rates" for more information regarding these average rates. As a rule, our estimates are calculated in local currencies, and then converted to U.S. dollars.

More detailed data on this market may be requested through our client inquiry service. Dataquest's qualitative analysis of this data can be found in other Dataquest documents located within the binder of the same name.

Segmentation

This section defines the market segments that are specific to this document. For a complete description of all semiconductor market segments tracked by Dataquest, please refer to the *Semiconductor Market Definitions* document.

Dataquest segments the MOS memory market into the following categories: DRAM, SRAM, EPROM, mask ROM, EEPROM, flash memory, and other MOS memory. MOS memory is defined as a MOS IC in which binary data is stored and electronically retrieved. Dataquest does not subdivide the bipolar memory category. Bipolar memory is defined as a bipolar IC in which binary data is stored and electronically retrieved.

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

Definitions

This section lists the definitions that are used by Dataquest to present the data in this document. Complete definitions for all Dataquest semiconductor terms can be found in the *Semiconductor Market Definitions* document.

Product Definitions

DRAM: Includes dynamic RAM, multiport-DRAM (M-DRAM), and video-DRAM (V-DRAM). DRAMs have memory cells consisting of a single transistor and require regular externally cycled memory cell refreshes. This category also includes new architecture DRAMs (NADs) such as Rambus, cache, enhanced, and synchronous DRAMs. These are volatile memories and addressing is multiplexed.

SRAM: Includes static RAM, multiport-SRAM (M-SRAM), battery backed-up SRAM (BB-SRAM), and pseudo-SRAM (P-SRAM). SRAMs have memory cells consisting of a minimum of four transistors (P-SRAMs have memory cells consisting of a single transistor and are similar to DRAMs). SRAMs do not require externally cycled memory cell refreshes. These are volatile memories and addressing is not multiplexed (except in the case of P-SRAM).

EPROM: Includes erasable programmable read-only memory. This product classification includes ultraviolet EPROM (UV EPROM) and one-time programmable read-only memory (OTPROM). EPROMs have memory cells consisting of a single transistor and do not require any memory cell refreshes. These devices are nonvolatile memories.

Flash Memory: Includes nonvolatile products designed as flash EPROM/EEPROM that incorporate either 5V or 12V programming supplies and one-transistor (1T) or two-transistor (2T) memory cells with electrical programming and fast bulk/chip erase. Flash memory can only erase data by bulk/chip, not by byte.

Mask ROM: Includes mask-programmable read-only memory. Mask ROM is a form of memory that is programmed by the manufacturer to a user specification using a mask step. Mask ROM is programmed in hardware rather than software. These devices are nonvolatile memories.

EEPROM: Includes electronically erasable programmable read-only memory. Included are serial EEPROM (S-EEPROM), parallel EEPROM (P-EEPROM), and electronically alterable read-only memory (EAROM). EEPROMs have memory cells consisting of a minimum of two transistors and do not require memory cell refreshes. This product classification also includes nonvolatile RAM (NV-RAM), also known as shadow RAM. These latter semiconductor products are a combination of SRAM and EEPROM technologies in each memory cell. The EEPROM functions as a shadow backup for the SRAM when power is lost. These devices are nonvolatile memories.

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

Bipolar Memory: Includes ECL random-access memory (RAM), read-only memory (ROM), programmable ROM (PROM), last-in/first-out (LIFO) memory, and first-in/first-out (FIFO) memory. This category does not include products made with mixed bipolar CMOS (that is, BiCMOS) with TTL or ECL outputs, which are classified as MOS.

Regional Definitions

North America: Includes Canada, Mexico, and the United States.

Japan: Japan is the only single-country region.

Western Europe: Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and rest of western Europe (Andorra, Cyprus, Gibraltar, Liechtenstein, Monaco, San Marino, Vatican City, Iceland, Malta, and Turkey).

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

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

Rest of World: Includes Africa, Caribbean, Central America, Middle East, Oceania, and South America.

Line Item Definitions

Factory revenue is defined as the money value received by a semiconductor manufacturer for its products. Revenue from the sale of semiconductors sold either as finished goods, die, or wafers to another semiconductor vendor for resale is attributed to the semiconductor vendor that sells the product to a distributor or equipment manufacturer.

Market Share Methodology

Dataquest utilizes both primary and secondary sources to produce market statistics data. In the fourth quarter of each year, Dataquest surveys all major participants within each industry. Selected companies are resurveyed during the first quarter of the following year to verify final annual results. This primary research is supplemented with additional primary research and secondary research to verify market size, shipment totals, and pricing information. Sources of data utilized by Dataquest include the following:

- Information published by major industry participants
- Estimates made by knowledgeable and reliable industry spokespersons
- Government data or trade association data (such as WSTS, MITI, and U.S. DOC)
- Published product literature and price lists
- Interviews with knowledgeable manufacturers, distributors, and users
- Relevant economic data
- Information and data from online and CD-ROM data banks
- Articles in both the general and trade press
- Reports from financial analysts
- End-user surveys

Dataquest believes that the estimates presented in this document are the most accurate and meaningful statistics available.

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

Notes on Market Share

In the process of conducting data collection and preparing market statistics information, Dataquest will sometimes consolidate or revise a particular company, model, series, or industry's numbers. In this section, we explain any such changes contained within this document for your reference.

Notes to Market Share Tables

1. Analog Devices' revenue includes Precision Monolithics' revenue from 1991 forward.

2. Cirrus Logic revenue includes Acumos and Crystal Semiconductor revenue from 1992 forward.

3. Cypress Semiconductor acquired the logic division of Performance Semiconductor in 1993.

4. Dialog, Eurosil, Matra, Telefunken, and Siliconix are now known as TEMIC.

5. Fujitsu acquired Ross Semiconductor from Cypress Semiconductor in 1993.

6. IBM's merchant revenue were included in our Market Statistics beginning in 1993, which was the first complete year that IBM sold product on the merchant market.

7. IMP was formerly known as International Microelectronic Products.

8. Inmos' revenue is included in SGS-Thomson's revenue.

9. Linfinity was formerly known as Silicon General.

10. Macronix's revenue, beginning in 1991, was moved from the North American Companies area to the Asia/Pacific Companies section.

11. Mitsubishi's revenue included Powerex's European revenue beginning in 1993.

12. MOSel and Vitelic merged in 1992 to form MOSel/Vitelic Corporation. In 1993, MOSel/Vitelic was moved to the Asia/Pacific-Rest of World region.

13. Nittetsu Semiconductor was formerly known as NMB Semiconductor.

14. Philips' revenue includes Signetics' revenue.

15. SGS-Thomson's revenue includes TAG in 1993.

16. Quality Technologies acquired Philips' Optocoupler Division in 1992.

17. Raytheon revenue includes that of TRW's LSI Division from 1992 forward.

18. Thomson Semiconductors Specific (TCS) was formed through the merger of Thomson Composants Microndes (TCM) and Thomson Composants Militaires et Spatiaux (TMS).

19. Unitrode's revenue includes that of Microsemi's Semiconductor Products Division from 1992 forward.

20. Vertex's (formerly known as Integrated CMOS Systems) revenue is included in Toshiba's revenue from 1991 forward.

21. Xilinx acquired Plus Logic in 1992.

22. The following companies were added to worldwide market share tables starting in 1994 and may result in higher 1994 market growth rates in certain product areas:

- Integrated Silicon Solution Inc.
- Ramtron
- Quick Logic
- International CMOS Technology

23. In 1994, three-fourths of Intel's PLD Division's revenue is included in Intel's revenue, and the last quarter's revenue is included in Altera's revenue to accurately reflect the sale of the PLD Division.

24. Telcom was formerly known as Teledyne Semiconductor.

25. National Semiconductor, SGS Thomson, and Siemens' revenue for 1993 was re-evaluated and restated.

26. Tektronix's revenue is now included with Maxim's revenue.

Exchange Rates

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar amounts. Table 1 outlines these rates for 1992 through 1994.

Table 1
Exchange Rates

	1992	1993	1994
Japan (Yen/U.S.$)	126.45	111.20	101.81
France (Franc/U.S.$)	5.27	5.67	5.54
Germany (Deutsche Mark/U.S.$)	1.56	1.66	1.62
United Kingdom (U.S.$/Pound Sterling)	1.77	1.50	1.53

Source: Dataquest (April 1995)

Table 2
Each Company's Factory Revenue from Shipments of MOS Memory to the World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	15,308	23,306	33,481	100.0	100.0	100.0
North American Companies	3,593	6,253	8,406	23.5	26.8	25.1
Advanced Micro Devices	282	427	442	1.8	1.8	1.3
Alliance Semiconductor	13	41	90	0.1	0.2	0.3
AT&T	33	10	3	0.2	0	0
Atmel	99	181	331	0.6	0.8	1.0
Catalyst	40	54	49	0.3	0.2	0.1
Cypress Semiconductor	187	235	285	1.2	1.0	0.9
Dallas Semiconductor	24	38	30	0.2	0.2	0.1
Electronic Designs	9	23	26	0.1	0.1	0.1
Gould AMI	15	23	44	0.1	0.1	0.1
Harris	20	19	12	0.1	0.1	0
IBM	NA	1,133	1,520	0	4.9	4.5
Integrated Device Technology	138	189	252	0.9	0.8	0.8
Integrated Silicon Solution Inc.	NA	NA	60	0	0	0.2
Intel	324	468	458	2.1	2.0	1.4
IMP	5	2	1	0	0	0
ITT	8	11	10	0.1	0	0
Logic Devices	4	4	2	0	0	0
Microchip Technology	47	64	82	0.3	0.3	0.2
Micron Technology	557	925	1,492	3.6	4.0	4.5
Motorola	610	762	948	4.0	3.3	2.8
NCR	2	2	0	0	0	0
National Semiconductor	128	172	155	0.8	0.7	0.5
Paradigm	7	34	36	0	0.1	0.1
Performance Semiconductor	16	8	5	0.1	0	0
Quality Semiconductor	9	12	7	0.1	0.1	0
Ramtron	NA	NA	15	0	0	0
SEEQ Technology	21	16	5	0.1	0.1	0
Texas Instruments	874	1,275	1,931	5.7	5.5	5.8
WaferScale Integration	22	20	15	0.1	0.1	0
Xicor	93	105	100	0.6	0.5	0.3
Other North American Companies	6	0	0	0	0	0

(Continued)

Table 2 (Continued)
Each Company's Factory Revenue from Shipments of MOS Memory to the World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Japanese Companies	8,008	11,180	15,519	52.3	48.0	46.4
Fujitsu	927	1,135	1,692	6.1	4.9	5.1
Hitachi	1,519	2,369	3,232	9.9	10.2	9.7
Matsushita	217	305	396	1.4	1.3	1.2
Mitsubishi	878	1,206	1,652	5.7	5.2	4.9
NEC	1,422	2,173	3,096	9.3	9.3	9.2
Nittetsu Semiconductor	120	148	160	0.8	0.6	0.5
OKI	424	486	697	2.8	2.1	2.1
Ricoh	8	21	19	0.1	0.1	0.1
Rohm	27	39	56	0.2	0.2	0.2
Sanyo	95	155	183	0.6	0.7	0.5
Seiko Epson	36	38	42	0.2	0.2	0.1
Sharp	519	697	867	3.4	3.0	2.6
Sony	197	287	387	1.3	1.2	1.2
Toshiba	1,618	2,101	3,018	10.6	9.0	9.0
Yamaha	1	1	1	0	0	0
Other Japanese Companies	0	19	21	0	0.1	0.1
European Companies	724	1,089	1,484	4.7	4.7	4.4
GEC Plessey	5	3	0	0	0	0
Philips	40	32	14	0.3	0.1	0
SGS-Thomson	304	467	589	2.0	2.0	1.8
Siemens	336	556	858	2.2	2.4	2.6
TEMIC	NA	31	23	0	0.1	0.1
Other European Companies	39	0	0	0.3	0	0
Asia/Pacific Companies	2,983	4,784	8,072	19.5	20.5	24.1
Daewoo	1	1	0	0	0	0
Goldstar	557	804	1,525	3.6	3.4	4.6
Hualon Microelectronics Corporation	29	36	46	0.2	0.2	0.1
Hyundai	556	851	1,515	3.6	3.7	4.5
Macronix	57	129	200	0.4	0.6	0.6
MOSel/Vitelic	136	223	259	0.9	1.0	0.8
Samsung	1,516	2,512	4,194	9.9	10.8	12.5
Silicon Integrated Systems	21	5	0	0.1	0	0
United Microelectronics	64	146	191	0.4	0.6	0.6
Winbond Electronics	46	77	142	0.3	0.3	0.4

NA = Not available
Source: Dataquest (April 1995)

Table 3
Each Company's Factory Revenue from Shipments of DRAMs to the World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	8,765	14,581	23,266	100.0	100.0	100.0
North American Companies	1,518	3,436	5,144	17.3	23.6	22.1
IBM	NA	1,133	1,520	0	7.8	6.5
Intel	23	0	0	0.3	0	0
Micron Technology	445	793	1,360	5.1	5.4	5.8
Motorola	383	514	610	4.4	3.5	2.6
Ramtron	NA	NA	15	0	0	0.1
Texas Instruments	667	996	1,639	7.6	6.8	7.0
Japanese Companies	4,714	7,035	10,895	53.8	48.2	46.8
Fujitsu	547	670	1,173	6.2	4.6	5.0
Hitachi	824	1,567	2,434	9.4	10.7	10.5
Matsushita	129	190	328	1.5	1.3	1.4
Mitsubishi	628	930	1,372	7.2	6.4	5.9
NEC	894	1,520	2,407	10.2	10.4	10.3
Nittetsu Semiconductor	120	148	160	1.4	1.0	0.7
OKI	366	403	605	4.2	2.8	2.6
Sanyo	31	69	86	0.4	0.5	0.4
Sharp	50	56	71	0.6	0.4	0.3
Sony	2	3	4	0	0	0
Toshiba	1,123	1,479	2,255	12.8	10.1	9.7
European Companies	296	493	786	3.4	3.4	3.4
Siemens	296	493	786	3.4	3.4	3.4
Asia/Pacific Companies	2,237	3,617	6,441	25.5	24.8	27.7
Goldstar	513	689	1,391	5.9	4.7	6.0
Hyundai	448	706	1,360	5.1	4.8	5.8
MOSel/Vitelic	84	176	231	1.0	1.2	1.0
Samsung	1,192	2,046	3,459	13.6	14.0	14.9

NA = Not available
Source: Dataquest (April 1995)

Table 4
Each Company's Factory Revenue from Shipments of SRAMs to the World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	3,038	3,908	4,514	100.0	100.0	100.0
North American Companies	690	875	1,074	22.7	22.4	23.8
Advanced Micro Devices	14	16	4	0.5	0.4	0.1
Alliance Semiconductor	13	41	90	0.4	1.0	2.0
AT&T	33	6	0	1.1	0.2	0
Atmel	2	2	0	0.1	0.1	0
Cypress Semiconductor	119	165	194	3.9	4.2	4.3
Dallas Semiconductor	24	38	30	0.8	1.0	0.7
Electronic Designs	9	23	26	0.3	0.6	0.6
Harris	16	18	8	0.5	0.5	0.2
Integrated Device Technology	61	104	139	2.0	2.7	3.1
Integrated Silicon Solution Inc.	NA	NA	48	0	0	1.1
Intel	12	3	0	0.4	0.1	0
Logic Devices	4	4	2	0.1	0.1	0
Micron Technology	111	130	132	3.7	3.3	2.9
Motorola	222	239	329	7.3	6.1	7.3
NCR	2	2	0	0.1	0.1	0
National Semiconductor	13	10	10	0.4	0.3	0.2
Paradigm	7	34	36	0.2	0.9	0.8
Performance Semiconductor	16	8	5	0.5	0.2	0.1
Quality Semiconductor	8	10	4	0.3	0.3	0.1
Ramtron	NA	NA	0	0	0	0
Texas Instruments	4	22	17	0.1	0.6	0.4
Japanese Companies	1,859	2,319	2,505	61.2	59.3	55.5
Fujitsu	245	307	322	8.1	7.9	7.1
Hitachi	494	567	557	16.3	14.5	12.3
Matsushita	21	26	26	0.7	0.7	0.6
Mitsubishi	162	186	212	5.3	4.8	4.7
NEC	264	333	353	8.7	8.5	7.8
OKI	17	19	19	0.6	0.5	0.4
Ricoh	0	10	9	0	0.3	0.2
Rohm	10	15	22	0.3	0.4	0.5
Sanyo	48	73	79	1.6	1.9	1.8
Seiko Epson	35	37	41	1.2	0.9	0.9
Sharp	123	139	140	4.0	3.6	3.1
Sony	179	261	349	5.9	6.7	7.7
Toshiba	261	346	376	8.6	8.9	8.3

(Continued)

Table 4 (Continued)
Each Company's Factory Revenue from Shipments of SRAMs to the World
(Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
European Companies	55	34	24	1.8	0.9	0.5
SGS-Thomson	18	7	4	0.6	0.2	0.1
TEMIC	NA	27	20	0	0.7	0.4
Other European Companies	37	0	0	1.2	0	0
Asia/Pacific Companies	434	680	911	14.3	17.4	20.2
Goldstar	37	79	69	1.2	2.0	1.5
Hualon Microelectronics Corporation	6	6	7	0.2	0.2	0.2
Hyundai	99	116	129	3.3	3.0	2.9
MOSel/Vitelic	52	47	28	1.7	1.2	0.6
Samsung	170	243	419	5.6	6.2	9.3
Silicon Integrated Systems	3	0	0	0.1	0	0
United Microelectronics	32	114	118	1.1	2.9	2.6
Winbond Electronics	35	75	141	1.2	1.9	3.1

NA = Not available
Source: Dataquest (April 1995)

Table 5
Each Company's Factory Revenue from Shipments of Nonvolatile Memory to the World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	3,316	4,551	5,383	100.0	100.0	100.0
North American Companies	1,253	1,783	1,966	37.8	39.2	36.5
Advanced Micro Devices	253	401	425	7.6	8.8	7.9
Atmel	97	179	331	2.9	3.9	6.1
Catalyst	40	54	49	1.2	1.2	0.9
Cypress Semiconductor	36	37	48	1.1	0.8	0.9
Gould AMI	15	23	44	0.5	0.5	0.8
Harris	4	1	4	0.1	0	0.1
Integrated Silicon Solution Inc.	NA	NA	12	0	0	0.2
Intel	289	465	458	8.7	10.2	8.5
IMP	5	2	1	0.2	0	0
ITT	8	11	10	0.2	0.2	0.2
Microchip Technology	47	64	82	1.4	1.4	1.5
Motorola	5	9	9	0.2	0.2	0.2
National Semiconductor	115	162	145	3.5	3.6	2.7
SEEQ Technology	21	16	5	0.6	0.4	0.1
Texas Instruments	203	234	240	6.1	5.1	4.5
WaferScale Integration	22	20	15	0.7	0.4	0.3
Xicor	93	105	88	2.8	2.3	1.6
Japanese Companies	1,432	1,799	2,089	43.2	39.5	38.8
Fujitsu	135	158	197	4.1	3.5	3.7
Hitachi	201	235	241	6.1	5.2	4.5
Matsushita	67	89	42	2.0	2.0	0.8
Mitsubishi	88	90	68	2.7	2.0	1.3
NEC	264	320	336	8.0	7.0	6.2
OKI	41	64	73	1.2	1.4	1.4
Ricoh	8	11	10	0.2	0.2	0.2
Rohm	17	24	34	0.5	0.5	0.6
Sanyo	14	6	10	0.4	0.1	0.2
Seiko Epson	1	1	1	0	0	0
Sharp	345	501	655	10.4	11.0	12.2
Sony	16	23	34	0.5	0.5	0.6
Toshiba	234	276	387	7.1	6.1	7.2
Yamaha	1	1	1	0	0	0

(Continued)

Table 5 (Continued)
Each Company's Factory Revenue from Shipments of Nonvolatile Memory to the World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
European Companies	327	511	635	9.9	11.2	11.8
Philips	40	32	14	1.2	0.7	0.3
SGS-Thomson	245	412	546	7.4	9.1	10.1
Siemens	40	63	72	1.2	1.4	1.3
TEMIC	NA	4	3	0	0.1	0.1
Other European Companies	2	0	0	0.1	0	0
Asia/Pacific Companies	304	458	693	9.2	10.1	12.9
Daewoo	1	1	0	0	0	0
Goldstar	7	36	65	0.2	0.8	1.2
Hualon Microelectronics Corporation	23	30	39	0.7	0.7	0.7
Hyundai	1	0	0	0	0	0
Macronix	57	129	200	1.7	2.8	3.7
MOSel/Vitelic	0	0	0	0	0	0
Samsung	154	223	315	4.6	4.9	5.9
Silicon Integrated Systems	18	5	0	0.5	0.1	0
United Microelectronics	32	32	73	1.0	0.7	1.4
Winbond Electronics	11	2	1	0.3	0	0

NA = Not available
Source: Dataquest (April 1995)

Table 6
Each Company's Factory Revenue from Shipments of MOS EPROMs to the World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	1,253	1,460	1,545	100.0	100.0	100.0
North American Companies	739	742	765	59.0	50.8	49.5
Advanced Micro Devices	207	169	215	16.5	11.6	13.9
Atmel	36	78	128	2.9	5.3	8.3
Catalyst	3	2	0	0.2	0.1	0
Cypress Semiconductor	36	37	48	2.9	2.5	3.1
Integrated Silicon Solution Inc.	NA	NA	12	0	0	0.8
Intel	122	70	8	9.7	4.8	0.5
Microchip Technology	29	30	27	2.3	2.1	1.7
National Semiconductor	87	112	103	6.9	7.7	6.7
Texas Instruments	197	224	209	15.7	15.3	13.5
WaferScale Integration	22	20	15	1.8	1.4	1.0
Japanese Companies	287	328	308	22.9	22.5	19.9
Fujitsu	71	82	79	5.7	5.6	5.1
Hitachi	59	67	69	4.7	4.6	4.5
Mitsubishi	56	60	41	4.5	4.1	2.7
NEC	35	40	43	2.8	2.7	2.8
OKI	5	8	9	0.4	0.5	0.6
Rohm	9	12	0	0.7	0.8	0
Sanyo	1	1	4	0.1	0.1	0.3
Sharp	3	3	3	0.2	0.2	0.2
Toshiba	48	55	60	3.8	3.8	3.9
European Companies	220	326	395	17.6	22.3	25.6
Philips	40	20	0	3.2	1.4	0
SGS-Thomson	180	306	395	14.4	21.0	25.6
Asia/Pacific Companies	7	64	77	0.6	4.4	5.0
Macronix	7	64	77	0.6	4.4	5.0

NA = Not available
Source: Dataquest (April 1995)

Table 7
Each Company's Factory Revenue from Shipments of Flash Memory to the World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	239	746	884	100.0	100.0	100.0
North American Companies	230	698	742	96.2	93.6	83.9
Advanced Micro Devices	46	232	210	19.2	31.1	23.8
Atmel	11	38	65	4.6	5.1	7.4
Catalyst	3	27	10	1.3	3.6	1.1
Intel	167	395	450	69.9	52.9	50.9
SEEQ Technology	1	1	0	0.4	0.1	0
Texas Instruments	2	5	7	0.8	0.7	0.8
Japanese Companies	7	27	100	2.9	3.6	11.3
Fujitsu	0	0	14	0	0	1.6
Hitachi	1	2	3	0.4	0.3	0.3
Mitsubishi	3	10	10	1.3	1.3	1.1
NEC	1	2	6	0.4	0.3	0.7
OKI	1	3	4	0.4	0.4	0.5
Rohm	0	0	2	0	0	0.2
Sharp	0	8	11	0	1.1	1.2
Toshiba	1	2	50	0.4	0.3	5.7
European Companies	2	21	36	0.8	2.8	4.1
SGS-Thomson	2	21	36	0.8	2.8	4.1
Asia/Pacific Companies	0	0	6	0	0	0.7
Macronix	0	0	3	0	0	0.3
Samsung	0	0	3	0	0	0.3

Source: Dataquest (April 1995)

Table 8
Each Company's Factory Revenue from Shipments of MOS ROMs to the World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	1,398	1,784	2,216	100.0	100.0	100.0
North American Companies	41	42	60	2.9	2.4	2.7
Gould AMI	15	23	44	1.1	1.3	2.0
Harris	4	1	4	0.3	0.1	0.2
IMP	5	2	1	0.4	0.1	0
ITT	8	11	10	0.6	0.6	0.5
Motorola	5	0	0	0.4	0	0
Texas Instruments	4	5	1	0.3	0.3	0
Japanese Companies	1,077	1,365	1,566	77.0	76.5	70.7
Fujitsu	54	64	92	3.9	3.6	4.2
Hitachi	135	160	162	9.7	9.0	7.3
Matsushita	67	89	42	4.8	5.0	1.9
Mitsubishi	26	13	10	1.9	0.7	0.5
NEC	197	241	248	14.1	13.5	11.2
OKI	25	39	45	1.8	2.2	2.0
Ricoh	8	11	10	0.6	0.6	0.5
Rohm	8	10	0	0.6	0.6	0
Sanyo	12	4	3	0.9	0.2	0.1
Seiko Epson	1	1	1	0.1	0.1	0
Sharp	342	490	641	24.5	27.5	28.9
Sony	16	23	34	1.1	1.3	1.5
Toshiba	185	219	277	13.2	12.3	12.5
Yamaha	1	1	1	0.1	0.1	0
Asia/Pacific Companies	280	377	590	20.0	21.1	26.6
Daewoo	1	1	0	0.1	0.1	0
Goldstar	7	36	65	0.5	2.0	2.9
Hualon Microelectronics Corporation	23	30	39	1.6	1.7	1.8
Macronix	50	65	120	3.6	3.6	5.4
Samsung	138	206	292	9.9	11.5	13.2
Silicon Integrated Systems	18	5	0	1.3	0.3	0
United Microelectronics	32	32	73	2.3	1.8	3.3
Winbond Electronics	11	2	1	0.8	0.1	0

Source: Dataquest (April 1995)

Table 9
Each Company's Factory Revenue from Shipments of MOS EEPROMs to the World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	426	561	738	100.0	100.0	100.0
North American Companies	243	301	399	57.0	53.7	54.1
Atmel	50	63	138	11.7	11.2	18.7
Catalyst	34	25	39	8.0	4.5	5.3
Microchip Technology	18	34	55	4.2	6.1	7.5
Motorola	0	9	9	0	1.6	1.2
National Semiconductor	28	50	42	6.6	8.9	5.7
SEEQ Technology	20	15	5	4.7	2.7	0.7
Texas Instruments	0	0	23	0	0	3.1
Xicor	93	105	88	21.8	18.7	11.9
Japanese Companies	61	79	115	14.3	14.1	15.6
Fujitsu	10	12	12	2.3	2.1	1.6
Hitachi	6	6	7	1.4	1.1	0.9
Mitsubishi	3	7	7	0.7	1.2	0.9
NEC	31	37	39	7.3	6.6	5.3
OKI	10	14	15	2.3	2.5	2.0
Rohm	0	2	32	0	0.4	4.3
Sanyo	1	1	3	0.2	0.2	0.4
European Companies	105	164	204	24.6	29.2	27.6
Philips	0	12	14	0	2.1	1.9
SGS-Thomson	63	85	115	14.8	15.2	15.6
Siemens	40	63	72	9.4	11.2	9.8
TEMIC	NA	4	3	0	0.7	0.4
Other European Companies	2	0	0	0.5	0	0
Asia/Pacific Companies	17	17	20	4.0	3.0	2.7
Hyundai	1	0	0	0.2	0	0
Samsung	16	17	20	3.8	3.0	2.7

NA = Not available
Source: Dataquest (April 1995)

Table 10
Each Company's Factory Revenue from Shipments of Other MOS Memory to the World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	189	266	318	100.0	100.0	100.0
North American Companies	132	159	222	69.8	59.8	69.8
Advanced Micro Devices	15	10	13	7.9	3.8	4.1
AT&T	0	4	3	0	1.5	0.9
Cypress Semiconductor	32	33	43	16.9	12.4	13.5
Integrated Device Technology	77	85	113	40.7	32.0	35.5
Micron Technology	1	2	0	0.5	0.8	0
Quality Semiconductor	1	2	3	0.5	0.8	0.9
Texas Instruments	0	23	35	0	8.6	11.0
Xicor	0	0	12	0	0	3.8
Other North American Companies	6	0	0	3.2	0	0
Japanese Companies	3	27	30	1.6	10.2	9.4
Sanyo	2	7	8	1.1	2.6	2.5
Sharp	1	1	1	0.5	0.4	0.3
Other Japanese Companies	0	19	21	0	7.1	6.6
European Companies	46	51	39	24.3	19.2	12.3
GEC Plessey	5	3	0	2.6	1.1	0
SGS-Thomson	41	48	39	21.7	18.0	12.3
Asia/Pacific Companies	8	29	27	4.2	10.9	8.5
Hyundai	8	29	26	4.2	10.9	8.2
Samsung	0	0	1	0	0	0.3

Source: Dataquest (April 1995)

Table 11
Each Company's Factory Revenue from Shipments of Bipolar Memory to the World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	318	244	198	100.0	100.0	100.0
North American Companies	88	59	43	27.7	24.2	21.7
Advanced Micro Devices	46	39	28	14.5	16.0	14.1
Harris	13	4	0	4.1	1.6	0
Motorola	3	2	1	0.9	0.8	0.5
National Semiconductor	8	5	4	2.5	2.0	2.0
Raytheon	10	6	5	3.1	2.5	2.5
Texas Instruments	3	3	5	0.9	1.2	2.5
Other North American Companies	5	0	0	1.6	0	0
Japanese Companies	203	182	141	63.8	74.6	71.2
Fujitsu	90	81	32	28.3	33.2	16.2
Hitachi	94	85	93	29.6	34.8	47.0
NEC	19	16	16	6.0	6.6	8.1
European Companies	27	3	14	8.5	1.2	7.1
Philips	27	3	14	8.5	1.2	7.1

Source: Dataquest (April 1995)

Table 12
Top 20 Companies' Factory Revenue from Shipment of MOS Memory to the World (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Samsung	2,512	4,194	67	12.5
2	2	Hitachi	2,369	3,232	36	9.7
3	3	NEC	2,173	3,096	42	9.2
4	4	Toshiba	2,101	3,018	44	9.0
5	5	Texas Instruments	1,275	1,931	51	5.8
6	7	Fujitsu	1,135	1,692	49	5.1
7	6	Mitsubishi	1,206	1,652	37	4.9
8	11	Goldstar	804	1,525	90	4.6
9	8	IBM	1,133	1,520	34	4.5
10	10	Hyundai	851	1,515	78	4.5
11	9	Micron Technology	925	1,492	61	4.5
12	12	Motorola	762	948	24	2.8
13	13	Sharp	697	867	24	2.6
14	14	Siemens	556	858	54	2.6
15	15	OKI	486	697	43	2.1
16	17	SGS-Thomson	467	589	26	1.8
17	16	Intel	468	458	-2	1.4
18	18	Advanced Micro Devices	427	442	4	1.3
19	19	Matsushita	305	396	30	1.2
20	20	Sony	287	387	35	1.2
		All Others	2,367	2,972	26	8.9
		North American Companies	6,253	8,406	34	25.1
		Japanese Companies	11,180	15,519	39	46.4
		European Companies	1,089	1,484	36	4.4
		Asia/Pacific Companies	4,784	8,072	69	24.1
		Total Market	23,306	33,481	44	100.0

Source: Dataquest (April 1995)

Table 13
Top 10 Companies' Factory Revenue from Shipments of MOS DRAMs to the World (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Samsung	2,046	3,459	69	14.9
2	2	Hitachi	1,567	2,434	55	10.5
3	3	NEC	1,520	2,407	58	10.3
4	4	Toshiba	1,479	2,255	52	9.7
5	6	Texas Instruments	996	1,639	65	7.0
6	5	IBM	1,133	1,520	34	6.5
7	10	Goldstar	689	1,391	102	6.0
8	7	Mitsubishi	930	1,372	48	5.9
9	8	Micron Technology	793	1,360	72	5.8
10	9	Hyundai	706	1,360	93	5.8
		All Others	2,722	4,069	49	17.5
		North American Companies	3,436	5,144	50	22.1
		Japanese Companies	7,035	10,895	55	46.8
		European Companies	493	786	59	3.4
		Asia/Pacific Companies	3,617	6,441	78	27.7
		Total Market	14,581	23,266	60	100.0

Source: Dataquest (April 1995)

Table 14
Top 10 Companies' Factory Revenue from Shipments of SRAMs to the World (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Hitachi	567	557	-2	12.3
2	6	Samsung	243	419	72	9.3
3	2	Toshiba	346	376	9	8.3
4	3	NEC	333	353	6	7.8
5	5	Sony	261	349	34	7.7
6	7	Motorola	239	329	38	7.3
7	4	Fujitsu	307	322	5	7.1
8	8	Mitsubishi	186	212	14	4.7
9	9	Cypress Semiconductor	165	194	18	4.3
10	16	Winbond	75	141	88	3.1
		All Others	1,186	1,262	6	28.0
		North American Companies	875	1,074	23	23.8
		Japanese Companies	2,319	2,505	8	55.5
		European Companies	34	24	-29	0.5
		Asia/Pacific Companies	680	911	34	20.2
		Total Market	3,908	4,514	16	100.0

Source: Dataquest (April 1995)

Table 15
Top 10 Companies' Factory Revenue from Shipments of MOS Nonvolatile Memory to the World (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Sharp	501	655	31	12.2
2	3	SGS-Thomson	412	546	33	10.1
3	2	Intel	465	458	-2	8.5
4	4	Advanced Micro Devices	401	425	6	7.9
5	6	Toshiba	276	387	40	7.2
6	5	NEC	320	336	5	6.2
7	10	Atmel	179	331	85	6.1
8	9	Samsung	223	315	41	5.9
9	7	Hitachi	235	241	3	4.5
10	8	Texas Instruments	234	240	3	4.5
		All Others	1,305	1,449	11	26.9
		North American Companies	1,783	1,966	10	36.5
		Japanese Companies	1,799	2,089	16	38.8
		European Companies	511	635	24	11.8
		Asia/Pacific Companies	458	693	51	12.9
		Total Market	4,551	5,383	18	100.0

Source: Dataquest (April 1995)

Table 16
Top 10 Companies' Factory Revenue from Shipments of EPROMs to the World (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	SGS-Thomson	306	395	29	25.6
2	3	Advanced Micro Devices	169	215	27	13.9
3	2	Texas Instruments	224	209	-7	13.5
4	6	Atmel	78	128	64	8.3
5	4	National Semiconductor	112	103	-8	6.7
6	5	Fujitsu	82	79	-4	5.1
7	9	Macronix	64	77	20	5.0
8	8	Hitachi	67	69	3	4.5
9	11	Toshiba	55	60	9	3.9
10	13	Cypress Semiconductor	37	48	30	3.1
		All Others	266	162	-39	10.5
		North American Companies	742	765	3	49.5
		Japanese Companies	328	308	-6	19.9
		European Companies	326	395	21	25.6
		Asia/Pacific Companies	64	77	20	5.0
		Total Market	1,460	1,545	6	100.0

Source: Dataquest (April 1995)

Table 17
Top 10 Companies' Factory Revenue from Shipments of Flash Memory to the World (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Intel	395	450	14	50.9
2	2	Advanced Micro Devices	232	210	-9	23.8
3	3	Atmel	38	65	71	7.4
4	10	Toshiba	2	50	2400	5.7
5	5	SGS-Thomson	21	36	71	4.1
6	NA	Fujitsu	0	14	NM	1.6
7	7	Sharp	8	11	38	1.2
8	4	Catalyst	27	10	-63	1.1
9	6	Mitsubishi	10	10	0	1.1
10	8	Texas Instruments	5	7	40	0.8
		All Others	8	21	163	2.4
		North American Companies	698	742	6	83.9
		Japanese Companies	27	100	270	11.3
		European Companies	21	36	71	4.1
		Asia/Pacific Companies	0	6	NM	0.7
		Total Market	746	884	18	100.0

NA = Not available
NM = Not meaningful
Source: Dataquest (April 1995)

Table 18
Top 10 Companies' Factory Revenue from Shipments of MOS ROMs to the World (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Sharp	490	641	31	28.9
2	4	Samsung	206	292	42	13.2
3	3	Toshiba	219	277	26	12.5
4	2	NEC	241	248	3	11.2
5	5	Hitachi	160	162	1	7.3
6	7	Macronix	65	120	85	5.4
7	8	Fujitsu	64	92	44	4.2
8	11	United Microelectronics	32	73	128	3.3
9	10	Goldstar	36	65	81	2.9
10	9	OKI	39	45	15	2.0
		All Others	232	201	-13	9.1
		North American Companies	42	60	43	2.7
		Japanese Companies	1,365	1,566	15	70.7
		European Companies	0	0	NM	0
		Asia/Pacific Companies	377	590	56	26.6
		Total Market	1,784	2,216	24	100.0

NM = Not meaningful
Source: Dataquest (April 1995)

Table 19
Top 10 Companies' Factory Revenue from Shipments of EEPROMs to the World (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	3	Atmel	63	138	119	18.7
2	2	SGS-Thomson	85	115	35	15.6
3	1	Xicor	105	88	-16	11.9
4	4	Siemens	63	72	14	9.8
5	7	Microchip Technology	34	55	62	7.5
6	5	National Semiconductor	50	42	-16	5.7
7	6	NEC	37	39	5	5.3
8	8	Catalyst	25	39	56	5.3
9	18	Rohm	2	32	1,500	4.3
10	NA	Texas Instruments	0	23	NM	3.1
		All Others	97	95	-2	12.9
		North American Companies	301	399	33	54.1
		Japanese Companies	79	115	46	15.6
		European Companies	164	204	24	27.6
		Asia/Pacific Companies	17	20	18	2.7
		Total Market	561	738	32	100.0

NA = Not available
NM = Not meaningful
Source: Dataquest (April 1995)

Table 20
Top 10 Companies' Factory Revenue from Shipments of Other MOS Memory to the World (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Integrated Device Technology	85	113	33	35.5
2	3	Cypress Semiconductor	33	43	30	13.5
3	2	SGS-Thomson	48	39	-19	12.3
4	5	Texas Instruments	23	35	52	11.0
5	4	Hyundai	29	26	-10	8.2
6	6	Advanced Micro Devices	10	13	30	4.1
7	NA	Xicor	0	12	NM	3.8
8	7	Sanyo	7	8	14	2.5
9	8	AT&T	4	3	-25	0.9
10	10	Quality Semiconductor	2	3	50	0.9
		All Others	25	23	-8	7.6
		North American Companies	159	222	40	69.8
		Japanese Companies	27	30	11	9.4
		European Companies	51	39	-24	12.3
		Asia/Pacific Companies	29	27	-7	8.5
		Total Market	266	318	20	100.0

NA = Not available
NM = Not meaningful
Source: Dataquest (April 1995)

Table 21
Top 10 Companies' Factory Revenue from Shipments of Bipolar Memory to the World (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Hitachi	85	93	9	47.0
2	2	Fujitsu	81	32	-60	16.2
3	3	Advanced Micro Devices	39	28	-28	14.1
4	4	NEC	16	16	0	8.1
5	8	Philips	3	14	367	7.1
6	5	Raytheon	6	5	-17	2.5
7	9	Texas Instruments	3	5	67	2.5
8	6	National Semiconductor	5	4	-20	2.0
9	10	Motorola	2	1	-50	0.5
10	7	Harris	4	0	-100	0
		All Others	0	0	NM	0
		North American Companies	59	43	-27	21.7
		Japanese Companies	182	141	-23	71.2
		European Companies	3	14	367	7.1
		Asia/Pacific Companies	0	0	NM	0
		Total Market	244	198	-19	100.0

NM = Not meaningful
Source: Dataquest (April 1995)

Table 22
Each Company's Factory Revenue from Shipments of MOS Memory to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	5,707	8,785	12,458	100.0	100.0	100.0
North American Companies	1,889	3,075	4,176	33.1	35.0	33.5
Advanced Micro Devices	133	225	224	2.3	2.6	1.8
Alliance Semiconductor	13	14	50	0.2	0.2	0.4
AT&T	27	5	3	0.5	0.1	0
Atmel	51	100	166	0.9	1.1	1.3
Catalyst	16	27	19	0.3	0.3	0.2
Cypress Semiconductor	143	171	199	2.5	1.9	1.6
Dallas Semiconductor	16	29	12	0.3	0.3	0.1
Electronic Designs	8	22	20	0.1	0.3	0.2
Gould AMI	11	19	23	0.2	0.2	0.2
Harris	15	17	8	0.3	0.2	0.1
IBM	NA	420	708	0	4.8	5.7
Integrated Device Technology	93	129	164	1.6	1.5	1.3
Integrated Silicon Solution Inc.	NA	NA	30	0	0	0.2
Intel	150	282	288	2.6	3.2	2.3
IMP	5	2	1	0.1	0	0
ITT	4	7	0	0.1	0.1	0
Logic Devices	3	3	2	0.1	0	0
Microchip Technology	17	24	31	0.3	0.3	0.2
Micron Technology	398	635	1,050	7.0	7.2	8.4
Motorola	310	359	483	5.4	4.1	3.9
NCR	2	2	0	0	0	0
National Semiconductor	48	68	61	0.8	0.8	0.5
Paradigm	6	31	32	0.1	0.4	0.3
Performance Semiconductor	12	6	3	0.2	0.1	0
Quality Semiconductor	6	8	5	0.1	0.1	0
Ramtron	NA	NA	3	0	0	0
SEEQ Technology	16	13	5	0.3	0.1	0
Texas Instruments	320	389	532	5.6	4.4	4.3
WaferScale Integration	14	14	6	0.2	0.2	0
Xicor	46	54	48	0.8	0.6	0.4
Other North American Companies	6	0	0	0.1	0	0

(Continued)

Table 22 (Continued)
Each Company's Factory Revenue from Shipments of MOS Memory to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Japanese Companies	2,549	3,796	5,261	44.7	43.2	42.2
Fujitsu	165	218	376	2.9	2.5	3.0
Hitachi	515	944	1,298	9.0	10.7	10.4
Matsushita	50	66	96	0.9	0.8	0.8
Mitsubishi	378	546	637	6.6	6.2	5.1
NEC	450	769	1,140	7.9	8.8	9.2
Nittetsu Semiconductor	47	75	56	0.8	0.9	0.4
OKI	181	184	300	3.2	2.1	2.4
Rohm	2	6	16	0	0.1	0.1
Sanyo	4	2	1	0.1	0	0
Seiko Epson	11	12	12	0.2	0.1	0.1
Sharp	56	65	89	1.0	0.7	0.7
Sony	45	79	115	0.8	0.9	0.9
Toshiba	645	822	1,116	11.3	9.4	9.0
Other Japanese Companies	0	8	9	0	0.1	0.1
European Companies	185	244	274	3.2	2.8	2.2
GEC Plessey	3	2	0	0.1	0	0
Philips	17	14	1	0.3	0.2	0
SGS-Thomson	82	140	147	1.4	1.6	1.2
Siemens	80	85	123	1.4	1.0	1.0
TEMIC	NA	3	3	0	0	0
Other European Companies	3	0	0	0.1	0	0
Asia/Pacific Companies	1,084	1,670	2,747	19.0	19.0	22.1
Goldstar	222	135	519	3.9	1.5	4.2
Hyundai	207	336	518	3.6	3.8	4.2
Macronix	2	23	40	0	0.3	0.3
MOSel/Vitelic	68	122	146	1.2	1.4	1.2
Samsung	580	1,047	1,503	10.2	11.9	12.1
Winbond Electronics	5	7	21	0.1	0.1	0.2

NA = Not available
Source: Dataquest (April 1995)

Table 23
Each Company's Factory Revenue from Shipments of DRAMs to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	3,555	5,832	9,030	100.0	100.0	100.0
North American Companies	761	1,483	2,392	21.4	25.4	26.5
IBM	NA	420	708	0	7.2	7.8
Intel	13	0	0	0.4	0	0
Micron Technology	328	546	953	9.2	9.4	10.6
Motorola	175	217	273	4.9	3.7	3.0
Ramtron	NA	NA	3	0	0	0
Texas Instruments	245	300	455	6.9	5.1	5.0
Japanese Companies	1,770	2,831	4,144	49.8	48.5	45.9
Fujitsu	87	119	260	2.4	2.0	2.9
Hitachi	300	715	1,050	8.4	12.3	11.6
Matsushita	37	52	83	1.0	0.9	0.9
Mitsubishi	314	452	574	8.8	7.8	6.4
NEC	384	687	1,040	10.8	11.8	11.5
Nittetsu Semiconductor	47	75	56	1.3	1.3	0.6
OKI	171	168	281	4.8	2.9	3.1
Sanyo	2	2	1	0.1	0	0
Sharp	13	15	18	0.4	0.3	0.2
Toshiba	415	546	781	11.7	9.4	8.6
European Companies	80	85	123	2.3	1.5	1.4
Siemens	80	85	123	2.3	1.5	1.4
Asia/Pacific Companies	944	1,433	2,371	26.6	24.6	26.3
Goldstar	219	126	500	6.2	2.2	5.5
Hyundai	185	295	466	5.2	5.1	5.2
MOSel/Vitelic	39	100	127	1.1	1.7	1.4
Samsung	501	912	1,278	14.1	15.6	14.2

NA = Not available
Source: Dataquest (April 1995)

Table 24
Each Company's Factory Revenue from Shipments of SRAMs to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	1,107	1,349	1,630	100.0	100.0	100.0
North American Companies	469	574	697	42.4	42.6	42.8
Advanced Micro Devices	11	11	0	1.0	0.8	0
Alliance Semiconductor	13	14	50	1.2	1.0	3.1
AT&T	27	3	0	2.4	0.2	0
Atmel	2	2	0	0.2	0.1	0
Cypress Semiconductor	91	117	136	8.2	8.7	8.3
Dallas Semiconductor	16	29	12	1.4	2.1	0.7
Electronic Designs	8	22	20	0.7	1.6	1.2
Harris	12	16	6	1.1	1.2	0.4
Integrated Device Technology	39	70	89	3.5	5.2	5.5
Integrated Silicon Solution Inc.	NA	NA	23	0	0	1.4
Intel	5	2	0	0.5	0.1	0
Logic Devices	3	3	2	0.3	0.2	0.1
Micron Technology	69	87	97	6.2	6.4	6.0
Motorola	135	142	210	12.2	10.5	12.9
NCR	2	2	0	0.2	0.1	0
National Semiconductor	11	9	9	1.0	0.7	0.6
Paradigm	6	31	32	0.5	2.3	2.0
Performance Semiconductor	12	6	3	1.1	0.4	0.2
Quality Semiconductor	5	6	2	0.5	0.4	0.1
Texas Instruments	2	2	6	0.2	0.1	0.4
Japanese Companies	517	639	707	46.7	47.4	43.4
Fujitsu	59	77	83	5.3	5.7	5.1
Hitachi	155	165	181	14.0	12.2	11.1
Mitsubishi	50	69	48	4.5	5.1	2.9
NEC	53	65	81	4.8	4.8	5.0
OKI	3	3	3	0.3	0.2	0.2
Rohm	0	2	4	0	0.1	0.2
Sanyo	2	0	0	0.2	0	0
Seiko Epson	11	12	12	1.0	0.9	0.7
Sharp	20	23	23	1.8	1.7	1.4
Sony	45	79	115	4.1	5.9	7.1
Toshiba	119	144	157	10.7	10.7	9.6

(Continued)

Table 24 (Continued)
Each Company's Factory Revenue from Shipments of SRAMs to North America
(Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
European Companies	9	6	6	0.8	0.4	0.4
SGS-Thomson	6	3	3	0.5	0.2	0.2
TEMIC	NA	3	3	0	0.2	0.2
Other European Companies	3	0	0	0.3	0	0
Asia/Pacific Companies	112	130	220	10.1	9.6	13.5
Goldstar	3	4	8	0.3	0.3	0.5
Hyundai	21	14	28	1.9	1.0	1.7
MOSel/Vitelic	29	22	19	2.6	1.6	1.2
Samsung	56	84	144	5.1	6.2	8.8
Winbond Electronics	3	6	21	0.3	0.4	1.3

NA = Not available
Source: Dataquest (April 1995)

Table 25
Each Company's Factory Revenue from Shipments of Nonvolatile Memory to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	924	1,449	1,623	100.0	100.0	100.0
North American Companies	564	923	955	61.0	63.7	58.8
Advanced Micro Devices	110	207	214	11.9	14.3	13.2
Atmel	49	98	166	5.3	6.8	10.2
Catalyst	16	27	19	1.7	1.9	1.2
Cypress Semiconductor	31	32	33	3.4	2.2	2.0
Gould AMI	11	19	23	1.2	1.3	1.4
Harris	3	1	2	0.3	0.1	0.1
Integrated Silicon Solution Inc.	NA	NA	7	0	0	0.4
Intel	132	280	288	14.3	19.3	17.7
IMP	5	2	1	0.5	0.1	0.1
ITT	4	7	0	0.4	0.5	0
Microchip Technology	17	24	31	1.8	1.7	1.9
National Semiconductor	37	59	52	4.0	4.1	3.2
SEEQ Technology	16	13	5	1.7	0.9	0.3
Texas Instruments	73	86	64	7.9	5.9	3.9
WaferScale Integration	14	14	6	1.5	1.0	0.4
Xicor	46	54	44	5.0	3.7	2.7
Japanese Companies	261	317	400	28.2	21.9	24.6
Fujitsu	19	22	33	2.1	1.5	2.0
Hitachi	60	64	67	6.5	4.4	4.1
Matsushita	13	14	13	1.4	1.0	0.8
Mitsubishi	14	25	15	1.5	1.7	0.9
NEC	13	17	19	1.4	1.2	1.2
OKI	7	13	16	0.8	0.9	1.0
Rohm	2	4	12	0.2	0.3	0.7
Sharp	22	26	47	2.4	1.8	2.9
Toshiba	111	132	178	12.0	9.1	11.0
European Companies	72	129	136	7.8	8.9	8.4
Philips	17	14	1	1.8	1.0	0.1
SGS-Thomson	55	115	135	6.0	7.9	8.3

(Continued)

Table 25 (Continued)
Each Company's Factory Revenue from Shipments of Nonvolatile Memory to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Asia/Pacific Companies	27	80	132	2.9	5.5	8.1
Goldstar	0	5	11	0	0.3	0.7
Macronix	2	23	40	0.2	1.6	2.5
Samsung	23	51	81	2.5	3.5	5.0
Winbond Electronics	2	1	0	0.2	0.1	0

NA = Not available
Source: Dataquest (April 1995)

Table 26
Each Company's Factory Revenue from Shipments of MOS EPROMs to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	417	489	519	100.0	100.0	100.0
North American Companies	290	294	314	69.5	60.1	60.5
Advanced Micro Devices	79	53	105	18.9	10.8	20.2
Atmel	13	30	53	3.1	6.1	10.2
Catalyst	2	1	0	0.5	0.2	0
Cypress Semiconductor	31	32	33	7.4	6.5	6.4
Integrated Silicon Solution Inc.	NA	NA	7	0	0	1.3
Intel	39	30	3	9.4	6.1	0.6
Microchip Technology	13	14	10	3.1	2.9	1.9
National Semiconductor	30	40	36	7.2	8.2	6.9
Texas Instruments	69	80	61	16.5	16.4	11.8
WaferScale Integration	14	14	6	3.4	2.9	1.2
Japanese Companies	65	76	74	15.6	15.5	14.3
Fujitsu	13	16	17	3.1	3.3	3.3
Hitachi	16	17	17	3.8	3.5	3.3
Mitsubishi	8	9	7	1.9	1.8	1.3
NEC	4	5	5	1.0	1.0	1.0
OKI	1	1	1	0.2	0.2	0.2
Rohm	2	3	0	0.5	0.6	0
Toshiba	21	25	27	5.0	5.1	5.2
European Companies	62	106	107	14.9	21.7	20.6
Philips	17	13	0	4.1	2.7	0
SGS-Thomson	45	93	107	10.8	19.0	20.6
Asia/Pacific Companies	0	13	24	0	2.7	4.6
Macronix	0	13	24	0	2.7	4.6

NA = Not available
Source: Dataquest (April 1995)

Table 27
Each Company's Factory Revenue from Shipments of Flash Memory to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	145	482	474	100.0	100.0	100.0
North American Companies	138	456	434	95.2	94.6	91.6
Advanced Micro Devices	31	154	109	21.4	32.0	23.0
Atmel	8	28	34	5.5	5.8	7.2
Catalyst	3	20	4	2.1	4.1	0.8
Intel	93	250	285	64.1	51.9	60.1
SEEQ Technology	1	1	0	0.7	0.2	0
Texas Instruments	2	3	2	1.4	0.6	0.4
Japanese Companies	7	17	27	4.8	3.5	5.7
Fujitsu	0	0	5	0	0	1.1
Hitachi	1	2	2	0.7	0.4	0.4
Mitsubishi	3	10	2	2.1	2.1	0.4
NEC	1	2	3	0.7	0.4	0.6
OKI	1	0	0	0.7	0	0
Rohm	0	0	2	0	0	0.4
Sharp	0	1	2	0	0.2	0.4
Toshiba	1	2	11	0.7	0.4	2.3
European Companies	0	9	12	0	1.9	2.5
SGS-Thomson	0	9	12	0	1.9	2.5
Asia/Pacific Companies	0	0	1	0	0	0.2
Samsung	0	0	1	0	0	0.2

Source: Dataquest (April 1995)

Table 28
Each Company's Factory Revenue from Shipments of MOS ROMs to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	223	300	400	100.0	100.0	100.0
North American Companies	25	32	27	11.2	10.7	6.8
Gould AMI	11	19	23	4.9	6.3	5.8
Harris	3	1	2	1.3	0.3	0.5
IMP	5	2	1	2.2	0.7	0.3
ITT	4	7	0	1.8	2.3	0
Texas Instruments	2	3	1	0.9	1.0	0.3
Japanese Companies	178	209	275	79.8	69.7	68.8
Fujitsu	5	5	10	2.2	1.7	2.5
Hitachi	43	45	48	19.3	15.0	12.0
Matsushita	13	14	13	5.8	4.7	3.3
Mitsubishi	2	1	1	0.9	0.3	0.3
NEC	4	5	6	1.8	1.7	1.5
OKI	0	9	12	0	3.0	3.0
Sharp	22	25	45	9.9	8.3	11.3
Toshiba	89	105	140	39.9	35.0	35.0
Asia/Pacific Companies	20	59	98	9.0	19.7	24.5
Goldstar	0	5	11	0	1.7	2.8
Macronix	2	10	16	0.9	3.3	4.0
Samsung	16	43	71	7.2	14.3	17.8
Winbond Electronics	2	1	0	0.9	0.3	0

Source: Dataquest (April 1995)

Table 29
Each Company's Factory Revenue from Shipments of MOS EEPROMs to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	139	178	230	100.0	100.0	100.0
North American Companies	111	141	180	79.9	79.2	78.3
Atmel	28	40	79	20.1	22.5	34.3
Catalyst	11	6	15	7.9	3.4	6.5
Microchip Technology	4	10	21	2.9	5.6	9.1
National Semiconductor	7	19	16	5.0	10.7	7.0
SEEQ Technology	15	12	5	10.8	6.7	2.2
Xicor	46	54	44	33.1	30.3	19.1
Japanese Companies	11	15	24	7.9	8.4	10.4
Fujitsu	1	1	1	0.7	0.6	0.4
Mitsubishi	1	5	5	0.7	2.8	2.2
NEC	4	5	5	2.9	2.8	2.2
OKI	5	3	3	3.6	1.7	1.3
Rohm	0	1	10	0	0.6	4.3
European Companies	10	14	17	7.2	7.9	7.4
Philips	0	1	1	0	0.6	0.4
SGS-Thomson	10	13	16	7.2	7.3	7.0
Asia/Pacific Companies	7	8	9	5.0	4.5	3.9
Samsung	7	8	9	5.0	4.5	3.9

Source: Dataquest (April 1995)

Table 30
Each Company's Factory Revenue from Shipments of Other MOS Memory to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	121	155	175	100.0	100.0	100.0
North American Companies	95	95	132	78.5	61.3	75.4
Advanced Micro Devices	12	7	10	9.9	4.5	5.7
AT&T	0	2	3	0	1.3	1.7
Cypress Semiconductor	21	22	30	17.4	14.2	17.1
Integrated Device Technology	54	59	75	44.6	38.1	42.9
Micron Technology	1	2	0	0.8	1.3	0
Quality Semiconductor	1	2	3	0.8	1.3	1.7
Texas Instruments	0	1	7	0	0.6	4.0
Xicor	0	0	4	0	0	2.3
Other North American Companies	6	0	0	5.0	0	0
Japanese Companies	1	9	10	0.8	5.8	5.7
Sharp	1	1	1	0.8	0.6	0.6
Other Japanese Companies	0	8	9	0	5.2	5.1
European Companies	24	24	9	19.8	15.5	5.1
GEC Plessey	3	2	0	2.5	1.3	0
SGS-Thomson	21	22	9	17.4	14.2	5.1
Asia/Pacific Companies	1	27	24	0.8	17.4	13.7
Hyundai	1	27	24	0.8	17.4	13.7

Source: Dataquest (April 1995)

Table 31
Each Company's Factory Revenue from Shipments of Bipolar Memory to North America (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	130	83	66	100.0	100.0	100.0
North American Companies	60	35	23	46.2	42.2	34.8
Advanced Micro Devices	25	21	13	19.2	25.3	19.7
Harris	13	4	0	10.0	4.8	0
Motorola	2	1	1	1.5	1.2	1.5
National Semiconductor	5	3	3	3.8	3.6	4.5
Raytheon	9	5	4	6.9	6.0	6.1
Texas Instruments	1	1	2	0.8	1.2	3.0
Other North American Companies	5	0	0	3.8	0	0
Japanese Companies	54	47	35	41.5	56.6	53.0
Fujitsu	32	29	10	24.6	34.9	15.2
Hitachi	21	18	25	16.2	21.7	37.9
NEC	1	0	0	0.8	0	0
European Companies	16	1	8	12.3	1.2	12.1
Philips	16	1	8	12.3	1.2	12.1

Source: Dataquest (April 1995)

Table 32
Each Company's Factory Revenue from Shipments of MOS Memory to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	4,037	5,570	7,242	100.0	100.0	100.0
North American Companies	456	815	954	11.3	14.6	13.2
Advanced Micro Devices	40	41	46	1.0	0.7	0.6
AT&T	5	1	0	0.1	0	0
Atmel	7	13	39	0.2	0.2	0.5
Catalyst	10	11	10	0.2	0.2	0.1
Cypress Semiconductor	5	6	22	0.1	0.1	0.3
Dallas Semiconductor	0	0	3	0	0	0
Gould AMI	2	2	0	0	0	0
IBM	NA	249	100	0	4.5	1.4
Integrated Device Technology	6	8	23	0.1	0.1	0.3
Intel	37	27	16	0.9	0.5	0.2
Microchip Technology	10	12	15	0.2	0.2	0.2
Micron Technology	19	9	18	0.5	0.2	0.2
Motorola	111	101	109	2.7	1.8	1.5
National Semiconductor	13	27	23	0.3	0.5	0.3
Paradigm	0	0	1	0	0	0
Ramtron	NA	NA	2	0	0	0
SEEQ Technology	3	2	0	0.1	0	0
Texas Instruments	170	288	504	4.2	5.2	7.0
WaferScale Integration	4	3	2	0.1	0.1	0
Xicor	14	15	21	0.3	0.3	0.3
Japanese Companies	3,367	4,274	5,234	83.4	76.7	72.3
Fujitsu	529	614	687	13.1	11.0	9.5
Hitachi	648	835	955	16.1	15.0	13.2
Matsushita	128	163	222	3.2	2.9	3.1
Mitsubishi	248	313	355	6.1	5.6	4.9
NEC	629	831	886	15.6	14.9	12.2
Nittetsu Semiconductor	8	10	46	0.2	0.2	0.6
OKI	88	107	134	2.2	1.9	1.9
Ricoh	8	18	16	0.2	0.3	0.2
Rohm	16	20	26	0.4	0.4	0.4
Sanyo	61	71	88	1.5	1.3	1.2
Seiko Epson	20	20	21	0.5	0.4	0.3
Sharp	395	512	608	9.8	9.2	8.4

(Continued)

Table 32 (Continued)
Each Company's Factory Revenue from Shipments of MOS Memory to Japan
(Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Sony	99	124	187	2.5	2.2	2.6
Toshiba	489	633	1,000	12.1	11.4	13.8
Yamaha	1	1	1	0	0	0
Other Japanese Companies	0	2	2	0	0	0
European Companies	30	57	94	0.7	1.0	1.3
Philips	2	1	1	0	0	0
SGS-Thomson	28	56	88	0.7	1.0	1.2
Siemens	0	0	5	0	0	0.1
Asia/Pacific Companies	184	424	960	4.6	7.6	13.3
Goldstar	14	72	106	0.3	1.3	1.5
Hyundai	28	59	124	0.7	1.1	1.7
Macronix	12	45	77	0.3	0.8	1.1
MOSel/Vitelic	7	8	8	0.2	0.1	0.1
Samsung	120	226	619	3.0	4.1	8.5
United Microelectronics	2	13	25	0	0.2	0.3
Winbond Electronics	1	1	1	0	0	0

NA = Not available
Source: Dataquest (April 1995)

Table 33
Each Company's Factory Revenue from Shipments of DRAMs to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	1,800	2,687	4,012	100.0	100.0	100.0
North American Companies	244	534	620	13.6	19.9	15.5
IBM	NA	249	100	0	9.3	2.5
Micron Technology	12	8	16	0.7	0.3	0.4
Motorola	95	65	72	5.3	2.4	1.8
Ramtron	NA	NA	2	0	0	0
Texas Instruments	137	212	430	7.6	7.9	10.7
Japanese Companies	1,477	1,962	2,717	82.1	73.0	67.7
Fujitsu	301	343	391	16.7	12.8	9.7
Hitachi	293	407	562	16.3	15.1	14.0
Matsushita	63	85	179	3.5	3.2	4.5
Mitsubishi	119	198	243	6.6	7.4	6.1
NEC	272	392	434	15.1	14.6	10.8
Nittetsu Semiconductor	8	10	46	0.4	0.4	1.1
OKI	45	54	76	2.5	2.0	1.9
Sanyo	16	16	27	0.9	0.6	0.7
Sharp	31	35	42	1.7	1.3	1.0
Sony	2	3	4	0.1	0.1	0.1
Toshiba	327	419	713	18.2	15.6	17.8
European Companies	0	0	5	0	0	0.1
Siemens	0	0	5	0	0	0.1
Asia/Pacific Companies	79	191	670	4.4	7.1	16.7
Goldstar	11	52	93	0.6	1.9	2.3
Hyundai	12	21	92	0.7	0.8	2.3
MOSel/Vitelic	4	5	8	0.2	0.2	0.2
Samsung	52	113	477	2.9	4.2	11.9

NA = Not available
Source: Dataquest (April 1995)

Table 34
Each Company's Factory Revenue from Shipments of SRAMs to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	1,029	1,305	1,397	100.0	100.0	100.0
North American Companies	38	70	77	3.7	5.4	5.5
Advanced Micro Devices	1	2	2	0.1	0.2	0.1
AT&T	5	1	0	0.5	0.1	0
Cypress Semiconductor	4	5	15	0.4	0.4	1.1
Dallas Semiconductor	0	0	3	0	0	0.2
Integrated Device Technology	3	5	13	0.3	0.4	0.9
Micron Technology	7	1	2	0.7	0.1	0.1
Motorola	16	36	37	1.6	2.8	2.6
Paradigm	0	0	1	0	0	0.1
Texas Instruments	2	20	4	0.2	1.5	0.3
Japanese Companies	948	1,158	1,227	92.1	88.7	87.8
Fujitsu	144	174	181	14.0	13.3	13.0
Hitachi	248	303	271	24.1	23.2	19.4
Matsushita	19	23	23	1.8	1.8	1.6
Mitsubishi	62	58	68	6.0	4.4	4.9
NEC	140	179	186	13.6	13.7	13.3
OKI	11	9	9	1.1	0.7	0.6
Ricoh	0	9	8	0	0.7	0.6
Rohm	8	10	14	0.8	0.8	1.0
Sanyo	33	43	44	3.2	3.3	3.1
Seiko Epson	19	19	20	1.8	1.5	1.4
Sharp	91	101	102	8.8	7.7	7.3
Sony	89	109	162	8.6	8.4	11.6
Toshiba	84	121	139	8.2	9.3	9.9
Asia/Pacific Companies	43	77	93	4.2	5.9	6.7
Goldstar	3	17	12	0.3	1.3	0.9
Hyundai	16	37	31	1.6	2.8	2.2
MOSel/Vitelic	3	3	0	0.3	0.2	0
Samsung	19	19	34	1.8	1.5	2.4
United Microelectronics	1	0	15	0.1	0	1.1
Winbond Electronics	1	1	1	0.1	0.1	0.1

Source: Dataquest (April 1995)

Table 35
Each Company's Factory Revenue from Shipments of Nonvolatile Memory to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	1,198	1,538	1,781	100.0	100.0	100.0
North American Companies	169	188	222	14.1	12.2	12.5
Advanced Micro Devices	38	38	43	3.2	2.5	2.4
Atmel	7	13	39	0.6	0.8	2.2
Catalyst	10	11	10	0.8	0.7	0.6
Cypress Semiconductor	0	0	4	0	0	0.2
Gould AMI	2	2	0	0.2	0.1	0
Intel	37	27	16	3.1	1.8	0.9
Microchip Technology	10	12	15	0.8	0.8	0.8
National Semiconductor	13	27	23	1.1	1.8	1.3
SEEQ Technology	3	2	0	0.3	0.1	0
Texas Instruments	31	38	50	2.6	2.5	2.8
WaferScale Integration	4	3	2	0.3	0.2	0.1
Xicor	14	15	20	1.2	1.0	1.1
Japanese Companies	940	1,145	1,280	78.5	74.4	71.9
Fujitsu	84	97	115	7.0	6.3	6.5
Hitachi	107	125	122	8.9	8.1	6.9
Matsushita	46	55	20	3.8	3.6	1.1
Mitsubishi	67	57	44	5.6	3.7	2.5
NEC	217	260	266	18.1	16.9	14.9
OKI	32	44	49	2.7	2.9	2.8
Ricoh	8	9	8	0.7	0.6	0.4
Rohm	8	10	12	0.7	0.7	0.7
Sanyo	10	5	9	0.8	0.3	0.5
Seiko Epson	1	1	1	0.1	0.1	0.1
Sharp	273	376	464	22.8	24.4	26.1
Sony	8	12	21	0.7	0.8	1.2
Toshiba	78	93	148	6.5	6.0	8.3
Yamaha	1	1	1	0.1	0.1	0.1
European Companies	27	50	83	2.3	3.3	4.7
Philips	2	1	1	0.2	0.1	0.1
SGS-Thomson	25	49	82	2.1	3.2	4.6

(Continued)

Table 35 (Continued)
Each Company's Factory Revenue from Shipments of Nonvolatile Memory to Japan
(Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Asia/Pacific Companies	62	155	196	5.2	10.1	11.0
Goldstar	0	3	1	0	0.2	0.1
Macronix	12	45	77	1.0	2.9	4.3
Samsung	49	94	108	4.1	6.1	6.1
United Microelectronics	1	13	10	0.1	0.8	0.6

Source: Dataquest (April 1995)

Table 36
Each Company's Factory Revenue from Shipments of MOS EPROMs to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	314	377	393	100.0	100.0	100.0
North American Companies	118	123	120	37.6	32.6	30.5
Advanced Micro Devices	35	28	28	11.1	7.4	7.1
Atmel	5	11	11	1.6	2.9	2.8
Cypress Semiconductor	0	0	4	0	0	1.0
Intel	28	15	2	8.9	4.0	0.5
Microchip Technology	5	5	5	1.6	1.3	1.3
National Semiconductor	10	23	20	3.2	6.1	5.1
Texas Instruments	31	38	48	9.9	10.1	12.2
WaferScale Integration	4	3	2	1.3	0.8	0.5
Japanese Companies	170	194	191	54.1	51.5	48.6
Fujitsu	47	55	59	15.0	14.6	15.0
Hitachi	31	35	35	9.9	9.3	8.9
Mitsubishi	43	45	29	13.7	11.9	7.4
NEC	22	25	27	7.0	6.6	6.9
OKI	3	7	8	1.0	1.9	2.0
Sanyo	1	1	4	0.3	0.3	1.0
Sharp	3	3	3	1.0	0.8	0.8
Toshiba	20	23	26	6.4	6.1	6.6
European Companies	24	44	69	7.6	11.7	17.6
Philips	2	0	0	0.6	0	0
SGS-Thomson	22	44	69	7.0	11.7	17.6
Asia/Pacific Companies	2	16	13	0.6	4.2	3.3
Macronix	2	16	13	0.6	4.2	3.3

Source: Dataquest (April 1995)

Table 37
Each Company's Factory Revenue from Shipments of Flash Memory to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	12	34	120	100.0	100.0	100.0
North American Companies	12	26	51	100.0	76.5	42.5
Advanced Micro Devices	3	10	15	25.0	29.4	12.5
Atmel	0	0	16	0	0	13.3
Catalyst	0	4	4	0	11.8	3.3
Intel	9	12	14	75.0	35.3	11.7
Texas Instruments	0	0	2	0	0	1.7
Japanese Companies	0	8	64	0	23.5	53.3
Fujitsu	0	0	5	0	0	4.2
Hitachi	0	0	1	0	0	0.8
Mitsubishi	0	0	6	0	0	5.0
NEC	0	0	3	0	0	2.5
OKI	0	3	4	0	8.8	3.3
Sharp	0	5	6	0	14.7	5.0
Toshiba	0	0	39	0	0	32.5
European Companies	0	0	4	0	0	3.3
SGS-Thomson	0	0	4	0	0	3.3
Asia/Pacific Companies	0	0	1	0	0	0.8
Samsung	0	0	1	0	0	0.8

Source: Dataquest (April 1995)

Table 38
Each Company's Factory Revenue from Shipments of MOS ROMs to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	793	1,039	1,147	100.0	100.0	100.0
North American Companies	2	2	0	0.3	0.2	0
Gould AMI	2	2	0	0.3	0.2	0
Japanese Companies	731	899	966	92.2	86.5	84.2
Fujitsu	28	31	40	3.5	3.0	3.5
Hitachi	75	89	85	9.5	8.6	7.4
Matsushita	46	55	20	5.8	5.3	1.7
Mitsubishi	23	11	8	2.9	1.1	0.7
NEC	172	209	209	21.7	20.1	18.2
OKI	25	30	33	3.2	2.9	2.9
Ricoh	8	9	8	1.0	0.9	0.7
Rohm	8	10	0	1.0	1.0	0
Sanyo	8	3	2	1.0	0.3	0.2
Seiko Epson	1	1	1	0.1	0.1	0.1
Sharp	270	368	455	34.0	35.4	39.7
Sony	8	12	21	1.0	1.2	1.8
Toshiba	58	70	83	7.3	6.7	7.2
Yamaha	1	1	1	0.1	0.1	0.1
Asia/Pacific Companies	60	138	181	7.6	13.3	15.8
Goldstar	0	3	1	0	0.3	0.1
Macronix	10	29	64	1.3	2.8	5.6
Samsung	49	93	106	6.2	9.0	9.2
United Microelectronics	1	13	10	0.1	1.3	0.9

Source: Dataquest (April 1995)

Table 39
Each Company's Factory Revenue from Shipments of MOS EEPROMs to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	79	88	121	100.0	100.0	100.0
North American Companies	37	37	51	46.8	42.0	42.1
Atmel	2	2	12	2.5	2.3	9.9
Catalyst	10	7	6	12.7	8.0	5.0
Microchip Technology	5	7	10	6.3	8.0	8.3
National Semiconductor	3	4	3	3.8	4.5	2.5
SEEQ Technology	3	2	0	3.8	2.3	0
Xicor	14	15	20	17.7	17.0	16.5
Japanese Companies	39	44	59	49.4	50.0	48.8
Fujitsu	9	11	11	11.4	12.5	9.1
Hitachi	1	1	1	1.3	1.1	0.8
Mitsubishi	1	1	1	1.3	1.1	0.8
NEC	23	26	27	29.1	29.5	22.3
OKI	4	4	4	5.1	4.5	3.3
Rohm	0	0	12	0	0	9.9
Sanyo	1	1	3	1.3	1.1	2.5
European Companies	3	6	10	3.8	6.8	8.3
Philips	0	1	1	0	1.1	0.8
SGS-Thomson	3	5	9	3.8	5.7	7.4
Asia/Pacific Companies	0	1	1	0	1.1	0.8
Samsung	0	1	1	0	1.1	0.8

Source: Dataquest (April 1995)

Table 40
Each Company's Factory Revenue from Shipments of Other MOS Memory to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	10	40	52	100.0	100.0	100.0
North American Companies	5	23	35	50.0	57.5	67.3
Advanced Micro Devices	1	1	1	10.0	2.5	1.9
Cypress Semiconductor	1	1	3	10.0	2.5	5.8
Integrated Device Technology	3	3	10	30.0	7.5	19.2
Texas Instruments	0	18	20	0	45.0	38.5
Xicor	0	0	1	0	0	1.9
Japanese Companies	2	9	10	20.0	22.5	19.2
Sanyo	2	7	8	20.0	17.5	15.4
Other Japanese Companies	0	2	2	0	5.0	3.8
European Companies	3	7	6	30.0	17.5	11.5
SGS-Thomson	3	7	6	30.0	17.5	11.5
Asia/Pacific Companies	0	1	1	0	2.5	1.9
Hyundai	0	1	1	0	2.5	1.9

Source: Dataquest (April 1995)

Table 41
Each Company's Factory Revenue from Shipments of Bipolar Memory to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	138	127	98	100.0	100.0	100.0
North American Companies	4	4	2	2.9	3.1	2.0
Advanced Micro Devices	3	3	1	2.2	2.4	1.0
Texas Instruments	1	1	1	0.7	0.8	1.0
Japanese Companies	133	123	95	96.4	96.9	96.9
Fujitsu	55	50	20	39.9	39.4	20.4
Hitachi	66	62	64	47.8	48.8	65.3
NEC	12	11	11	8.7	8.7	11.2
European Companies	1	0	1	0.7	0	1.0
Philips	1	0	1	0.7	0	1.0

Source: Dataquest (April 1995)

Table 42
Each Company's Factory Revenue from Shipments of MOS Memory to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	2,660	4,040	6,571	100.0	100.0	100.0
North American Companies	728	1,316	1,914	27.4	32.6	29.1
Advanced Micro Devices	71	123	123	2.7	3.0	1.9
Alliance Semiconductor	0	4	5	0	0.1	0.1
AT&T	1	4	0	0	0.1	0
Atmel	22	33	70	0.8	0.8	1.1
Catalyst	10	11	10	0.4	0.3	0.2
Cypress Semiconductor	27	43	46	1.0	1.1	0.7
Dallas Semiconductor	4	9	6	0.2	0.2	0.1
Electronic Designs	1	1	6	0	0	0.1
Gould AMI	0	0	4	0	0	0.1
Harris	4	2	4	0.2	0	0.1
IBM	NA	331	632	0	8.2	9.6
Integrated Device Technology	25	30	52	0.9	0.7	0.8
Integrated Silicon Solution Inc.	NA	NA	4	0	0	0.1
Intel	109	119	109	4.1	2.9	1.7
ITT	2	2	0	0.1	0	0
Microchip Technology	10	14	18	0.4	0.3	0.3
Micron Technology	71	111	170	2.7	2.7	2.6
Motorola	96	148	193	3.6	3.7	2.9
National Semiconductor	40	37	38	1.5	0.9	0.6
Paradigm	1	2	1	0	0	0
Performance Semiconductor	2	1	1	0.1	0	0
Ramtron	NA	NA	1	0	0	0
SEEQ Technology	2	1	0	0.1	0	0
Texas Instruments	202	261	389	7.6	6.5	5.9
WaferScale Integration	3	2	5	0.1	0	0.1
Xicor	25	27	27	0.9	0.7	0.4
Japanese Companies	1,028	1,357	2,163	38.6	33.6	32.9
Fujitsu	95	132	319	3.6	3.3	4.9
Hitachi	207	292	450	7.8	7.2	6.8
Matsushita	9	12	15	0.3	0.3	0.2
Mitsubishi	126	166	256	4.7	4.1	3.9
NEC	221	298	522	8.3	7.4	7.9
Nittetsu Semiconductor	3	6	0	0.1	0.1	0

(Continued)

Table 42 (Continued)
Each Company's Factory Revenue from Shipments of MOS Memory to Europe
(Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
OKI	67	83	117	2.5	2.1	1.8
Rohm	3	5	5	0.1	0.1	0.1
Sanyo	8	2	4	0.3	0	0.1
Seiko Epson	3	3	5	0.1	0.1	0.1
Sharp	25	29	36	0.9	0.7	0.5
Sony	25	33	38	0.9	0.8	0.6
Toshiba	236	296	396	8.9	7.3	6.0
European Companies	418	589	783	15.7	14.6	11.9
GEC Plessey	2	1	0	0.1	0	0
Philips	11	10	7	0.4	0.2	0.1
SGS-Thomson	146	201	266	5.5	5.0	4.0
Siemens	225	352	492	8.5	8.7	7.5
TEMIC	NA	25	18	0	0.6	0.3
Other European Companies	34	0	0	1.3	0	0
Asia/Pacific Companies	486	778	1,711	18.3	19.3	26.0
Goldstar	86	132	379	3.2	3.3	5.8
Hyundai	73	134	337	2.7	3.3	5.1
Macronix	0	3	3	0	0.1	0
MOSel/Vitelic	2	2	3	0.1	0	0
Samsung	322	500	978	12.1	12.4	14.9
United Microelectronics	2	6	10	0.1	0.1	0.2
Winbond Electronics	1	1	1	0	0	0

NA = Not available
Source: Dataquest (April 1995)

Table 43
Each Company's Factory Revenue from Shipments of DRAMs to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	1,557	2,671	4,927	100.0	100.0	100.0
North American Companies	283	747	1,236	18.2	28.0	25.1
IBM	NA	331	632	0	12.4	12.8
Intel	10	0	0	0.6	0	0
Micron Technology	56	95	146	3.6	3.6	3.0
Motorola	56	112	140	3.6	4.2	2.8
Ramtron	NA	NA	1	0	0	0
Texas Instruments	161	209	317	10.3	7.8	6.4
Japanese Companies	672	942	1,711	43.2	35.3	34.7
Fujitsu	61	94	281	3.9	3.5	5.7
Hitachi	136	219	370	8.7	8.2	7.5
Matsushita	9	12	15	0.6	0.4	0.3
Mitsubishi	87	125	198	5.6	4.7	4.0
NEC	142	203	431	9.1	7.6	8.7
Nittetsu Semiconductor	3	6	0	0.2	0.2	0
OKI	63	77	110	4.0	2.9	2.2
Sanyo	7	0	0	0.4	0	0
Sharp	2	2	3	0.1	0.1	0.1
Toshiba	162	204	303	10.4	7.6	6.1
European Companies	185	298	420	11.9	11.2	8.5
Siemens	185	298	420	11.9	11.2	8.5
Asia/Pacific Companies	417	684	1,560	26.8	25.6	31.7
Goldstar	82	125	375	5.3	4.7	7.6
Hyundai	60	123	325	3.9	4.6	6.6
MOSel/Vitelic	1	1	2	0.1	0	0
Samsung	274	435	858	17.6	16.3	17.4

NA = Not available
Source: Dataquest (April 1995)

Table 44
Each Company's Factory Revenue from Shipments of SRAMs to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	458	525	620	100.0	100.0	100.0
North American Companies	105	122	165	22.9	23.2	26.6
Advanced Micro Devices	2	3	2	0.4	0.6	0.3
Alliance Semiconductor	0	4	5	0	0.8	0.8
AT&T	1	2	0	0.2	0.4	0
Cypress Semiconductor	15	31	31	3.3	5.9	5.0
Dallas Semiconductor	4	9	6	0.9	1.7	1.0
Electronic Designs	1	1	6	0.2	0.2	1.0
Harris	3	2	2	0.7	0.4	0.3
Integrated Device Technology	12	14	30	2.6	2.7	4.8
Integrated Silicon Solution Inc.	NA	NA	3	0	0	0.5
Intel	7	1	0	1.5	0.2	0
Micron Technology	15	16	24	3.3	3.0	3.9
Motorola	40	35	52	8.7	6.7	8.4
National Semiconductor	2	1	1	0.4	0.2	0.2
Paradigm	1	2	1	0.2	0.4	0.2
Performance Semiconductor	2	1	1	0.4	0.2	0.2
Texas Instruments	0	0	1	0	0	0.2
Japanese Companies	252	301	317	55.0	57.3	51.1
Fujitsu	18	21	22	3.9	4.0	3.5
Hitachi	55	56	60	12.0	10.7	9.7
Mitsubishi	33	35	52	7.2	6.7	8.4
NEC	62	76	66	13.5	14.5	10.6
OKI	2	2	2	0.4	0.4	0.3
Rohm	0	1	1	0	0.2	0.2
Sanyo	1	2	4	0.2	0.4	0.6
Seiko Epson	3	3	5	0.7	0.6	0.8
Sharp	10	12	12	2.2	2.3	1.9
Sony	25	33	38	5.5	6.3	6.1
Toshiba	43	60	55	9.4	11.4	8.9
European Companies	43	24	15	9.4	4.6	2.4
SGS-Thomson	11	3	0	2.4	0.6	0
TEMIC	NA	21	15	0	4.0	2.4
Other European Companies	32	0	0	7.0	0	0

(Continued)

Table 44 (Continued)
Each Company's Factory Revenue from Shipments of SRAMs to Europe
(Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Asia/Pacific Companies	58	78	123	12.7	14.9	19.8
Goldstar	4	7	4	0.9	1.3	0.6
Hyundai	12	11	12	2.6	2.1	1.9
MOSel/Vitelic	1	1	1	0.2	0.2	0.2
Samsung	38	52	100	8.3	9.9	16.1
United Microelectronics	2	6	5	0.4	1.1	0.8
Winbond Electronics	1	1	1	0.2	0.2	0.2

NA = Not available
Source: Dataquest (April 1995)

Table 45
Each Company's Factory Revenue from Shipments of Nonvolatile Memory to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	607	798	963	100.0	100.0	100.0
North American Companies	318	417	473	52.4	52.3	49.1
Advanced Micro Devices	67	118	119	11.0	14.8	12.4
Atmel	22	33	70	3.6	4.1	7.3
Catalyst	10	11	10	1.6	1.4	1.0
Cypress Semiconductor	5	5	8	0.8	0.6	0.8
Gould AMI	0	0	4	0	0	0.4
Harris	1	0	2	0.2	0	0.2
Integrated Silicon Solution Inc.	NA	NA	1	0	0	0.1
Intel	92	118	109	15.2	14.8	11.3
ITT	2	2	0	0.3	0.3	0
Microchip Technology	10	14	18	1.6	1.8	1.9
Motorola	0	1	1	0	0.1	0.1
National Semiconductor	38	36	37	6.3	4.5	3.8
SEEQ Technology	2	1	0	0.3	0.1	0
Texas Instruments	41	49	69	6.8	6.1	7.2
WaferScale Integration	3	2	5	0.5	0.3	0.5
Xicor	25	27	20	4.1	3.4	2.1
Japanese Companies	104	114	135	17.1	14.3	14.0
Fujitsu	16	17	16	2.6	2.1	1.7
Hitachi	16	17	20	2.6	2.1	2.1
Mitsubishi	6	6	6	1.0	0.8	0.6
NEC	17	19	25	2.8	2.4	2.6
OKI	2	4	5	0.3	0.5	0.5
Rohm	3	4	4	0.5	0.5	0.4
Sharp	13	15	21	2.1	1.9	2.2
Toshiba	31	32	38	5.1	4.0	3.9
European Companies	175	251	327	28.8	31.5	34.0
Philips	11	10	7	1.8	1.3	0.7
SGS-Thomson	122	183	245	20.1	22.9	25.4
Siemens	40	54	72	6.6	6.8	7.5
TEMIC	NA	4	3	0	0.5	0.3
Other European Companies	2	0	0	0.3	0	0

(Continued)

Table 45 (Continued)
Each Company's Factory Revenue from Shipments of Nonvolatile Memory to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Asia/Pacific Companies	10	16	28	1.6	2.0	2.9
Macronix	0	3	3	0	0.4	0.3
Samsung	10	13	20	1.6	1.6	2.1
United Microelectronics	0	0	5	0	0	0.5

NA = Not available
Source: Dataquest (April 1995)

Table 46
Each Company's Factory Revenue from Shipments of MOS EPROMs to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	293	323	346	100.0	100.0	100.0
North American Companies	173	170	172	59.0	52.6	49.7
Advanced Micro Devices	56	55	58	19.1	17.0	16.8
Atmel	4	8	24	1.4	2.5	6.9
Catalyst	1	1	0	0.3	0.3	0
Cypress Semiconductor	5	5	8	1.7	1.5	2.3
Integrated Silicon Solution Inc.	NA	NA	1	0	0	0.3
Intel	37	25	3	12.6	7.7	0.9
Microchip Technology	5	5	6	1.7	1.5	1.7
National Semiconductor	23	22	22	7.8	6.8	6.4
Texas Instruments	39	47	45	13.3	14.6	13.0
WaferScale Integration	3	2	5	1.0	0.6	1.4
Japanese Companies	34	33	24	11.6	10.2	6.9
Fujitsu	9	9	1	3.1	2.8	0.3
Hitachi	5	5	6	1.7	1.5	1.7
Mitsubishi	4	4	4	1.4	1.2	1.2
NEC	6	6	7	2.0	1.9	2.0
OKI	1	0	0	0.3	0	0
Rohm	3	3	0	1.0	0.9	0
Toshiba	6	6	6	2.0	1.9	1.7
European Companies	86	117	147	29.4	36.2	42.5
Philips	11	4	0	3.8	1.2	0
SGS-Thomson	75	113	147	25.6	35.0	42.5
Asia/Pacific Companies	0	3	3	0	0.9	0.9
Macronix	0	3	3	0	0.9	0.9

NA = Not available

Source: Dataquest (April 1995)

Table 47
Each Company's Factory Revenue from Shipments of Flash Memory to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	71	181	206	100.0	100.0	100.0
North American Companies	69	169	181	97.2	93.4	87.9
Advanced Micro Devices	11	63	61	15.5	34.8	29.6
Atmel	3	10	12	4.2	5.5	5.8
Catalyst	0	3	1	0	1.7	0.5
Intel	55	93	106	77.5	51.4	51.5
Texas Instruments	0	0	1	0	0	0.5
Japanese Companies	0	1	6	0	0.6	2.9
Fujitsu	0	0	3	0	0	1.5
Mitsubishi	0	0	1	0	0	0.5
Sharp	0	1	2	0	0.6	1.0
European Companies	2	11	18	2.8	6.1	8.7
SGS-Thomson	2	11	18	2.8	6.1	8.7
Asia/Pacific Companies	0	0	1	0	0	0.5
Samsung	0	0	1	0	0	0.5

Source: Dataquest (April 1995)

Table 48
Each Company's Factory Revenue from Shipments of MOS ROMs to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	73	80	110	100.0	100.0	100.0
North American Companies	5	4	6	6.8	5.0	5.5
Gould AMI	0	0	4	0	0	3.6
Harris	1	0	2	1.4	0	1.8
ITT	2	2	0	2.7	2.5	0
Texas Instruments	2	2	0	2.7	2.5	0
Japanese Companies	63	68	87	86.3	85.0	79.1
Fujitsu	7	8	12	9.6	10.0	10.9
Hitachi	8	9	10	11.0	11.3	9.1
Mitsubishi	1	1	0	1.4	1.3	0
NEC	9	10	14	12.3	12.5	12.7
Sharp	13	14	19	17.8	17.5	17.3
Toshiba	25	26	32	34.2	32.5	29.1
Asia/Pacific Companies	5	8	17	6.8	10.0	15.5
Samsung	5	8	12	6.8	10.0	10.9
United Microelectronics	0	0	5	0	0	4.5

Source: Dataquest (April 1995)

Table 49
Each Company's Factory Revenue from Shipments of MOS EEPROMs to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	170	214	301	100.0	100.0	100.0
North American Companies	71	74	114	41.8	34.6	37.9
Atmel	15	15	34	8.8	7.0	11.3
Catalyst	9	7	9	5.3	3.3	3.0
Microchip Technology	5	9	12	2.9	4.2	4.0
Motorola	0	1	1	0	0.5	0.3
National Semiconductor	15	14	15	8.8	6.5	5.0
SEEQ Technology	2	1	0	1.2	0.5	0
Texas Instruments	0	0	23	0	0	7.6
Xicor	25	27	20	14.7	12.6	6.6
Japanese Companies	7	12	18	4.1	5.6	6.0
Hitachi	3	3	4	1.8	1.4	1.3
Mitsubishi	1	1	1	0.6	0.5	0.3
NEC	2	3	4	1.2	1.4	1.3
OKI	1	4	5	0.6	1.9	1.7
Rohm	0	1	4	0	0.5	1.3
European Companies	87	123	162	51.2	57.5	53.8
Philips	0	6	7	0	2.8	2.3
SGS-Thomson	45	59	80	26.5	27.6	26.6
Siemens	40	54	72	23.5	25.2	23.9
TEMIC	NA	4	3	0	1.9	1.0
Other European Companies	2	0	0	1.2	0	0
Asia/Pacific Companies	5	5	7	2.9	2.3	2.3
Samsung	5	5	7	2.9	2.3	2.3

NA = Not available
Source: Dataquest (April 1995)

Table 50
Each Company's Factory Revenue from Shipments of Other MOS Memory to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	38	46	61	100.0	100.0	100.0
North American Companies	22	30	40	57.9	65.2	65.6
Advanced Micro Devices	2	2	2	5.3	4.3	3.3
AT&T	0	2	0	0	4.3	0
Cypress Semiconductor	7	7	7	18.4	15.2	11.5
Integrated Device Technology	13	16	22	34.2	34.8	36.1
Texas Instruments	0	3	2	0	6.5	3.3
Xicor	0	0	7	0	0	11.5
European Companies	15	16	21	39.5	34.8	34.4
GEC Plessey	2	1	0	5.3	2.2	0
SGS-Thomson	13	15	21	34.2	32.6	34.4
Asia/Pacific Companies	1	0	0	2.6	0	0
Hyundai	1	0	0	2.6	0	0

Source: Dataquest (April 1995)

Table 51
Each Company's Factory Revenue from Shipments of Bipolar Memory to Europe (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	38	27	28	100.0	100.0	100.0
North American Companies	20	17	16	52.6	63.0	57.1
Advanced Micro Devices	17	14	12	44.7	51.9	42.9
Motorola	0	1	0	0	3.7	0
National Semiconductor	2	1	1	5.3	3.7	3.6
Raytheon	1	1	1	2.6	3.7	3.6
Texas Instruments	0	0	2	0	0	7.1
Japanese Companies	11	8	8	28.9	29.6	28.6
Fujitsu	3	2	2	7.9	7.4	7.1
Hitachi	2	1	1	5.3	3.7	3.6
NEC	6	5	5	15.8	18.5	17.9
European Companies	7	2	4	18.4	7.4	14.3
Philips	7	2	4	18.4	7.4	14.3

Source: Dataquest (April 1995)

Table 52
Each Company's Factory Revenue from Shipments of MOS Memory to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	2,904	4,911	7,210	100.0	100.0	100.0
North American Companies	520	1,047	1,362	17.9	21.3	18.9
Advanced Micro Devices	38	38	49	1.3	0.8	0.7
Alliance Semiconductor	0	23	35	0	0.5	0.5
Atmel	19	35	56	0.7	0.7	0.8
Catalyst	4	5	10	0.1	0.1	0.1
Cypress Semiconductor	12	15	18	0.4	0.3	0.2
Dallas Semiconductor	4	0	9	0.1	0	0.1
Gould AMI	2	2	17	0.1	0	0.2
Harris	1	0	0	0	0	0
IBM	NA	133	80	0	2.7	1.1
Integrated Device Technology	14	22	13	0.5	0.4	0.2
Integrated Silicon Solution Inc.	NA	NA	26	0	0	0.4
Intel	28	40	45	1.0	0.8	0.6
ITT	2	2	10	0.1	0	0.1
Logic Devices	1	1	0	0	0	0
Microchip Technology	10	14	18	0.3	0.3	0.2
Micron Technology	69	170	254	2.4	3.5	3.5
Motorola	93	154	163	3.2	3.1	2.3
National Semiconductor	27	40	33	0.9	0.8	0.5
Paradigm	0	1	2	0	0	0
Performance Semiconductor	2	1	1	0.1	0	0
Quality Semiconductor	3	4	2	0.1	0.1	0
Ramtron	NA	NA	9	0	0	0.1
Texas Instruments	182	337	506	6.3	6.9	7.0
WaferScale Integration	1	1	2	0	0	0
Xicor	8	9	4	0.3	0.2	0.1
Japanese Companies	1,064	1,753	2,861	36.6	35.7	39.7
Fujitsu	138	171	310	4.8	3.5	4.3
Hitachi	149	298	529	5.1	6.1	7.3
Matsushita	30	64	63	1.0	1.3	0.9
Mitsubishi	126	181	404	4.3	3.7	5.6
NEC	122	275	548	4.2	5.6	7.6
Nittetsu Semiconductor	62	57	58	2.1	1.2	0.8
OKI	88	112	146	3.0	2.3	2.0

(Continued)

Table 52 (Continued)
Each Company's Factory Revenue from Shipments of MOS Memory to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Ricoh	0	3	3	0	0.1	0
Rohm	6	8	9	0.2	0.2	0.1
Sanyo	22	80	90	0.8	1.6	1.2
Seiko Epson	2	3	4	0.1	0.1	0.1
Sharp	43	91	134	1.5	1.9	1.9
Sony	28	51	47	1.0	1.0	0.7
Toshiba	248	350	506	8.5	7.1	7.0
Other Japanese Companies	0	9	10	0	0.2	0.1
European Companies	91	199	333	3.1	4.1	4.6
Philips	10	7	5	0.3	0.1	0.1
SGS-Thomson	48	70	88	1.7	1.4	1.2
Siemens	31	119	238	1.1	2.4	3.3
TEMIC	NA	3	2	0	0.1	0
Other European Companies	2	0	0	0.1	0	0
Asia/Pacific Companies	1,229	1,912	2,654	42.3	38.9	36.8
Daewoo	1	1	0	0	0	0
Goldstar	235	465	521	8.1	9.5	7.2
Hualon Microelectronics Corporation	29	36	46	1.0	0.7	0.6
Hyundai	248	322	536	8.5	6.6	7.4
Macronix	43	58	80	1.5	1.2	1.1
MOSel/Vitelic	59	91	102	2.0	1.9	1.4
Samsung	494	739	1,094	17.0	15.0	15.2
Silicon Integrated Systems	21	5	0	0.7	0.1	0
United Microelectronics	60	127	156	2.1	2.6	2.2
Winbond Electronics	39	68	119	1.3	1.4	1.7

NA = Not available
Source: Dataquest (April 1995)

Table 53
Each Company's Factory Revenue from Shipments of DRAMs to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	1,853	3,391	5,297	100.0	100.0	100.0
North American Companies	230	672	896	12.4	19.8	16.9
IBM	NA	133	80	0	3.9	1.5
Micron Technology	49	144	245	2.6	4.2	4.6
Motorola	57	120	125	3.1	3.5	2.4
Ramtron	NA	NA	9	0	0	0.2
Texas Instruments	124	275	437	6.7	8.1	8.2
Japanese Companies	795	1,300	2,323	42.9	38.3	43.9
Fujitsu	98	114	241	5.3	3.4	4.5
Hitachi	95	226	452	5.1	6.7	8.5
Matsushita	20	41	51	1.1	1.2	1.0
Mitsubishi	108	155	357	5.8	4.6	6.7
NEC	96	238	502	5.2	7.0	9.5
Nittetsu Semiconductor	62	57	58	3.3	1.7	1.1
OKI	87	104	138	4.7	3.1	2.6
Sanyo	6	51	58	0.3	1.5	1.1
Sharp	4	4	8	0.2	0.1	0.2
Toshiba	219	310	458	11.8	9.1	8.6
European Companies	31	110	238	1.7	3.2	4.5
Siemens	31	110	238	1.7	3.2	4.5
Asia/Pacific Companies	797	1,309	1,840	43.0	38.6	34.7
Goldstar	201	386	423	10.8	11.4	8.0
Hyundai	191	267	477	10.3	7.9	9.0
MOSel/Vitelic	40	70	94	2.2	2.1	1.8
Samsung	365	586	846	19.7	17.3	16.0

NA = Not available
Source: Dataquest (April 1995)

Table 54
Each Company's Factory Revenue from Shipments of SRAMs to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	444	729	867	100.0	100.0	100.0
North American Companies	78	109	135	17.6	15.0	15.6
Alliance Semiconductor	0	23	35	0	3.2	4.0
Cypress Semiconductor	9	12	12	2.0	1.6	1.4
Dallas Semiconductor	4	0	9	0.9	0	1.0
Harris	1	0	0	0.2	0	0
Integrated Device Technology	7	15	7	1.6	2.1	0.8
Integrated Silicon Solution Inc.	NA	NA	22	0	0	2.5
Logic Devices	1	1	0	0.2	0.1	0
Micron Technology	20	26	9	4.5	3.6	1.0
Motorola	31	26	30	7.0	3.6	3.5
Paradigm	0	1	2	0	0.1	0.2
Performance Semiconductor	2	1	1	0.5	0.1	0.1
Quality Semiconductor	3	4	2	0.7	0.5	0.2
Texas Instruments	0	0	6	0	0	0.7
Japanese Companies	142	221	254	32.0	30.3	29.3
Fujitsu	24	35	36	5.4	4.8	4.2
Hitachi	36	43	45	8.1	5.9	5.2
Matsushita	2	3	3	0.5	0.4	0.3
Mitsubishi	17	24	44	3.8	3.3	5.1
NEC	9	13	20	2.0	1.8	2.3
OKI	1	5	5	0.2	0.7	0.6
Ricoh	0	1	1	0	0.1	0.1
Rohm	2	2	3	0.5	0.3	0.3
Sanyo	12	28	31	2.7	3.8	3.6
Seiko Epson	2	3	4	0.5	0.4	0.5
Sharp	2	3	3	0.5	0.4	0.3
Sony	20	40	34	4.5	5.5	3.9
Toshiba	15	21	25	3.4	2.9	2.9
European Companies	3	4	3	0.7	0.5	0.3
SGS-Thomson	1	1	1	0.2	0.1	0.1
TEMIC	NA	3	2	0	0.4	0.2
Other European Companies	2	0	0	0.5	0	0

(Continued)

Table 54 (Continued)
Each Company's Factory Revenue from Shipments of SRAMs to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Asia/Pacific Companies	221	395	475	49.8	54.2	54.8
Goldstar	27	51	45	6.1	7.0	5.2
Hualon Microelectronics Corporation	6	6	7	1.4	0.8	0.8
Hyundai	50	54	58	11.3	7.4	6.7
MOSel/Vitelic	19	21	8	4.3	2.9	0.9
Samsung	57	88	141	12.8	12.1	16.3
Silicon Integrated Systems	3	0	0	0.7	0	0
United Microelectronics	29	108	98	6.5	14.8	11.3
Winbond Electronics	30	67	118	6.8	9.2	13.6

NA = Not available
Source: Dataquest (April 1995)

Table 55
Each Company's Factory Revenue from Shipments of Nonvolatile Memory to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	587	766	1,016	100.0	100.0	100.0
North American Companies	202	255	316	34.4	33.3	31.1
Advanced Micro Devices	38	38	49	6.5	5.0	4.8
Atmel	19	35	56	3.2	4.6	5.5
Catalyst	4	5	10	0.7	0.7	1.0
Cypress Semiconductor	0	0	3	0	0	0.3
Gould AMI	2	2	17	0.3	0.3	1.7
Integrated Silicon Solution Inc.	NA	NA	4	0	0	0.4
Intel	28	40	45	4.8	5.2	4.4
ITT	2	2	10	0.3	0.3	1.0
Microchip Technology	10	14	18	1.7	1.8	1.8
Motorola	5	8	8	0.9	1.0	0.8
National Semiconductor	27	40	33	4.6	5.2	3.2
Texas Instruments	58	61	57	9.9	8.0	5.6
WaferScale Integration	1	1	2	0.2	0.1	0.2
Xicor	8	9	4	1.4	1.2	0.4
Japanese Companies	127	223	274	21.6	29.1	27.0
Fujitsu	16	22	33	2.7	2.9	3.2
Hitachi	18	29	32	3.1	3.8	3.1
Matsushita	8	20	9	1.4	2.6	0.9
Mitsubishi	1	2	3	0.2	0.3	0.3
NEC	17	24	26	2.9	3.1	2.6
OKI	0	3	3	0	0.4	0.3
Ricoh	0	2	2	0	0.3	0.2
Rohm	4	6	6	0.7	0.8	0.6
Sanyo	4	1	1	0.7	0.1	0.1
Sharp	37	84	123	6.3	11.0	12.1
Sony	8	11	13	1.4	1.4	1.3
Toshiba	14	19	23	2.4	2.5	2.3
European Companies	53	81	89	9.0	10.6	8.8
Philips	10	7	5	1.7	0.9	0.5
SGS-Thomson	43	65	84	7.3	8.5	8.3
Siemens	0	9	0	0	1.2	0

(Continued)

Table 55 (Continued)
Each Company's Factory Revenue from Shipments of Nonvolatile Memory to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Asia/Pacific Companies	205	207	337	34.9	27.0	33.2
Daewoo	1	1	0	0.2	0.1	0
Goldstar	7	28	53	1.2	3.7	5.2
Hualon Microelectronics Corporation	23	30	39	3.9	3.9	3.8
Hyundai	1	0	0	0.2	0	0
Macronix	43	58	80	7.3	7.6	7.9
Samsung	72	65	106	12.3	8.5	10.4
Silicon Integrated Systems	18	5	0	3.1	0.7	0
United Microelectronics	31	19	58	5.3	2.5	5.7
Winbond Electronics	9	1	1	1.5	0.1	0.1

NA = Not available
Source: Dataquest (April 1995)

Table 56
Each Company's Factory Revenue from Shipments of MOS EPROMs to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	229	271	287	100.0	100.0	100.0
North American Companies	158	155	159	69.0	57.2	55.4
Advanced Micro Devices	37	33	24	16.2	12.2	8.4
Atmel	14	29	40	6.1	10.7	13.9
Cypress Semiconductor	0	0	3	0	0	1.0
Integrated Silicon Solution Inc.	NA	NA	4	0	0	1.4
Intel	18	0	0	7.9	0	0
Microchip Technology	6	6	6	2.6	2.2	2.1
National Semiconductor	24	27	25	10.5	10.0	8.7
Texas Instruments	58	59	55	25.3	21.8	19.2
WaferScale Integration	1	1	2	0.4	0.4	0.7
Japanese Companies	18	25	19	7.9	9.2	6.6
Fujitsu	2	2	2	0.9	0.7	0.7
Hitachi	7	10	11	3.1	3.7	3.8
Mitsubishi	1	2	1	0.4	0.7	0.3
NEC	3	4	4	1.3	1.5	1.4
Rohm	4	6	0	1.7	2.2	0
Toshiba	1	1	1	0.4	0.4	0.3
European Companies	48	59	72	21.0	21.8	25.1
Philips	10	3	0	4.4	1.1	0
SGS-Thomson	38	56	72	16.6	20.7	25.1
Asia/Pacific Companies	5	32	37	2.2	11.8	12.9
Macronix	5	32	37	2.2	11.8	12.9

NA = Not available

Source: Dataquest (April 1995)

Table 57
Each Company's Factory Revenue from Shipments of Flash Memory to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	11	49	84	100.0	100.0	100.0
North American Companies	11	47	76	100.0	95.9	90.5
Advanced Micro Devices	1	5	25	9.1	10.2	29.8
Atmel	0	0	3	0	0	3.6
Catalyst	0	0	1	0	0	1.2
Intel	10	40	45	90.9	81.6	53.6
Texas Instruments	0	2	2	0	4.1	2.4
Japanese Companies	0	1	3	0	2.0	3.6
Fujitsu	0	0	1	0	0	1.2
Mitsubishi	0	0	1	0	0	1.2
Sharp	0	1	1	0	2.0	1.2
European Companies	0	1	2	0	2.0	2.4
SGS-Thomson	0	1	2	0	2.0	2.4
Asia/Pacific Companies	0	0	3	0	0	3.6
Macronix	0	0	3	0	0	3.6

Source: Dataquest (April 1995)

Table 58
Each Company's Factory Revenue from Shipments of MOS ROMs to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	309	365	559	100.0	100.0	100.0
North American Companies	9	4	27	2.9	1.1	4.8
Gould AMI	2	2	17	0.6	0.5	3.0
ITT	2	2	10	0.6	0.5	1.8
Motorola	5	0	0	1.6	0	0
Japanese Companies	105	189	238	34.0	51.8	42.6
Fujitsu	14	20	30	4.5	5.5	5.4
Hitachi	9	17	19	2.9	4.7	3.4
Matsushita	8	20	9	2.6	5.5	1.6
Mitsubishi	0	0	1	0	0	0.2
NEC	12	17	19	3.9	4.7	3.4
Ricoh	0	2	2	0	0.5	0.4
Sanyo	4	1	1	1.3	0.3	0.2
Sharp	37	83	122	12.0	22.7	21.8
Sony	8	11	13	2.6	3.0	2.3
Toshiba	13	18	22	4.2	4.9	3.9
Asia/Pacific Companies	195	172	294	63.1	47.1	52.6
Daewoo	1	1	0	0.3	0.3	0
Goldstar	7	28	53	2.3	7.7	9.5
Hualon Microelectronics Corporation	23	30	39	7.4	8.2	7.0
Macronix	38	26	40	12.3	7.1	7.2
Samsung	68	62	103	22.0	17.0	18.4
Silicon Integrated Systems	18	5	0	5.8	1.4	0
United Microelectronics	31	19	58	10.0	5.2	10.4
Winbond Electronics	9	1	1	2.9	0.3	0.2

Source: Dataquest (April 1995)

Table 59
Each Company's Factory Revenue from Shipments of MOS EEPROMs to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	38	81	86	100.0	100.0	100.0
North American Companies	24	49	54	63.2	60.5	62.8
Atmel	5	6	13	13.2	7.4	15.1
Catalyst	4	5	9	10.5	6.2	10.5
Microchip Technology	4	8	12	10.5	9.9	14.0
Motorola	0	8	8	0	9.9	9.3
National Semiconductor	3	13	8	7.9	16.0	9.3
Xicor	8	9	4	21.1	11.1	4.7
Japanese Companies	4	8	14	10.5	9.9	16.3
Hitachi	2	2	2	5.3	2.5	2.3
NEC	2	3	3	5.3	3.7	3.5
OKI	0	3	3	0	3.7	3.5
Rohm	0	0	6	0	0	7.0
European Companies	5	21	15	13.2	25.9	17.4
Philips	0	4	5	0	4.9	5.8
SGS-Thomson	5	8	10	13.2	9.9	11.6
Siemens	0	9	0	0	11.1	0
Asia/Pacific Companies	5	3	3	13.2	3.7	3.5
Hyundai	1	0	0	2.6	0	0
Samsung	4	3	3	10.5	3.7	3.5

Source: Dataquest (April 1995)

Table 60
Each Company's Factory Revenue from Shipments of Other MOS Memory to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	20	25	30	100.0	100.0	100.0
North American Companies	10	11	15	50.0	44.0	50.0
Cypress Semiconductor	3	3	3	15.0	12.0	10.0
Integrated Device Technology	7	7	6	35.0	28.0	20.0
Texas Instruments	0	1	6	0	4.0	20.0
Japanese Companies	0	9	10	0	36.0	33.3
Other Japanese Companies	0	9	10	0	36.0	33.3
European Companies	4	4	3	20.0	16.0	10.0
SGS-Thomson	4	4	3	20.0	16.0	10.0
Asia/Pacific Companies	6	1	2	30.0	4.0	6.7
Hyundai	6	1	1	30.0	4.0	3.3
Samsung	0	0	1	0	0	3.3

Source: Dataquest (April 1995)

Table 61
Each Company's Factory Revenue from Shipments of Bipolar Memory to Asia/Pacific-Rest of World (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	12	7	6	100.0	100.0	100.0
North American Companies	4	3	2	33.3	42.9	33.3
Advanced Micro Devices	1	1	2	8.3	14.3	33.3
Motorola	1	0	0	8.3	0	0
National Semiconductor	1	1	0	8.3	14.3	0
Texas Instruments	1	1	0	8.3	14.3	0
Japanese Companies	5	4	3	41.7	57.1	50.0
Hitachi	5	4	3	41.7	57.1	50.0
European Companies	3	0	1	25.0	0	16.7
Philips	3	0	1	25.0	0	16.7

Source: Dataquest (April 1995)

For More Information...

Sue Kapoor, Market Research Analyst.....(408) 437-8505
Internet address .....skapoor@dataquest.com
Via fax.....(408) 437-0292

Dataquest®

A company of The Dun & Bradstreet Corporation

Dataquest®

a company of
The Dun & Bradstreet Corporation

Corporate Headquarters
Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 1-408-437-8000
Facsimile: 1-408-437-0292

Dataquest Incorporated
Nine Technology Drive
Westborough, Massachusetts 01581-5093
United States
Phone: 1-508-871-5555
Facsimile: 1-508-871-6180

European Headquarters
Dataquest Europe Limited
Holmers Farm Way
High Wycombe, Buckinghamshire
HP12 4XH
United Kingdom
Phone: 44-1494-422722
Facsimile: 44-1494-422742

Dataquest GmbH
Kronstadter Strasse 9
81677 München
Germany
Phone: 49-89-930-9090
Facsimile: 49-89-930-3277

Dataquest Europe SA
Immeuble Défense Bergères
345, avenue Georges Clémenceau
TSA 40002
92882 - Nanterre CTC Cedex 9
France
Phone: 33-1-41-35-13-00
Facsimile: 33-1-41-35-13-13

Japan Headquarters
Dataquest Japan K.K.
Shinkawa Sanko Building, 6th Floor
1-3-17, Shinkawa, Chuo-ku
Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

Asia/Pacific Headquarters
7/F China Underwriters Centre
88 Gloucester Road
Wan Chai
Hong Kong
Phone: 852-2824-6168
Facsimile: 852-2824-6138

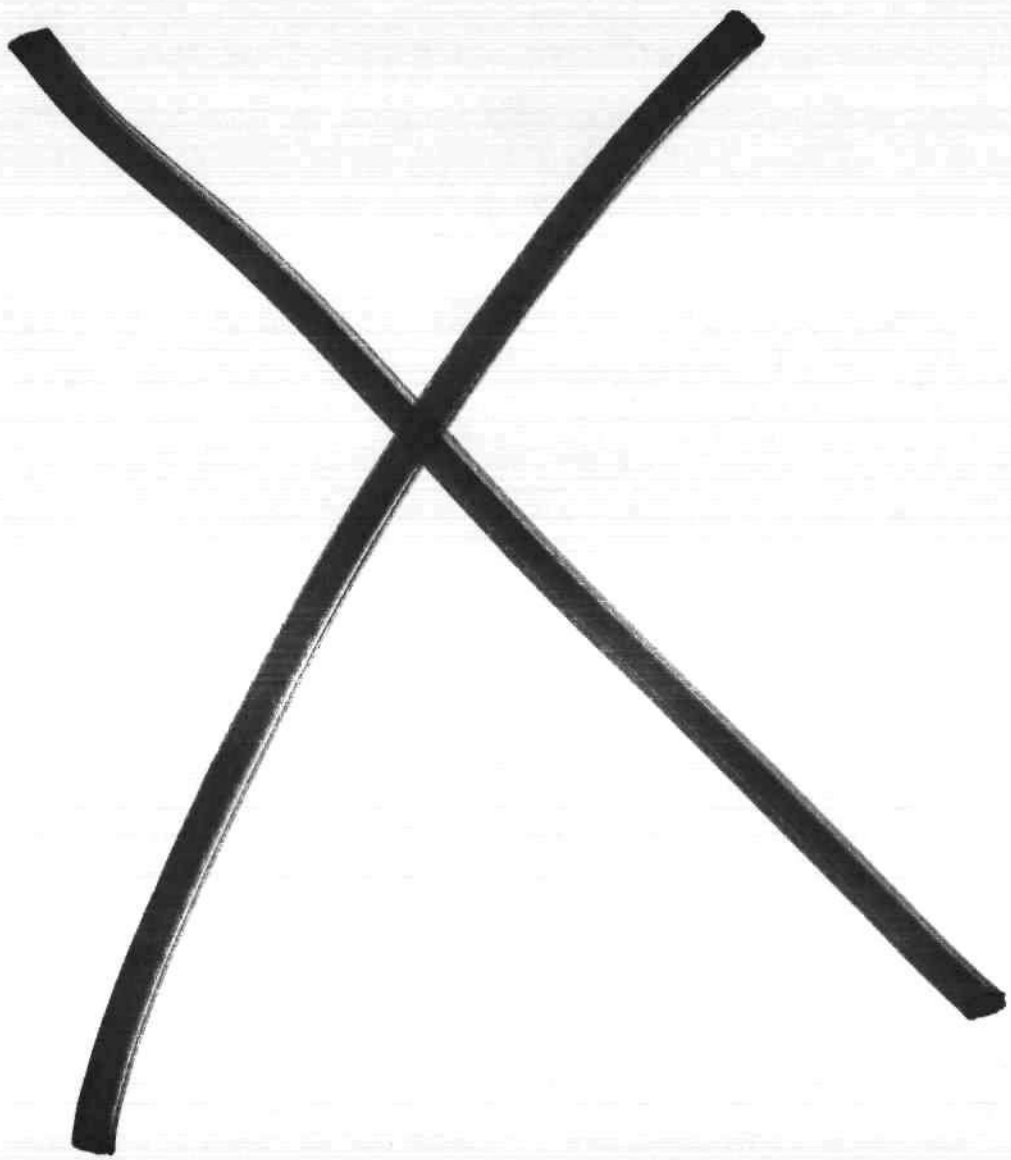
Dataquest Korea
2506 Trade Tower
159 Samsung-dong
Kangnam-gu, Seoul 135-729
Korea
Phone: 822-551-1331
Facsimile: 822-551-1330

Dataquest Taiwan
3/F, No. 87 Sung Chiang Road
Taipei 10428
Taiwan, R.O.C.
Phone: 8862-509-5390
Facsimile: 8862-509-4234

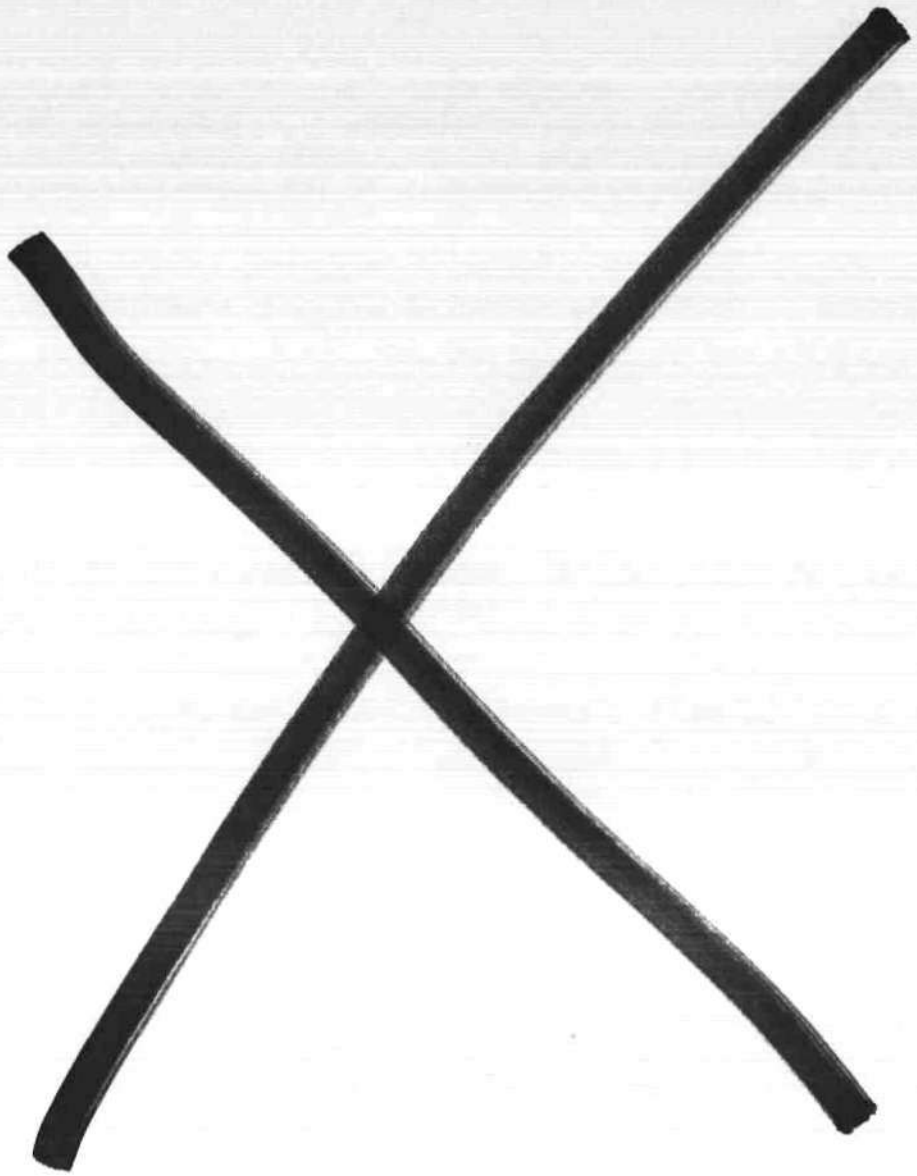
Dataquest ICC (conferences)
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: 1-714-476-9117
Facsimile: 1-714-476-9969

Other research offices in Beijing, Singapore, and Thailand

Sales agents in Australia, Belgium, Germany (Kronberg), Israel, Italy, South Africa, and Spain



Dataquest

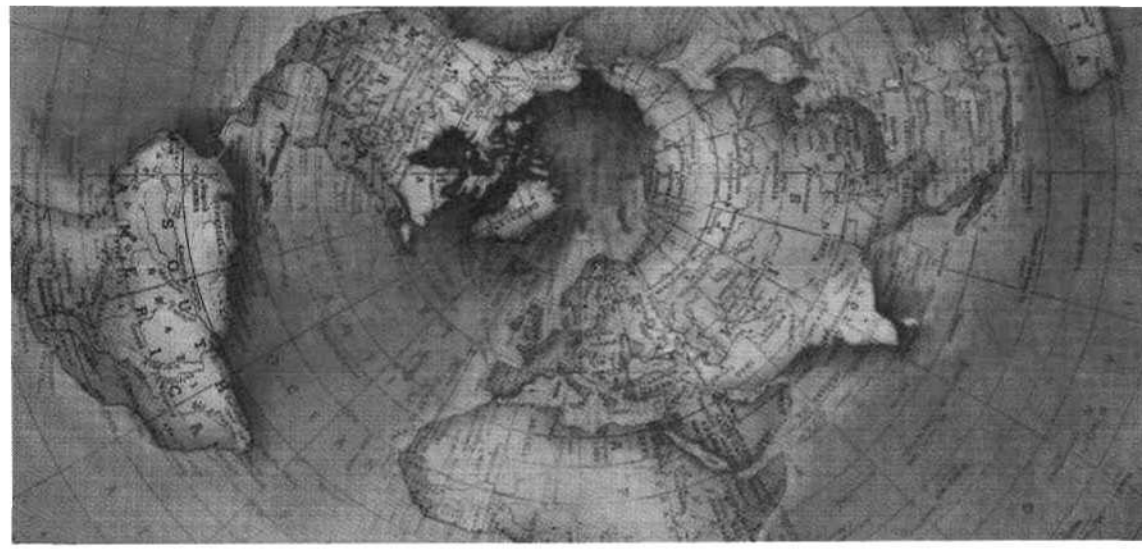


Dataquest

Focus Studies

Dataquest

Focus Studies



Memories Worldwide

Focus Analysis

How Windows 95 Will Impact Today's DRAM Shortage

Abstract: *There is quite a bit of concern about the impact of Windows 95 on the DRAM shortage we have been seeing for the past three years. What should DRAM suppliers and users expect?*

This newsletter is divided into three parts. The first part is a round-table discussion of the effects of the Windows 95 environment on the user as seen by several Dataquest analysts that have used beta-test versions of the product. The second part shows the result of certain speed tests in a static hardware environment with variable main memory sizes. The third part is a republished recent Dataquest Alert written by two of our key software and PC analysts (Rob Enderle and Kimball Brown) that discusses Microsoft's rollout of the Windows 95 operating system.
By Jim Handy

Part I: Windows 95 Round-Table Discussion

Dataquest recently held a round-table discussion about the main memory requirements of the Windows 95 operating environment. The following section is a transcript of a conversation among Dataquest's panel of experts in Dataquest's PCs, Operating Systems, and Multimedia services, many of whom are using beta-test copies of Windows 95.

Dan Lavin (Senior Industry Analyst, Personal Computing Software Worldwide): I'm getting a lot of feedback that 4MB RAM is not enough to run Windows 95 effectively. This is a critical issue in our Multimedia/Windows 95 report (MULT-WW-PD-9501, published May 29, 1995). If 8MB is needed, then there is a significant upgrade issue.

Ron Bohn (Senior Industry Analyst, Memories Worldwide): I'm not sure there's anyone to disagree on the 8MB issue. The impact will be that those who haven't already upgraded to Microsoft Office, for example, will

Dataquest

Program: Memories Worldwide
Product Code: MMRY-WW-FA-9502
Publication Date: August 14, 1995
Filing: Focus Studies

upgrade. This could provide lots of revenue for the DRAM manufacturers, but could also serve to exacerbate the current undersupply.

Pat Cox (Senior Market Analyst, Research Operations): It seems that there are three RAM questions:

- Do you need 8MB to run multimedia applications in Windows 95? It sounds like the answer to that is probably yes. (By the way, the Dataquest multimedia-capable computer definition specifies a minimum of 5MB of RAM.)
- How many people are likely to spend the money to upgrade to 8MB or already have at least 8MB?
- Will there be enough RAM available for those who want to upgrade?

Mario Morales (Market Research Analyst, Research Operations): Windows 95 will be able to run with about 4MB of RAM (That was one of the objectives that the software engineers were aiming for in Windows 95), but when you begin to include multimedia, object linking and embedding (OLE), and games, the requirement for memory will easily exceed 8MB. Most industry experts believe that the most common memory size for Pentium machines will be about 14 to 16MB by the end of 1995. I believe that most machines running Windows 95 will be shipping with at least 16MB of DRAM by the end of 1995 and early 1996.

The Memories Worldwide group forecasts a DRAM shortage going into 1997. Because PCs represent about two-thirds of DRAM consumption, I do not see any relief in prices or availability for users that want to upgrade their PCs, especially when buying through the spot market. For 1995, I believe prices for DRAM will increase to equilibrate the demand-versus-supply curve. Also, the appreciation of the yen will put pressure on Japanese DRAM suppliers to increase prices. The Memories Worldwide group does not see the DRAM demand slowing down anytime soon.

Jim Handy (Director/Principal Analyst, Memories Worldwide): DRAM manufacturers want to hear how Windows 95 will impact the demand for DRAM per system sold. Most worry that delays will cause an oversupply of DRAM. Oddly enough, one inquirer asked if the average memory size of a PC was likely to drop, because the virtual memory model could do more work using less DRAM! So far, the Memories Worldwide service has taken the stand that DRAM consumption would continue to rise through the near term, even if Windows 95 slipped out to 1997.

There is a misconception some of my clients hold that would make them disagree with the statement that 8MB is the right size. They believe that Windows 95 is based heavily upon Windows NT. As far back as in 1993 users complained that performance of NT was insufferably slow unless you used at least 16MB. Based on this assumption, 16MB would be the number forecasters should use as the ideal main memory size for Windows 95.

Rob Enderle (Senior Industry Analyst, Client/Server Software Worldwide): Let me comment on this association between Windows 95 and Windows NT. There is no truth to the notion that Windows 95 is a by-product of Windows NT. Windows 95 was developed by a different team. Although both products are being merged over time, the design goal for Windows 95,

which was met, was to run as well as 3.1 on the same systems. This means that Windows 95 will run as well as Windows 3.1 on 4MB of memory – that is to say it will run very badly. As others have pointed out, if the systems are being used to run any large application, such as Word, for instance, users have likely already upgraded their memory to 8MB. However, if they really want to use the advanced multitasking feature of Windows 95, they will quickly want 16MB. With Windows 95 the perceived performance increases dramatically with additional memory, and I too believe there will be a shortage of memory chips in the fourth quarter.

I do agree this will drive DRAM, lots of it.

Handy: Just remember to let your clients know that the cost per megabyte at the OEM level is now anticipated to be $25 or more through 1995 and into 1996.

Bruce Ryon (Director/Principal Analyst, Multimedia Worldwide): We'll test this in the *Home Multimedia User Wants and Needs* report for this summer on the likelihood of home multimedia users upgrading to Windows 95. But my sense is that $300 to $400 street prices to upgrade RAM will be a significant deterrent. The only driver for home users to upgrade will be pressure to have an equivalent system at home for work.

For new home multimedia sales, I believe people will opt for Pentium or a color printer over Windows 95. To do both is a real stretch at an extra $500 to $700 investment for not a lot of advantages, especially if everything is already preconfigured.

The home market is extremely price-conscious. I do not believe people are going to find a better interface and plug-and-play all significant purchase drivers. Apple's Macintosh would have won out a long time ago if that were the case. I believe the home market will be purely early adopters going to Windows 95.

Handy: I had heard that there would be some cost to upgrade to Windows 95, but I didn't believe you could put a $300 to $400 price on it.

Karl Wong (Director/Principal Analyst, Workgroup and Personal Computing Software Worldwide): I dare to say Bruce may be right about the upgrade price. In addition to the memory upgrade costs (about $120 for 4MB), the cost of Windows 95 itself (more than $100), and maybe a new video board (Windows 95 really likes SVGA – another $100 to $200), you get up there very fast. This is not factoring in a new hard drive ($0.50 per megabyte) because most of the programs are larger with Windows 95, and maybe a new HDD controller to handle the new E-IDE or SCSI large-capacity drive.

We included a question on Windows 95 migration and awareness as well as OS/2 in our survey of consumers. We have some interesting results.

Ryon: Pricing is a make-or-break factor in the consumer market. We'll get more data when we review the survey.

Andy Baul-Lewis (Online Multimedia and Software): I'll add some comments from OMAS and a European Perspective. Note: Please do not miss our comments on the application programs. This is an important consideration to the users, over and above the Windows 95 decision.

Microsoft design teams have hit the "run as fast on 4MB as 3.1" target. You can run it at 4MB. This issue would have been well known by now among the beta sites if it didn't even function on 4MB.

The operating system is optimized for 8MB to 16MB. The performance peak is basically about 16MB. After 24MB there is little gain (just as Windows 3.1 has little gain in performance after 12MB).

The immediate upgrade to Windows 95 will involve a large bulk of the Installed Windows 3.1 base. But the full Windows 32 application programs will take longer to follow on, and so the users will get a gain from simply upgrading if they've got 8MB and higher.

Another trend in business application programs is that the suites are becoming a little "slimmer" than they used to be. Novell has a lot of joint-code in PerfectOffice (and Microsoft and Lotus, among others, are set to follow). This could over the long term mean less RAM use and possibly an easier switch into OLE and other connections between application programs and files. But what probably will happen is less or the same RAM needed by today's application programs, but more and more application programs-per-PC running will increase RAM demand.

When the full-blown Windows 32 application programs hit the streets in late 95, this will help up the Windows 95 upgrade rate, and to up the RAM demand.

Note: If this happens later in Europe (as expected with staggered language rollouts), then the European DRAM demand will lag a little behind the United States.

Microsoft wants to maximize its returns on its already well-overbudget development costs. It will want to get Windows 95 onto anything that moves, regardless of RAM, so demand for RAM increases on new PCs is likely to come from the hardware players first (in time) that do not want their machine to look slow, and from the installed base (the upgrade business is second in time, but larger in the first six to nine months).

The DRAM players should play the "you need more than 8MB RAM" game to run Windows 95 strap-line from day one, like now—it's their marketing budget, it's their opportunity. People are half expecting this, whether or not it turns out to be true.

Users and buyers will now want to start getting ready for the "Great Upgrade."

Handy: Who is likely to do (or has done) a benchmark on Windows 95 running the same software on the same system with different sizes of main memory?

Martin Reynolds (Director/Principal Analyst, PC Technology Directions): I have prepared a brief report on using Windows 95 in 4MB, 8MB, and 12MB configurations. (An excerpt of the relevant parts of Mr. Reynolds' analysis is in the second part of this newsletter.)

The conclusion is that 4MB is a counting horse (yes, it can be done, but what good is it?), 8MB works, and 12MB is a useful improvement.

Ryon: I received a beta copy of the March version of Windows 95 recently and have been using it frequently as a part of a report I am writing now. I have 12MB on my system now and it runs just as slow if not slower than Windows 3.1. I really believe I will need 16MB.

I realize I am not running Windows 95 optimized applications, but this thing is nothing special. It is really warmed-over Windows 3.1 from an interface standpoint. Most of the improvements seem to be in the integration of the File Manager. I do not believe Apple has much to worry about.

Reynolds: This is not my experience at all... the system that I have is really quick with Windows 95, subjectively faster than Windows 3.11.

I did have to mess with it to get it right, though. You may want to check the performance section in the control panel:

- I had to work with the control panels to strip out some stuff that I had put in (network, among others) and to compensate for loading with 12MB of memory and then backing down to 4MB.
- My systems tend to be oddball. The average garden-variety Compaq or IBM or other with mainstream peripherals will load and run just fine. The big catch is the need to have 8MB of memory and no backward path.
- A lot of multimedia stuff will work, and a lot of older stuff will not. Doom and Magic Carpet came up with absolutely zero effort. That is quite unusual. An NDA MPEG player that I have couldn't see the CD-ROM drive well enough to execute.
- Once the 8MB hurdle is over, the consumer will upgrade. Windows 95 is really fast and its handling of DOS stuff is pretty good.
- The March release of Windows 95 has certain really stupid bugs that I haven't been able to look for yet in the released version of the program. PowerPoint slide sorter, for example, doesn't display the text on many of the slides after you look at them. Still, I have great faith in Bill Gates' affinity for upgrade revenue and expect this thing to pop successfully in the fourth quarter.

I agree that Apple doesn't have much to worry about. Frankly, if the interface is so superior (and it mattered), it would be a lot more than 10 percent of the market. Conversely, a better interface in Windows won't kill the Mac – that is something that Apple will have to do.

Ryon: I totally agree that interface doesn't matter and if it did Apple should have a much greater market share.

You tell me that you had to fiddle with the control panels. Rob tells me I have to be aware of the 32-bit drivers. This tells me this isn't an OS for the

masses. I got a CD from Microsoft and let it load by itself. The fact that it didn't do performance tweaking on its own, which it seemed to suggest it was doing during the install phase, says a lot.

The other problem with Windows 95, especially with multimedia titles that modify the autoexec.bat and config.sys files extensively, is that now that DOS is a task under Windows rather than the other way around, I do not know how to work things so I can run them. I now have to do the research on whether I can run them and how to make the tweaks. I believe developers will have a huge support hit, once Windows 95 ships, to deal with people who upgrade and now want to run everything they had before.

I believe these optimistic projections on Windows 95 upgrades in the consumer market are worrisome. I believe the word on the street will be to wait, and only upgrade if your company forces you to by going to those Windows 95 application programs you really need to have on your home system.

Enderle: You can't jump to conclusions, however, based on what appears to be an early impression. My own testing, which seems to be more comprehensive, indicates improvements over Windows 3.1 in all areas, including games (and I run a lot of games), and you have not taken into account the $100 million Microsoft fourth-quarter marketing budget nor other related budgets. I've been working with this platform for three months now and I assure you that my projections are for widespread adoption.

Part II: Windows 95 Memory Requirements

- Windows 95 can run with 4MB memory, but the performance is unlikely to be acceptable.
- A 4MB memory upgrade (to 8MB) is very desirable, making the system more usable.
- New systems running Windows 95 should not ship with less than 8MB of memory.

The Test System

Dataquest's test system was set up as follows:

- Processor—Intel 486 DX4/100
- Cache—256KB write-back
- Motherboard—Micronics LX30WBVL (house-marked SIS472 chipset)
- Hard drive—WD 720MB EIDE
- Hard drive controller—Suspected CMD VL-to-IDE enhanced controller
- Video—800x600 ATI Mach 32 VL
- Sound, network—None
- Windows 95 cache—242KB
- Windows 95—Current beta (as of April 1995)
- Office version—4.2

Micronics systems with the SIS chipset are typically faster than average systems. The on-board local bus IDE controller helps hard-drive performance significantly under Windows 3.11 and DOS, although Windows 95 suggested that we could improve performance with a Windows 95 driver.

For comparison, loading Excel on a Pentium/90 system running Windows 3.11 took 14 seconds; the 11 to 16 seconds taken in the Windows 95 tests on the 486/100 does point to some performance gains from Windows 95.

The Test

The test was simple. We timed the load process starting from the time when the message "Starting Windows 95" appeared on the screen to the time when the Microsoft Office icon bar was ready to accept the command to start Excel, and then to the time when Excel accepted a few keystrokes. We also waited for all swapping to stop and then loaded Word through the Office icon bar. We judged Word to be ready when it recorded a few keystrokes that we stacked up while it was loading. The test was performed for 4MB, 8MB, and 12MB configurations. Table 1 shows the results for the three memory configurations.

Table 1
Load Times under Windows 95 for Various Memory Configurations (Seconds)

	4MB	8MB	12MB
Load (to Office)	127	66	63
Load Excel	119	16	11
Stop Swapping	15	3	2
Add Word	96	23	14

Source: Dataquest (April 1995)

Initially the disk cache was set to over 1MB, leaving less than 2.6MB for Windows 95 in the 4MB configuration. Windows 95 would load and run, but it never stopped swapping to the disk drive. We note that it did not crash; this is significant as excessive swapping is quite stressful to the software and can expose weaknesses.

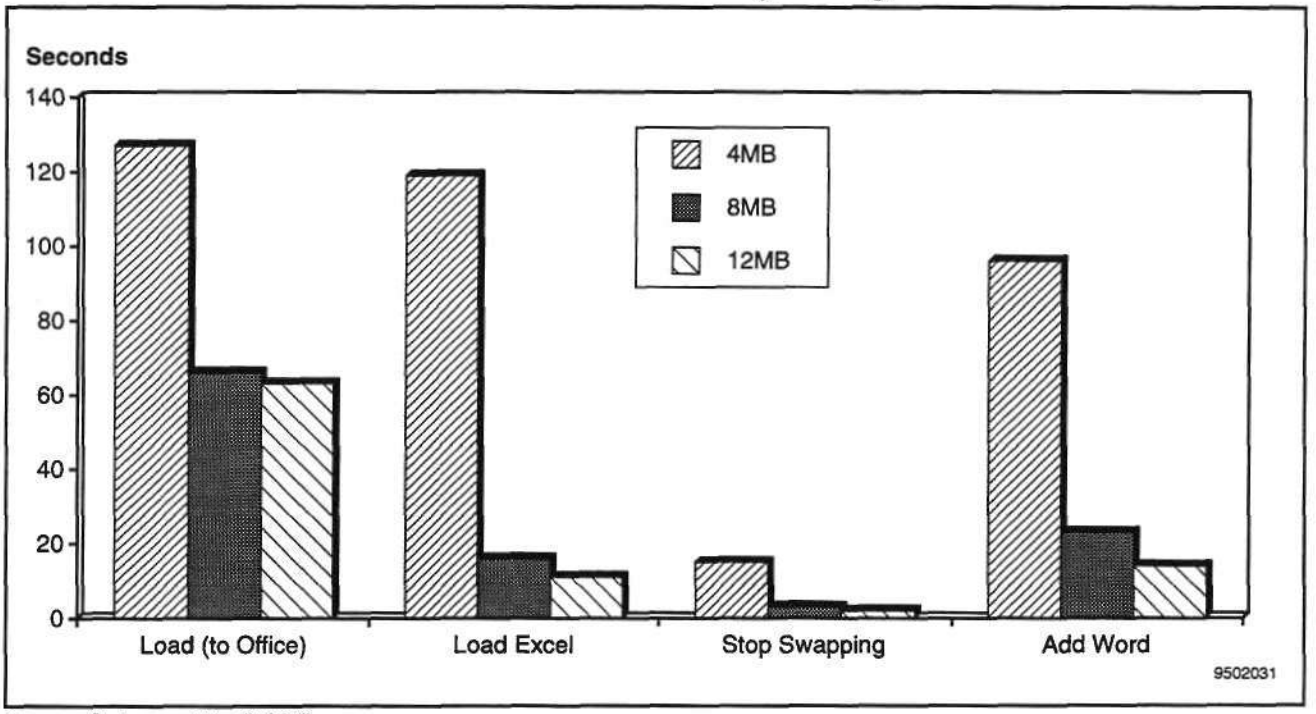
Windows 95 has a system performance section, located in the system icon in the control panel. When running with 4MB, Windows 95 suggests the addition of more memory as an option to improve performance. It does not make this suggestion when running with 8MB of memory.

Our Conclusions

The test results are shown in Figure 1 in a graphical form.

Clearly, the load times for Windows 95 running in 4MB of memory border on the unacceptable given the dramatic improvement in the 8MB memory configuration. Although a single application is useful once loaded, we suspect that any attempt to run a second task would result in extensive swapping. The 486/100 and fast disk drive used in the test system provide perhaps better results than many installed machines could deliver,

Figure 1
Load Times under Windows 95 for Various Memory Configurations



Source: Dataquest (April 1995)

although a Windows 95 system tuned to run with 4MB of memory could do a little better.

Therefore, we must conclude that for all practical purposes, a Windows 95 machine must be configured with 8MB of memory.

We also conclude that 8MB is adequate for many users. The 30 percent improvement in application load time achieved by going to 12MB is desirable, but not as essential as the transition from 4MB to 8MB.

As a side note, the Windows 95 HDD cache memory allocation is dynamic. It can use more or less memory for disk cache as required. Unlike Windows 3.1, the machine is therefore much less sensitive to the cache size setting, alleviating the classic upgrade problem of balancing the cache against the installed memory.

This memory requirement has significant connotations for the upgrade market. Our experience with Windows 95 is that, once loaded, it is very difficult to step back to Windows 3.11. Both DOS and Windows directories are overlaid with new, incompatible drivers and utilities; recovering the originals is a lengthy and time-consuming process, best addressed by a clean-off and complete reload of the system. (Note: Microsoft advises us that the ship version will include an uninstall feature; however, our suspicion is that most users will want to buy the extra memory to run Windows 95. Whatever else is said about it, it is a very nice enhancement to Windows 3.x.)

Therefore, an end user who upgrades a 4MB machine to run Windows 95 is likely to be forced to upgrade to 8MB of memory simply to be able to use the machine. This factor is likely to result in strong demand for upgrade memory at the retail level. As users will pay more for system memory than systems manufacturers do, there is likely to be continued support for higher memory prices, and systems manufacturers must take steps to secure an adequate supply of memory at prices that enable them to compete.

Rambus

This experiment underlines an interesting opportunity for a Rambus-based design. The significant performance step from 8MB to 12MB suggests that a 12MB Pentium system would be desirable. This memory size, between 8MB and 16MB, is difficult for system manufacturers to achieve because of the granularity of main memory and the need to use an even number of SIMMs in a Pentium system. The Rambus architecture, however, allows for these odd configurations without compromising performance.

Dataquest Perspective

Users of current machines configured with 4MB will want to move to 8MB when they purchase Windows 95. The pressure from the upgrade base, coupled with the need to go to 8MB at first shipment, will serve to keep demand high. Analysis from the memory service at Dataquest indicates that supply will continue to be inadequate to satisfy the market, resulting in stable or only slowly dropping prices.

Part III: Microsoft Begins Manufacturing Windows 95

Microsoft began manufacturing Windows 95 on Friday, July 14, 1995. This date officially begins the final countdown to actual product sales on August 24.

From here Microsoft begins filling the channel, and Saturday July 15 is the first day that Windows 95 can be sold to retail channels and presold to end users. To kick this off, QVC, the television shopping network, will be having a three-hour Windows 95 sale during prime Saturday afternoon shopping periods. To our knowledge this is the first time a software product has been sold exclusively by QVC for this length of time during a prime period.

Software developers can now begin testing on the final Windows 95 code, and many should be able to meet their own deadlines for having Windows 95 product in the market by October 1995. We expect that an inability to meet this date with a solid offering will result in substantial shifts in market share in certain segments and that the impact of this launch will have a profound effect on the PC Software market, and the public perception of that market, for years to come. A solid demo of what is coming can buy a vendor a few additional months.

At this time we are holding to our forecast of nearly 30 million copies of Windows 95 shipped in 1995, as published in our "Operating System Top-Level Statistics" report (CSSW-WW-ML-9503). More detail surrounding the launch of Windows 95 can be found in "Race to 95: A View of Microsoft" (CSSW-WW-RB-9501). We should point out that we expect over 3 million copies of Windows 95 to be installed prior to August 24 and that, as we

predicted in December of 1994, key corporate accounts can now receive the final Windows 95 version.

Viewpoint from PC OEMs

Microsoft had promised to freeze the Windows 95 code in June, according to OEMs. First it was June 23, then it slipped to June 30. In fact, the beta version dated June 30 was the first that carried the build number of 950 (Windows 95, get it?). However, the build that shipped on July 7 was also called "build 950" but was actually revision 3 of the final code.

This delay of two to three weeks has been troubling for OEMs. With delivery of the final code, OEMs can now begin testing it. They also need to troubleshoot the interaction between the final code and the preinstalled applications and utilities that ship with the computer. Most OEMs should complete this in short order, but the ones with dual boot option—or, worse yet, with triple boot options (IBM?)—will have a harder time with the testing. We do not recommend a dual boot strategy; rather, we recommend that users be given the choice at the initial boot, with the operating system not chosen being deleted from the disk drive.

OEMs' inventory cycles will also impact when products with Windows 95 can reach customers. A company such as Dell with very few finished goods and the ability to preload software ordered by the customer just before shipment will hardly be affected at all by the late availability of the final code.

However, a company such as Compaq will probably be put at a competitive disadvantage in retail channels with the transition to Windows 95. Because Compaq's inventory turns are just over four times per year, months pass before Windows 3.11-based PCs pass through the channel and allow Windows 95-based PCs to be put on shelves. If the code had shipped in June, Compaq could probably have weathered the storm. However, with the half-month slip, the company has five weeks rather than the seven or eight it had expected to test and transition the manufacturing operation to produce Windows 95-based PCs. In the business market, this is hardly a problem. Most businesses will transition to Windows 95 over months or years. The home market is where the problem is.

We have found that Windows 95 is very stable once correctly installed. The betas in March left much to be desired, but the most recent versions have improved radically. Although Windows 95 code is stable, the upgrade process from Windows 3.11 is not without problems. Often, peripherals will not work without further tweaking or adjustment. Some applications also need tweaking before they work. The new user interface takes some getting used to as well. With Windows 95 preinstalled, a tutorial can instruct the user through much of this.

We believe many novice PC users will want to upgrade to Windows 95 as soon as possible—not a huge percentage of users, but a large number. The new user interface is exciting and more user-friendly. The early advertising for new 32-bit applications coming in the fourth quarter should also drive users to the new operating system. Compaq recently stated that its Presario (read "home PC") line will not have Windows 95 preinstalled on August 24 when general availability for end users starts. As a result, many proud

Presario buyers will drop by Egghead, CompUSA, or another store to buy the upgrade. Technical support lines will light up at Microsoft and Compaq. If the buyer has problems (and we expect many will), having to manually upgrade, rather than having Windows 95 preinstalled on the system, will detract from the user's buying experience and will also distract Compaq during the all-important fourth quarter in the retail market. This is far from a disaster for Compaq. It should move Windows 95-based PCs into the channel only a few weeks late, but we expect the delay to be troublesome nonetheless.

We recommend that all OEMs aiming their products at the retail channel convert to Windows 95 preinstalled on their system as close to the August 24 date as possible. We expect a very strong retail season for PCs this fourth quarter, and OEMs need to make this transition as smoothly as possible. Negative sentiment resulting from a botched transition will push the fickle home buyer to opt for another brand.

MMRY-WW-FA-9502 Qty: 1
Mr. Joe Grenier
Dataquest Incorporated
1-1100
.,
--INTERNAL DIST.--

For More Information...
Jim Handy, Director/Principal Analyst..... (408) 437-8228
Internet address..... jhandy@dataquest.com
Via fax..... (408) 437-0292

Dataquest
a company of The Dun & Bradstreet Corporation

Focus Studies

Memories Worldwide

Focus Analysis

Dataquest's Forecast of the Acceptance of New DRAM I/O Structures

Abstract: *Dataquest expects to see substantial changes in the DRAM market. While EDO is going to sweep the market, many other interfaces, namely Rambus, EDRAM, and CDRAM, will only make nominal inroads. Dataquest also believes that the key factors for success in the market revolve around cost and multiple sourcing, rather than technology and sheer speed.*
By Jim Handy

With all of the new DRAM I/O structures floating around, it's sometimes hard to figure out where the world is heading. Dataquest is often consulted by DRAM manufacturers that are trying to make key decisions about which breed of part they should introduce first. This is a reasonable need. Had any manufacturer targeted the 1Mx16 version of the 16Mb DRAM, rather than the more traditional 16Mx1 and 4Mx4, as the first design it should debug, that company would currently be riding on a wave of popularity. Instead, there is a current shortage of the 1Mx16 DRAM, and a slight over-supply of the 16Mx1 device.

What's driving all of these changes? There are several forces working in conjunction to cause designers to modify the ways they use DRAMs. On the main memory side, you have the spiraling clock speed of the CPU, and the need to refill a primary cache line as quickly as possible after a cache miss. This means that the DRAM not only needs to be fast, but it also has to match increases in data bus widths, which CPU designers use to get more data into a 32-bit CPU in less time. This drives increasing width on this side. In graphics applications, width and speed are being driven by totally different mechanisms: the growing use of graphical user interfaces (GUIs), which drives a need for high-resolution screens, with the development of

Dataquest

Program: Memories Worldwide
Product Code: MMRY-WW-FA-9501
Publication Date: March 13, 1995
Filing: Focus Studies

highly sophisticated graphics accelerators. The display and the graphics accelerator compete for bandwidth out of the frame buffer. This situation is difficult enough to address now and promises to become even more difficult in the future with widespread use of 3-D graphics, which dramatically increase the bandwidth requirements of the graphics processor to frame buffer channel, and with the advent of video-based multimedia, which puts massive bandwidth through all parts of the graphics display channel.

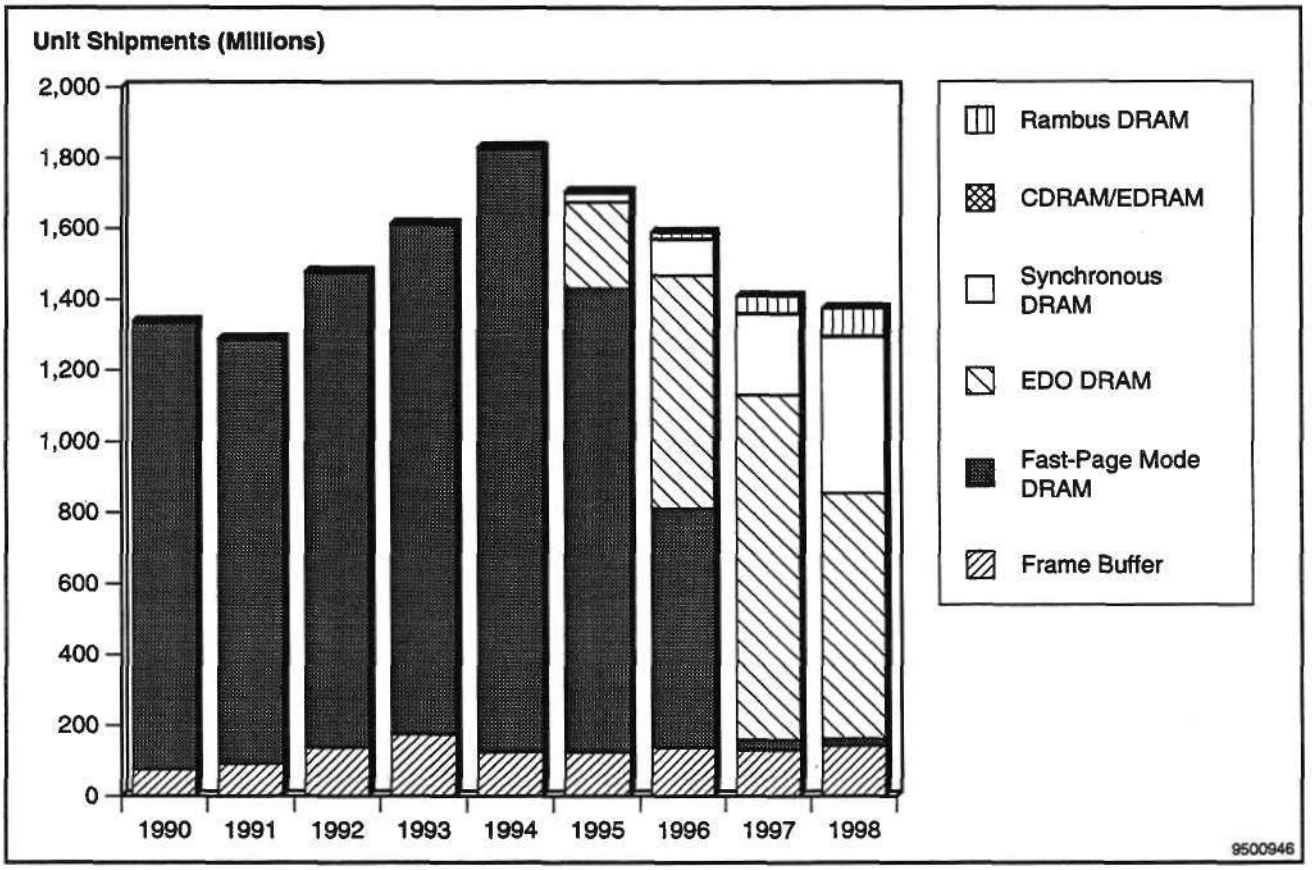
Dataquest conducts ongoing interviews with companies on all sides of this equation, DRAM manufacturers, DRAM users, and those who make chips that interface with DRAMs. The results of these interviews appear in the chart in Figure 1. We have found that the graphics design community expects to be the first to use new technology to improve performance while reducing costs. The market is represented by the lower portion of the curve, which we have titled "frame buffer" for want of a better name. This promises to be a turbulent field, and although we acknowledge the portion of the market represented by this need, we do not forecast the types of solutions that will be chosen to fill it. Today, a large portion of this bracket is composed of Video RAMs (VRAMs); however, designers express to us that they are eager to drop this technology in favor of less expensive solutions. We received some mixed signals in a prior survey with designers saying that they wanted to design out VRAMs in favor of synchronous DRAMs (SDRAMs) but looked forward to designing systems based on synchronous VRAMs! Dataquest has left out any conjecture about the prospects for the Window RAM from Samsung, Rambus DRAMs at only the 8Mb density (the reasoning behind this will be explained in the Rambus section), and the synchronous graphics RAM (SGRAM), which we expect to be produced by a number of sources. Other devices that are tailored to this category include Mitsubishi's new 3DRAM, a DRAM with built-in three-dimensional rendering hardware.

Asynchronous versus Synchronous

After graphics applications will follow main memory applications, which will harness whichever is the best technology at the lowest cost. We tend to look at these in two categories: synchronous and asynchronous. The two major categories can then be subdivided into several subcategories. In the asynchronous category, we count conventional fast-page-mode DRAM of any bit width, Extended Data Out (EDO) or hyper-page-mode DRAM, and other less widely sourced DRAMs like the Ramtron Enhanced DRAM (EDRAM) and the Mitsubishi/Samsung Cache DRAM (CDRAM). In the synchronous camp, we count standard synchronous DRAM (both single- and dual-banked), the Rambus interface (RDRAMs), the MoSys interface, and future standards that have not yet been sampled.

As a general rule, the decision of which memory to use is based more upon expected price than upon any other criterion. Designers want the most performance for the lowest cost and will often compromise the former for the latter. Perceptions of availability play an important part of the decision-making process here, because designers look at widely sourced devices and expect to get competitive pricing. This lessens the likelihood of success of sole-sourced products like the EDRAM and the CDRAM and even serves to hinder the acceptance of the Rambus interface, because designers, unaware of the royalty structure charged under a Rambus license, suspect that the use of a Rambus DRAM will force system costs to be uncompetitively high.

Figure 1
Worldwide DRAM Unit Shipments by Interface Type, 1990-1998

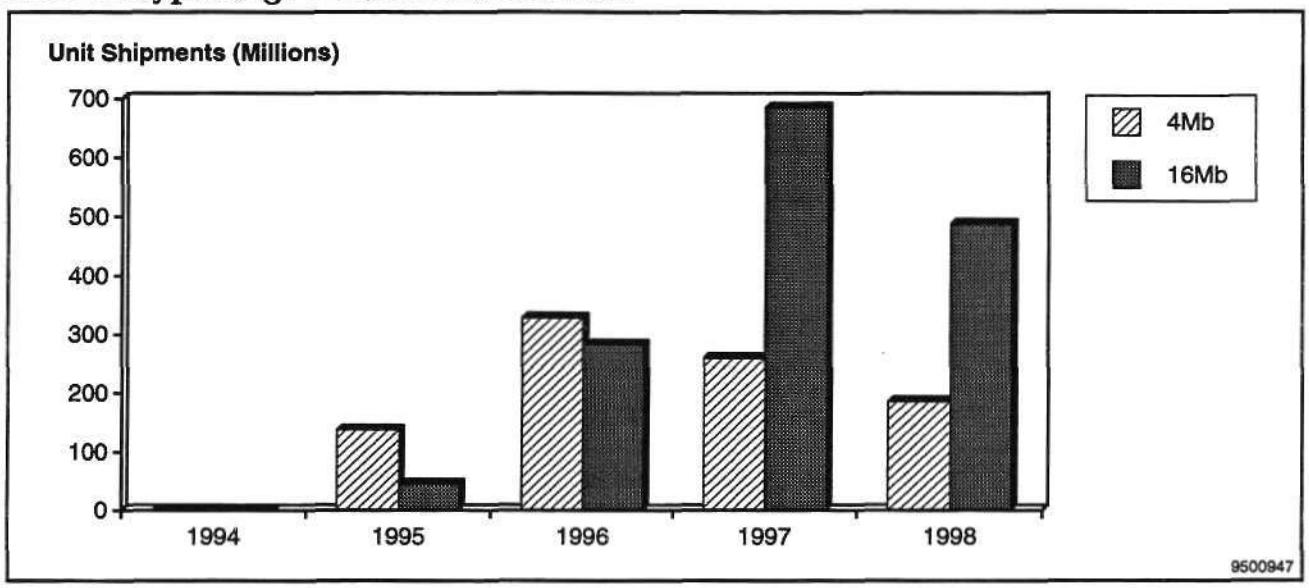


Source: Dataquest (February 1995)

In the main memory arena, Dataquest expects the EDO DRAM to sweep the asynchronous DRAM market in two years' time just as other similar interface changes like fast page mode have done in the past (see Figure 2). This enhancement can be easily used in any system, whether in graphics or in main memory, and comes at almost no die penalty. It doesn't take designers long to embrace a popular new standard once it is offered. The only question we have is why such a simple, low-cost enhancement was invented now, rather than 10 years ago.

By 1997 the production of standard fast-page-mode DRAMs will be converted largely over to EDO DRAMS. This acceptance is driven by the expectations on the designers' end that EDO will be offered in the near future at no additional cost, a stand supported by a number of DRAM manufacturers. The quick acceptance of EDO will serve to postpone the acceptance of the synchronous DRAM (SDRAM), because the speed limit posed by standard fast-page-mode DRAMs will be broken by EDO. Still, with the issues of refilling primary cache lines at the fastest possible speed, and with the constraint that continual bus-width doubling is not a viable option, systems using denser DRAMs will be forced into using one or another of the synchronous DRAM interfaces now being offered. All of these interfaces allow streams of addresses to be fed to the processor at a rate of either one or two addresses per clock, a very fast rate in comparison to how the data is

Figure 2
EDO or Hyper Page Mode DRAM Market



Source: Dataquest (February 1995)

handled by an asynchronous interface. Burst EDO is a new interface that appears to further the benefits offered by standard EDO, but we have studied this part for too short of a time to be able to take a shot at forecasting its potential for success.

Low-density DRAMs (4Mb) are already available in EDO and will play into the graphics niche nicely until parts of these densities are no longer made. Dataquest has estimated that 4Mb EDO DRAMs were sold at unappreciable quantities in 1994, ramping to 20 percent of units in 1995, to 50 percent in 1996, and to be all asynchronous sales that are not CDRAM or EDRAM in 1997 and 1998.

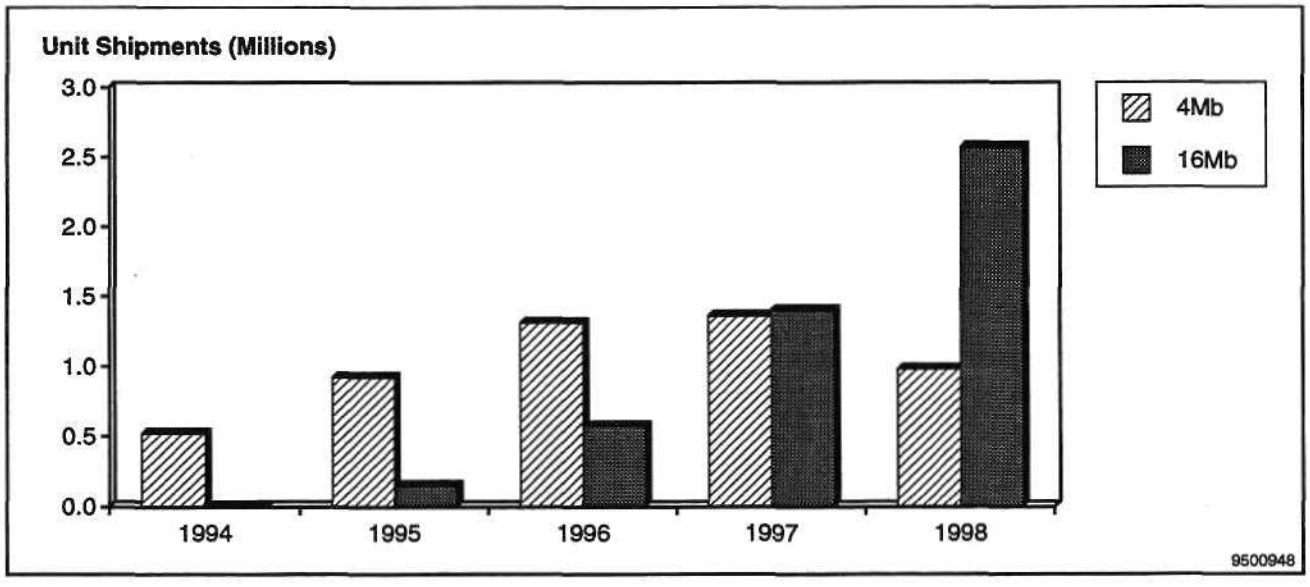
Sixteen Megabit EDO DRAMs are expected to make up unappreciable portion of asynchronous 16Mb DRAM sales in 1994, but to jump to 15 percent and then 50 percent of units in 1995 and 1996 and to sweep the portion of the asynchronous market not taken by CDRAM and EDRAM in 1997 and 1998.

At the top of Figure 1, we see relatively slow emergence of the devices that we found designers are somewhat skeptical of using, despite the fact that they overwhelmingly admire the technology used in these approaches. These are the Rambus interface, Ramtron's EDRAM, and the Mitsubishi CDRAM. Each of these will be discussed in turn.

CDRAM/EDRAM

We have lumped together two dissimilar interfaces, the EDRAM, which is sole-sourced by Ramtron, and the CDRAM from Mitsubishi and Samsung (see Figure 3). The reason for doing this is that neither is expected to make up a very large portion of the market.

Figure 3
Enhanced DRAM and Cache DRAM Market, 1994-1998



Source: Dataquest (February 1995)

At the 4Mb density, we anticipate these configurations to account for 0.05 percent of asynchronous DRAM sales in 1994, growing to 0.1 percent in 1995, 0.2 percent in 1996, and leveling off at 0.5 percent in 1997 and 1998.

At 16Mb, the portion of asynchronous DRAM units made up of CDRAM and EDRAM should follow similar percentages, but skewed by one year. We expect a level of 0.05 percent in 1995, 0.1 percent in 1996, 0.2 percent in 1997, and 0.5 percent in 1998.

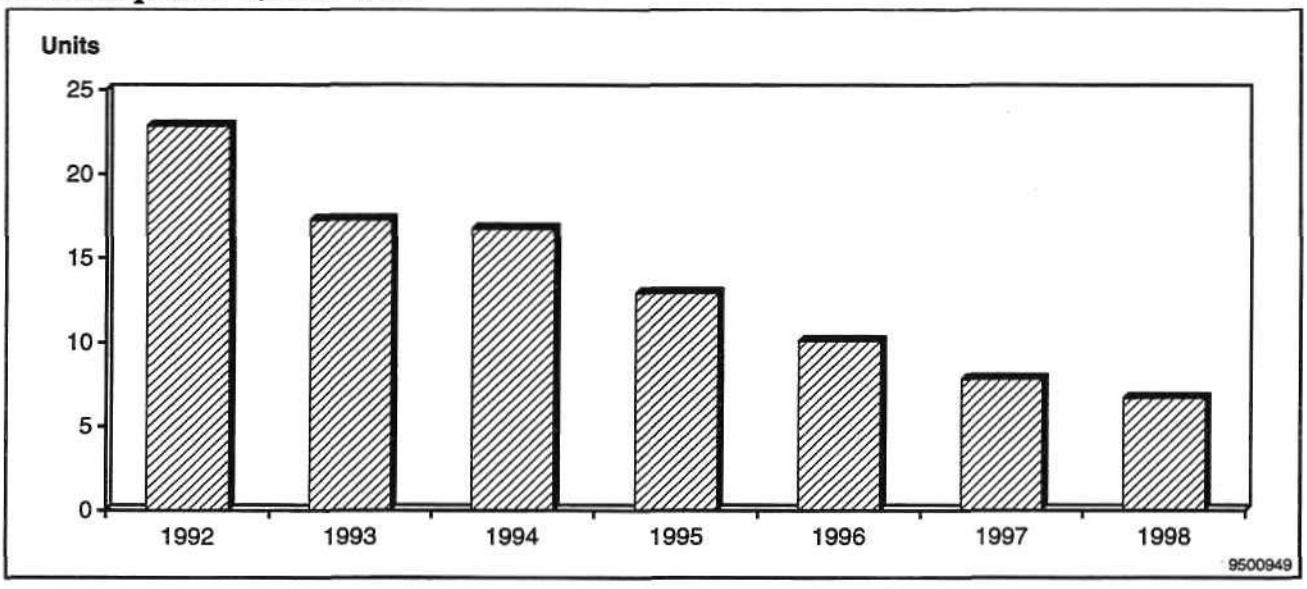
Dataquest does not anticipate the continuance of these interfaces into the 64Mb or 256Mb density.

Synchronous DRAMs

One difficulty addressed by the synchronous interfaces is the trend for fewer DRAMs to be used per CPU. Main memory sizes in any level of system grow far more slowly than do the densities of the DRAMs used to make up these main memories. One consultant, Steve Przbylski, contends that the main memory of any size computer grows at half the rate of the density increases of DRAMs. Assuming Moore's law, which asserts that DRAM densities quadruple every three years (which is really close to Dataquest's findings), then the amount of main memory per system should be expected to double every three years, and the number of DRAMs per system would be expected to be cut in half. Interestingly enough, when you take Dataquest's DRAM forecast of unit shipments for all densities combined, divide it by our forecast for 32-bit microprocessors (once again with all types combined), the resulting chart (see Figure 4) shows a decreasing trend in the number of DRAMs shipped per CPU.

In this situation, we would soon be faced with a need to use 64-bit wide DRAMs in a Pentium system, while the processor designers would be crying out for the need to move to a 128-bit bus to improve cache line refill

Figure 4
DRAMs per CPU, 1992-1998



Source: Dataquest (February 1995)

times. Instead, Dataquest expects processor designers to move to architectures that employ the burst capabilities of the SDRAM to emulate a multiplexed wide bus on a bus that might actually be no wider than 16 bits.

By the turn of the century, the synchronous DRAM will move toward replacing all asynchronous DRAMs, which will have been exclusively EDO since 1997.

All this boils down to the acceptance of synchronous DRAMs at the 16Mb density at a rate approaching 50 percent at the 16Mb-to-64Mb crossover and the nearly exclusive use of a synchronous interface at the 64Mb density. This shows in the synchronous portion of Figure 1; it really starts to grow in 1997.

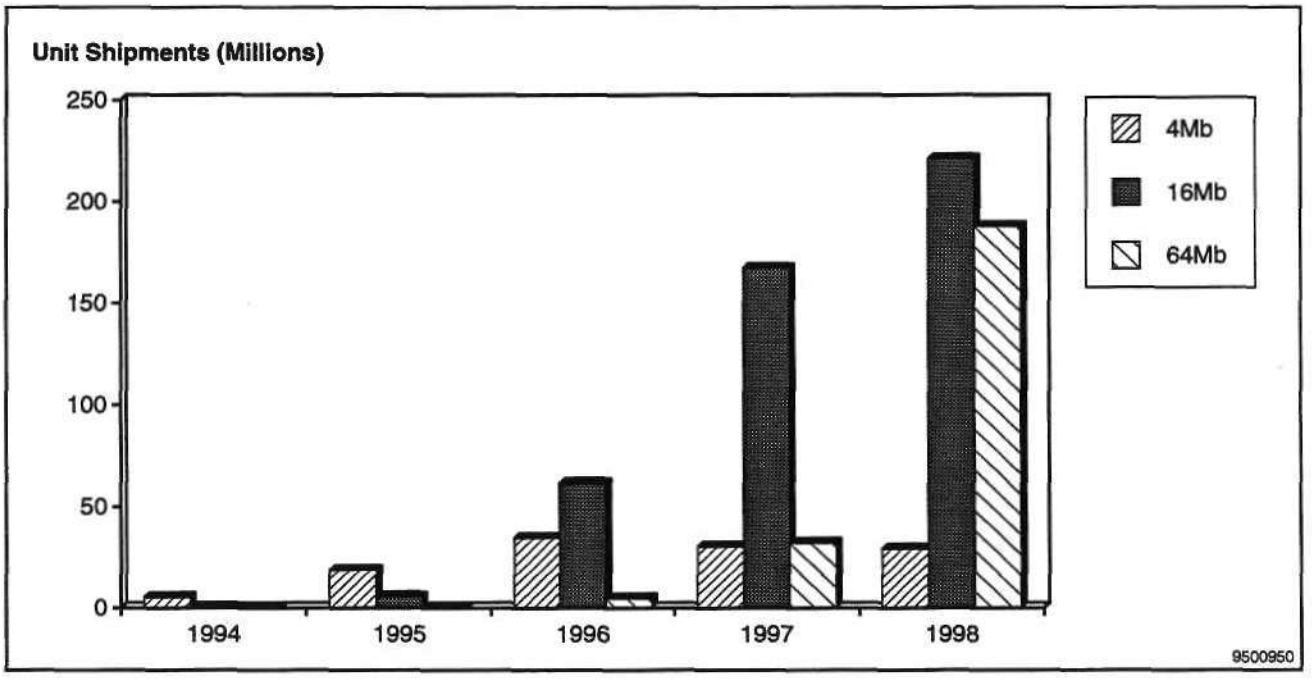
There exists a negligible market in games for a synchronous DRAM of a density lower than 4Mb, therefore it is not shown in the chart.

At the 4Mb level, synchronous shipments are expected to total about 0.5 percent of units in 1994, ramping to 2 percent in 1995, 5 percent in 1996, 10 percent in 1997, and 13 percent in 1998 (see Figure 5). A lot of this ramping will be attributable to the reduction in 4Mb density shipments into main memory applications.

At the 16Mb level, acceptance of the SDRAM will be considerably greater, moving from nothing in 1994 to 2 percent in 1995, 12 percent in 1996, 23 percent in 1997, and 35 percent in 1998.

Nearly all 64Mb and larger DRAM sales will be synchronous devices. Although the asynchronous interface might have an early false start at volume production, the synchronous device will predominate.

Figure 5
Synchronous DRAM Market, 1994-1998



Source: Dataquest (February 1995)

Rambus

Dataquest is not extremely bullish on the Rambus interface. This is from the perception of system designers that Rambus will not be a strong price competitor. Such perceptions, whether true or false, can hinder a device's acceptance.

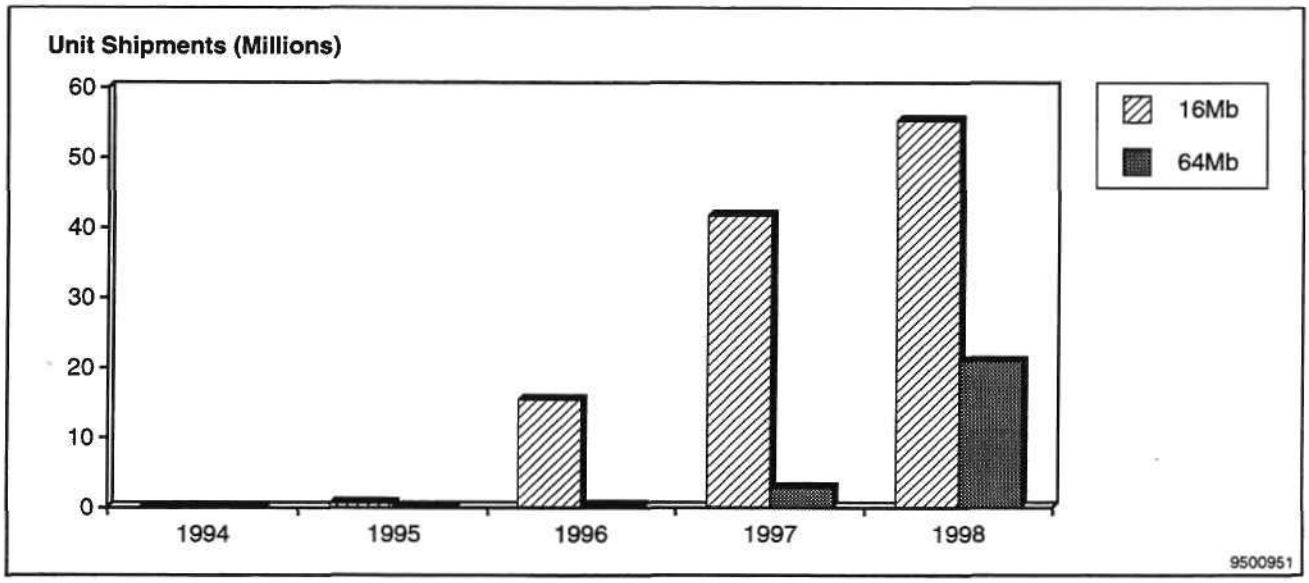
It is our expectation that by the turn of the century the Rambus and other less-accepted interfaces will make minor inroads into main memory applications, and that the interface will maintain a portion of the market that requires the use of specialized memories for the construction of the frame buffer in displays.

The recently-announced Rambus 8Mb DRAM is narrowly targeted at the frame buffer market, where designers need an even megabyte per color (24Mb), so we combine this device into the "frame buffer memory" category. Other densities should realize strong sales in main memory applications.

At the 16Mb density, we expect Rambus to comprise no more than 10 percent of all SDRAM sales in 1995 (see Figure 6). From 1996 through the end of the forecast, we expect Rambus DRAMs' penetration in the 16Mb SDRAM market to be a flat 20 percent.

At the 64Mb density, we anticipate a low acceptance of 5 percent of SDRAM sales in 1995, with sales increasing to 6 percent, 8 percent, and 10 percent in 1996, 1997, and 1998, respectively.

Figure 6
Rambus DRAM Market, 1994-1998



Source: Dataquest (February 1995)

Dataquest Perspective

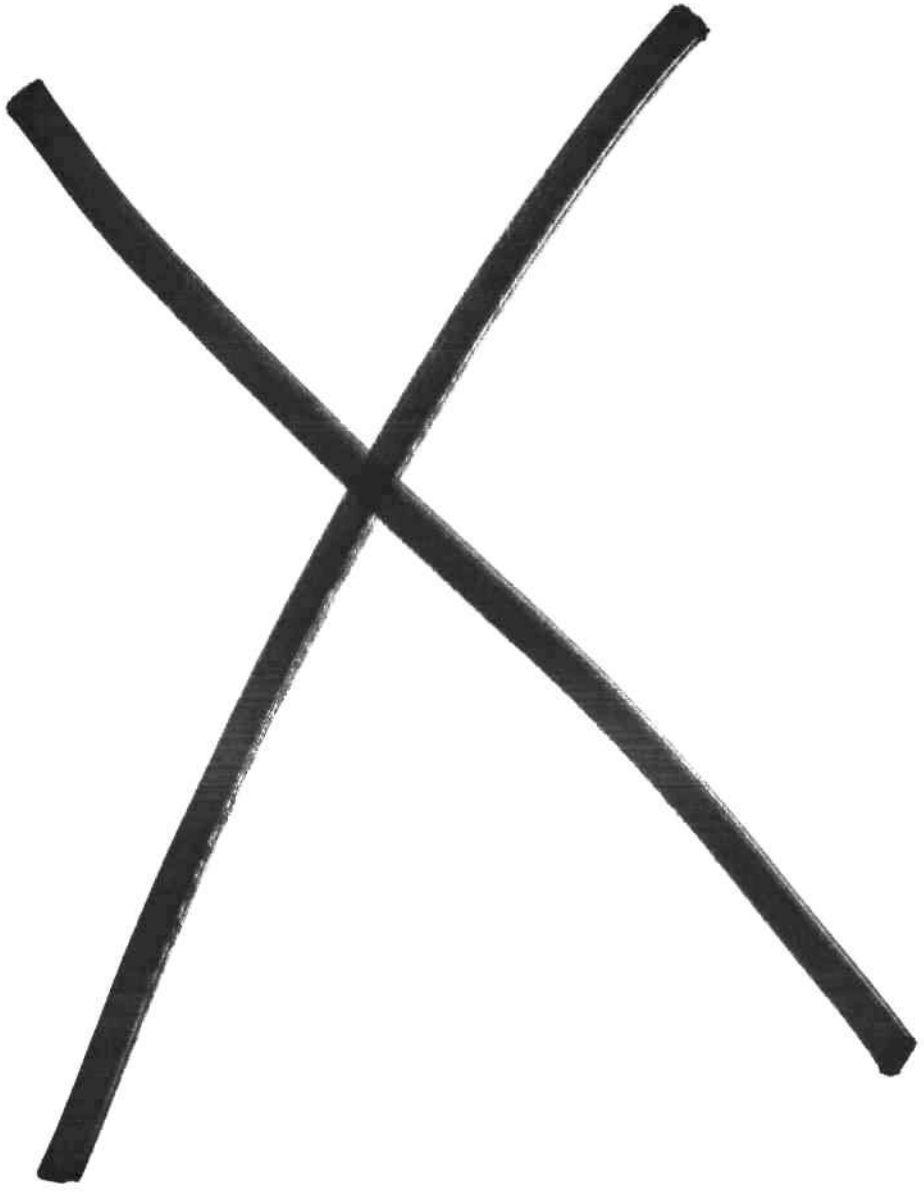
Overall, Dataquest expects to see substantial changes in the DRAM market, although some won't be substantial enough for certain interested parties. While we expect EDO to sweep the market, a lot of other interfaces, namely Rambus, EDRAM, and CDRAM, will only make nominal inroads.

The frame buffer memory market is the one that is hardest to predict. All of the new solutions to the problem of increasing bandwidth while reducing cost are promising, and the final result depends solely on the decisions that system architects will make over the next few years.

All DRAM applications need increased bandwidth without increased cost. This means that there will be big changes in the way that systems and memory communicate and will cause a large impact to the nature of the parts DRAM manufacturers ship. Dataquest believes that the key factors to success in this market revolve around cost and multiple sourcing, rather than technology and sheer speed.

For More Information...
Jim Handy, Director and Principal Analyst ..... (408) 437-8228
Internet address ..... jhandy@dataquest.com
Via fax ..... (408) 437-0292

Dataquest
a company of The Dun & Bradstreet Corporation



Dataquest