Dataquest

Global
IT Market
Insight

PERSONAL COMPUTER SEMICONDUCTORS AND APPLICATIONS WORLDWIDE

As PC product life cycles grow shorter than ever, semiconductor vendors must work harder to get and keep the big design-wins. Don't miss out on your share of this rapidly growing market! Dataquest's Personal Computer Semiconductors and Applications (PSAM) program keeps your finger on the pulse of the semiconductor industry as it relates to PCs. Dataquest's hard-hitting analysis and industry statistics ensure that you know what is selling today as well as what features and products you'll need to gain market share tomorrow. Grounded in primary research and system teardown analysis, this program provides its clients with forward-looking analysis for all major semiconductor devices in PCs.

Key Topics

Want to learn more about Dataquest?

Please visit **Dataquest Interactive** *our Internet-based information service at:* **www.dataquest.com**

The PC Semiconductors and Applications program provides advice and analysis to help clients make successful business decisions. Publications include a mix of analytical articles, weekly news bulletins and event-driven faxes, focused reports, and timely market statistics published on a regular schedule throughout the year. Briefings and conference presentations bring clients together with analysts to share insights and opinions. Core topics as well as emerging issues are covered. Documents covering emerging topics may include:

- The role of media processors in an MMX world
- Network computers
- When will DVD replace the CD-ROM?
- The living room PC
- What is the impact of AGP?
- PC audio chips and implementation trends
- Leveraging PC semiconductors into digital consumer electronic equipment
- USB and 1394
- What will it take to get rid of the ISA bus?
- New memory technologies for PCs

Market Coverage

Multimedia is the Key

Graphics, video, audio, and communications are all driving PC architecture harder than ever before. These data types place tremendous demands on all parts of the PC and create opportunity for semiconductor vendors.

Focused Research

With this in mind, Dataquest has developed a program to focus on the MPU and surrounding technologies in next-generation PC designs. Core content includes coverage of the markets for specific semiconductor devices as well as applications. Statistics and forecasts are provided for the following:

- Compute microprocessors
- PC graphics chips
- PC core logic chips
- PC audio chips
- PC communications chips

Application-focused research is also included with data and analysis of:

- PC semiconductor content based on system teardown analysis and industry trends
- Penetration rates for new technologies and features
- Implementation trends and the impact of new PC form factors.

Complementary Research

Dataquest offers complementary services, including bill of materials of electronic equipment.

WHAT YOU WILL RECEIVE AS A CLIENT

PC SEMICONDUCTORS AND APPLICATIONS WORLDWIDE

Perspectives

Event Summary
Product Analysis
Market Analysis
Technology Analysis
Competitive Analysis
Vendor Analysis
Dataquest Predicts

Dataquest Perspectives: These documents give you a summary of issues, standards, and trends for the semiconductor opportunities in specific subsystems or new PC product categories. A minimum of 12 Dataquest Perspectives will be delivered to you on a regular schedule throughout the year. Topical in nature, these documents provide timely information and advice to help you stay ahead of your competition.

Twelve Issues Available Throughout 1997

Market Trends

Market Trends Reports: Worldwide trends in demand for various microcomponents, PC unit production, industry competition, system architecture trends, and semiconductor device opportunities are addressed in these detailed reports. These reports are published annually and represent the core topics of this service. An overview document provides information from Dataquest's PC semiconductor content model while separate documents cover key topics such as microprocessors and graphics controllers.

Available Second and Third Quarters 1997

Guides

Each Dataquest research program publishes an annual Market Segmentation Guide to assist clients in understanding its market segmentation scheme. In addition, clients receive an annual guide to Dataquest's research methodology.

Electronic News

News and analysis delivered directly to your desktop

Clients have a choice of receiving one of the following weekly electronic newsletters:

- **DQ Monday Report:** Top news and commentary on semiconductor industry events and issues with a monthly snapshot of semiconductor pricing for 25 key semiconductors in six regions.
- **Desktop and Mobile Review:** Top news and analysis from around the world related to the PC industry.

Available Weekly via Electronic Mail

Dataquest Alerts: These fax bulletins provide analysis of fast-breaking news, events, or announcements in the PC and semiconductor industries, as they unfold. Alerts also will be provided in hard copy to file in your binder.

Event-Driven Faxes

Inquiry Support

Personalized inquiry support is a primary component of your annual subscription program. Dataquest analysts work with you to tailor the program to meet your needs.

Information Resource Centers

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

Market Statistics

Market statistics are delivered in a variety of documents, predominantly the Market Trends and Competitive Trends reports.

Worldwide Semiconductor Consumption and Shipment Forecast: Five-year revenue forecasts for the global semiconductor market by region.

Available Second and Fourth Quarters 1997

Special Reports

Focus Report
Competitive Trends Report
Industry Trends Report
Company Profile Report

Competitive Trends Report: This report will deliver market statistics for the first half of 1997 for graphics and audio chip shipments by vendor. Market trend information for these categories, as well as other PC semiconductor trends, will also be included. This document is planned as a fall update to some of the Market Trends information published through spring.

Available Fourth Quarter 1997

Conferences and Briefings

Dataquest hosts the semiconductor industry's most-respected conferences and briefings in locations throughout the United States, Europe, and Japan. Contact Dataquest Global Events at 1-800-899-9599 for more information (conference seat is optional).

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Fax: 813-3481-3644

Dataquest Document Checklist
January - March 1997

Dear Dataquest Client,

This checklist is mailed to you on a quarterly basis to help you verify that you have received every printed document that has been produced by this research program during the quarter. Please review this checklist against the contents of your program binder. If you never received any of the documents listed, let us know and we'll be glad to send you a replacement copy.

To Order Missing Documents: Please check box next to missing document(s), and then fax this sheet to the fax number listed below. Your replacement document(s) will be shipped to you within 10 business days.

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PC Semiconductors and Applications Worldwide—PSAM-WW

Check to Re-order	Document Code	Publication Date	Document Title
Tab: Perspective			
☐	PSAM-WW-DP-9701	January 20, 1997	Surfing the Net at Twice the Speed: 56-Kbps Technology Promises New Life for Analog Modem Chipset Market
☐	PSAM-WW-DP-9702	February 3, 1997	Can Network Computers Topple the Wintel Paradigm?
☐	PSAM-WW-DP-9703	February 3, 1997	Opening the Window on Handheld PCs
☐	PSAM-WW-DP-9704	February 17, 1997	1996 Microcomponent Revenue Increases 16 Percent
☐	PSAM-WW-DP-9705	March 10, 1997	WebTV: An Early Example of Convergence between Computing and Consumer Electronics
☐	PSAM-WW-DP-9706	March 17, 1997	Personal Computer Chip Market Quarterly Outlook: Demand Strong, Inventories Down
☐	PSAM-WW-DP-9707	March 31, 1997	Quarterly x86 Forecast: Send in the Clones
☐	PSAM-WW-DP-9708	March 24, 1997	S3 Dominated the PC Graphics Market in 1996

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Dataquest Document Checklist
April - June 1997

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Check to Re-order	Document Code	Publication Date	Document Title
Tab: Perspective			
☐	PSAM-WW-DP-9709	April 21, 1997	The Intel-Microsoft NetPC and Wired for Management
☐	PSAM-WW-DP-9710	June 16, 1997	PC Market Growth is Tied to New Directions for PCs
Tab: Market Trends			
☐	PSAM-WW-MT-9701	June 16, 1997	Sound and Vision: Trends for the PC Graphics and PC Audio Chip Markets

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Dataquest Document Checklist
July - September 1997

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PC Semiconductors and Applications Worldwide—PSAM-WW

Check to Re-order	Document Code	Publication Date	Document Title
Tab: Perspective			
☐	PSAM-WW-DP-9711	July 21, 1997	Personal Computer Chip Market Quarterly Outlook: The Calm Before the Storm?
☐	PSAM-WW-DP-9712	September 1, 1997	PC Semiconductors and the Three M's: Multimedia, Microprocessors, and Memory
Tab: Market Trends			
☐	PSAM-WW-MT-9702	September 22, 1997	1997 Trends in Computational Microprocessors and Core Logic

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Dataquest ALERT

251 River Oaks Parkway • San Jose • CA • 95134-1913 • Phone 408-468-8000 • Fax 408-954-1780

Intel Buys Chips and Technologies

The Deal

Monday morning, Intel announced its intention to buy graphics chip vendor Chips and Technologies Inc. (Chips). The two companies have entered a definitive agreement regarding the acquisition and are seeking regulatory approval for the transaction. Intel has offered $17.50 per share for Chips' stock, putting the value of the deal at just more than $384 million.

Intel's imminent entry into the graphics chip market has been well publicized, and this acquisition addresses a number of issues that Intel faces as it enters that market. The company has been working with Real3D, a subsidiary of Lockheed Martin, and Chips on a single-chip graphics product for some time. The product of that partnership is code-named Auburn and combines Chips' 2-D graphics and video acceleration technologies with Real3D's powerful 3-D graphics technology. Auburn was originally slated for a Q3 1997 production ramp, but industry rumor now indicates that ramp has been pushed out to Q1 1998.

Chips is the largest supplier of mobile PC graphics chips. The company led the market in 1996 with more than 46 percent market share and revenue of $134 million, according to Dataquest estimates.

Why Would Intel Do Such a Thing?

Dataquest can only speculate that Intel was envious of Microsoft's $450 million acquisition of WebTV and needed to close a similarly-sized deal for emotional well-being. Alternatively, Intel may recognize some synergy between Chips' business assets and Intel's business needs in the graphics arena. That synergy could be tied to the following:

- Human resources—Chips has a seasoned graphics design team, and design engineers are in short supply. The attraction here is getting a ready-made engineering team instead of creating one from scratch. Intel has tremendous design expertise for microprocessors and core logic but relatively little experience in graphics.

- Mobile graphics technology—Chips has a strong technology portfolio for displaying graphics and video on passive LCDs. Image quality on passive LCDs is limited because they cannot display as many colors as active-matrix LCDs and CRTs can display. Chips has developed a number of techniques to work around those limitations and improve display quality, particularly for motion video display.

- Current graphics products—Chips' products are still designed into a variety of mobile PCs, so Intel gains immediate entry into the graphics market. However, the existing product line is aging and does not include a 3-D product. Competitors ATI, Trident, and S3 are bringing 3-D products to market now.

- Manufacturing capacity and expertise—Intel has it; Chips can use it.

- Industry clout and resources—Intel has them; Chips can use them.

Does This Acquisition Change Anything?

Until today, Dataquest was lukewarm as to the real impact of Intel's foray into the graphics business for a number of reasons, including the following:

- Dataquest believed that Intel began the Auburn project as both an insurance bet and a threat to the graphics industry. The chip was an insurance bet because Intel needed a powerful 3-D graphics chip to complement the Pentium II and AGP core logic products. The chip was a threat because the thought of an industry gorilla like Intel entering a market is enough to make almost any company run faster.

- The graphics market today is quite different from the core logic market that Intel took by storm. The graphics vendors today are executing well overall, and the market is characterized by many vendors selling competitive products. The core logic market was different because those vendors were not executing well on their new designs, and the lack of good core logic products was an impediment to Intel's microprocessor sales, particularly the transition from 486 to Pentium. That is simply not the case for the graphics market.

- It is difficult to envision Intel adding unique value to this market. The graphics chip market will be competitive whether or not Intel chooses to participate. Sure, Intel can leverage its manufacturing strengths to compete aggressively on price. The question is whether Intel will produce a superior graphics product. Many other graphics chip vendors have allied with strong manufacturing partners or made equity investments in fabs.

- Intel tried entering the graphics market before but failed. Is this time around different?

But Dataquest now believes that this acquisition changes many of these issues. First of all, $400 million is a lot of money. The magnitude of the investment indicates that Intel is serious about entering the graphics business for market share rather than just market presence. The graphics market may not be ripe for picking like the core logic market was a few years back, but Intel appears to be ready to fight for a share of it. Intel is also well positioned with its manufacturing resources and could weather a price war in the graphics market longer than most other suppliers.

Is This Deal Good for the Graphics Chip Market?

The short answer is, "No." This deal is good for Intel and good for Chips, but not for the overall graphics market. The graphics market is entering a period of consolidation. During the

Dataquest Predicts conference last February, we predicted the industry would face consolidation through 1997 and 1998 because there are too many vendors targeting the PC graphics market. This consolidation has clearly begun with the announcements a month ago from Brooktree and S-MOS that each was getting out of the graphics controller market. Intel's purchase of Chips is another brick in that wall—or maybe a few bricks in that wall.

The concentration of power is the reason this deal is not good for the graphics market. Intel controls too many graphics design wins through its motherboard designs for other chip vendors to compete on an equal footing. Once Intel graphics chips get designed onto the leading Intel motherboard designs, it will be difficult to displace them. The graphics market has been characterized by rotating leadership on a two- to three-year cycle. Tseng Labs, Cirrus Logic, and S3 are examples of companies that have risen quickly to dominate the graphics market. If Intel gains that No. 1 spot, it will be difficult indeed to budge it.

Dataquest previously believed that AGP would cause PC OEMs to lean back toward add-in cards for graphics rather than having them soldered down on the motherboard. This does not appear to be the case, as we have heard of design activity for AGP graphics chips on motherboards. If the market does swing back toward add-in cards for the PCI-to-AGP transition, Intel will be forced to compete on more of an equal footing. Otherwise, Intel will enjoy significant advantages because of its motherboard business.

Dataquest Perspective

Success is still not assured for Intel, but the company just bulldozed a number of barriers it faced before the acquisition. When this deal closes, Intel will have the tools to compete aggressively in the graphics market. Intel will need to revamp Chips' product line over the next 10 to 12 months, but initial success from new products next spring and fall could snowball into serious market momentum. The near-term impact of this deal is minimal, but the impact 12 to 18 months from now could be much greater.

Consolidation is necessary in the graphics chip market today, but overconsolidation is unlikely to bring long-term prosperity. PC OEMs and other buyers of graphics chips are advised to evaluate critically the impact of their purchasing decisions.

By Geoff Ballew

Dataquest ALERT

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By Geoff Ballew

PSAM Teleconference

June 24, 1997

Geoff Ballew and Nathan Brookwood

Semiconductor Group

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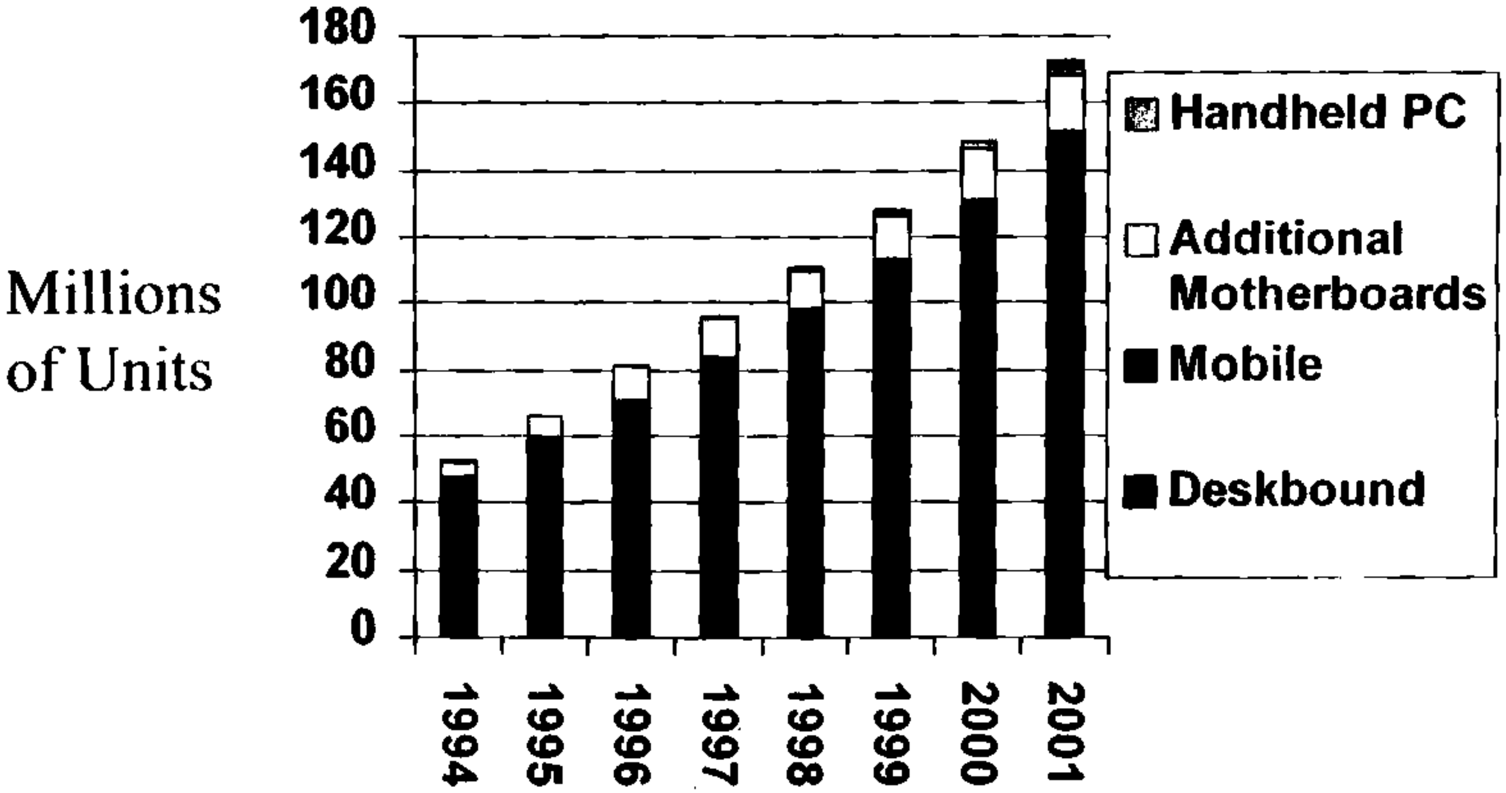
Agenda: MPU and Core Logic

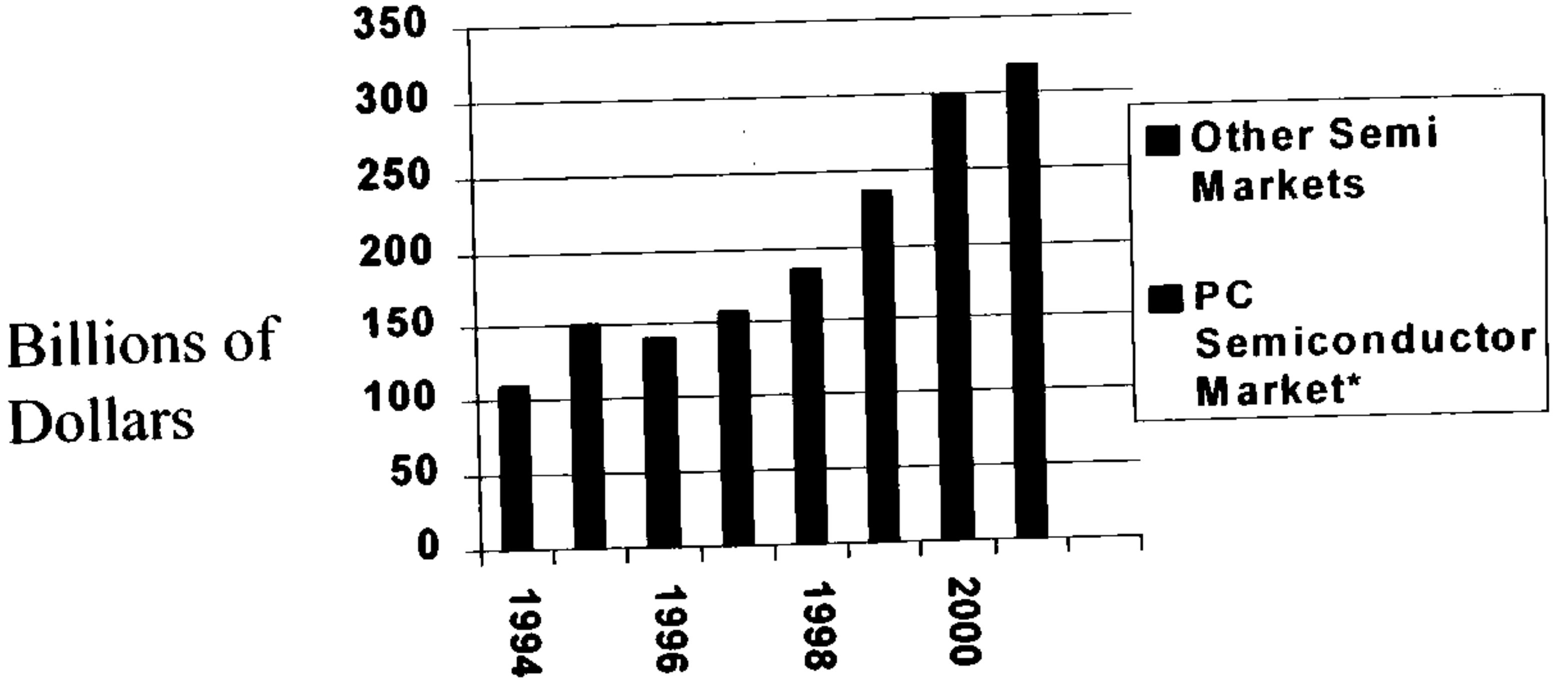
- Compute MPU Forecast
- Compute x86 Forecast
- 1996 Compute MPU Market Recap
- 1996 Core Logic Market Recap

PC Unit Shipment Forecast



Source: Dataquest April 1997

PC Semiconductor Revenue



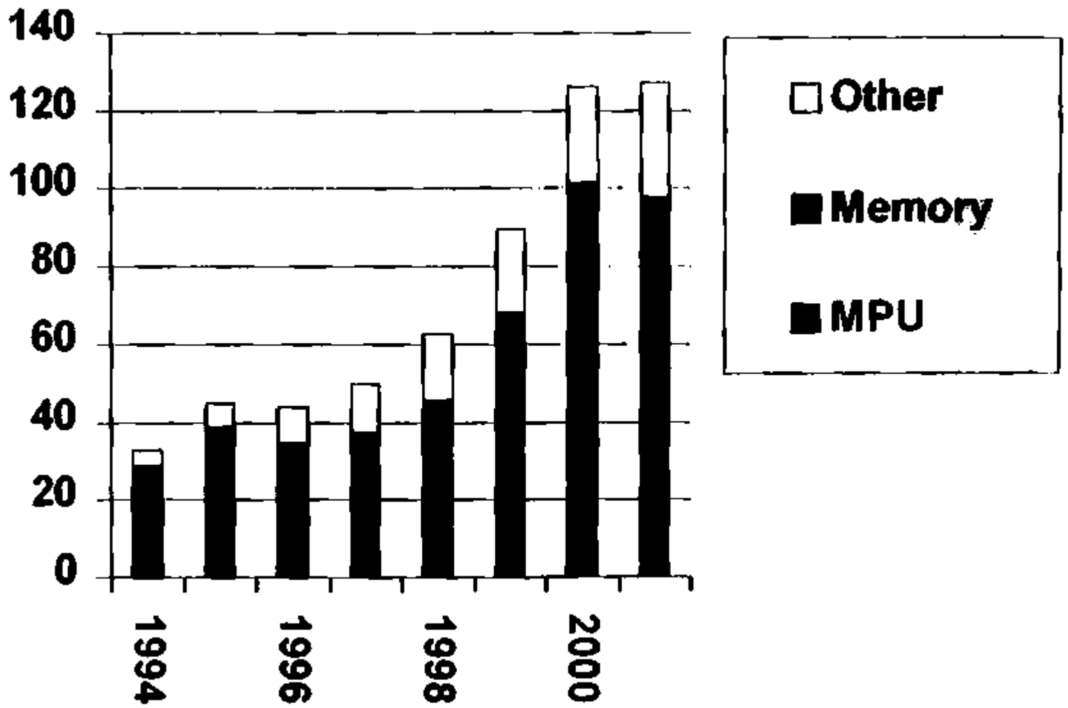
Data from Above Chart (Billions of Dollars)	1994	1995	1996	1997	1998	1999	2000	2001	CAGR 96-01
PC Semiconductor Market*	33.01	45.20	43.99	50.07	63.10	89.29	126.42	127.09	23 6%
Year-to-Year Growth		36.9%	-2.7%	13 8%	26.0%	41.5%	41.6%	0.5%	
Other Semi Markets	77.51	106.07	97.70	108.72	123.99	147.37	172.98	191.20	14 4%
Total Semiconductor Market	110.51	151 26	141 69	158.79	187.09	236.66	299 40	318 29	17 6%

*Includes semiconductor content of all PC categories: deskbound, mobile, handheld and additional motherboards

Source: Dataquest June 1997

PC Semiconductor Consumption By Major Category

Billions of Dollars

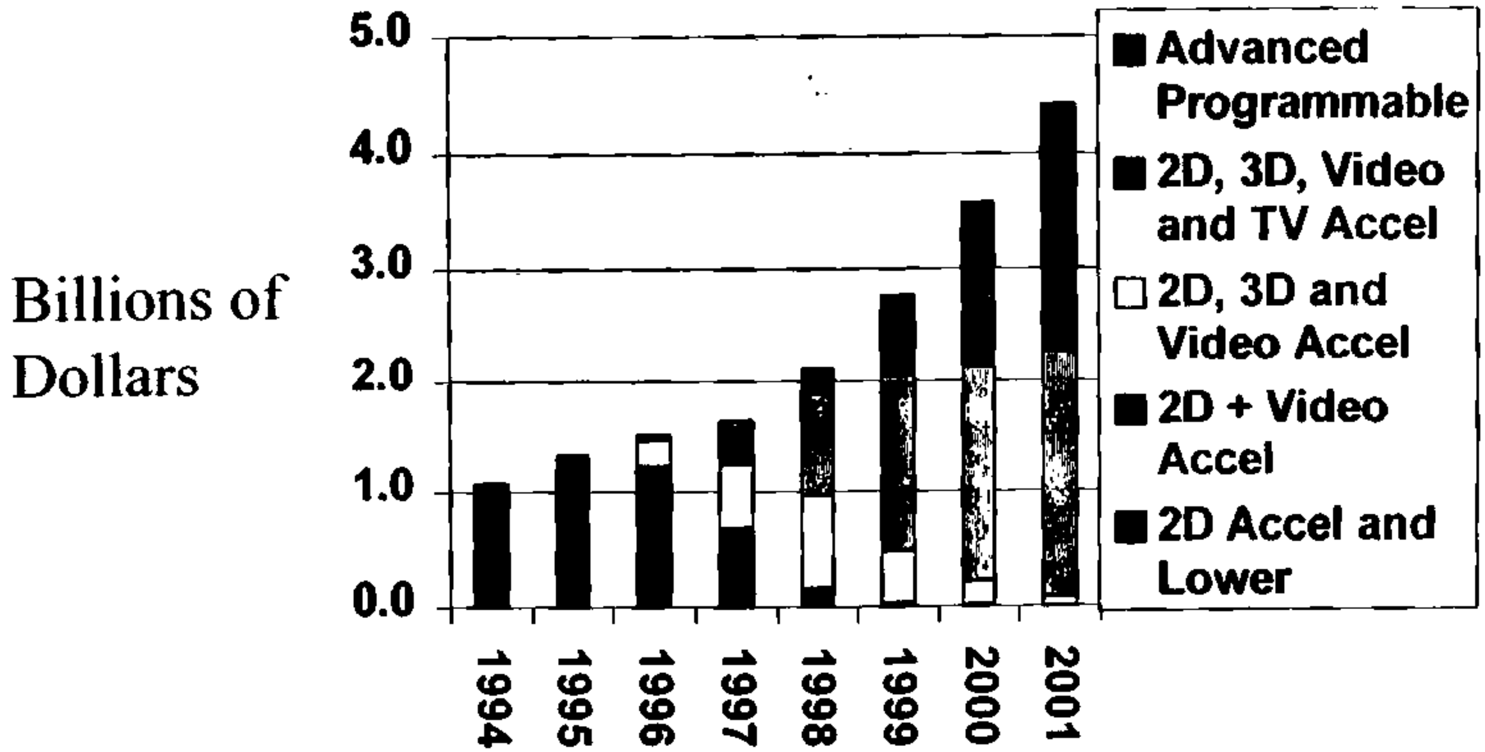


Data from Above Chart (Billions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR 96-01
Microprocessor (MPU)	9.25	10.96	14.16	16.77	20.94	29.11	36.98	43 17	25 0%
Memory	19.44	28.09	20.90	20.73	25.12	39.11	64.24	54 51	21.1%
Other	4.32	6.15	8.94	12.57	17.04	21.08	25.20	29 42	26 9%
Total	33.01	45.20	43.99	50.07	63.10	89.29	126.42	127 09	23 6%

Source: Dataquest June 1997

PC Graphics Controller Forecast

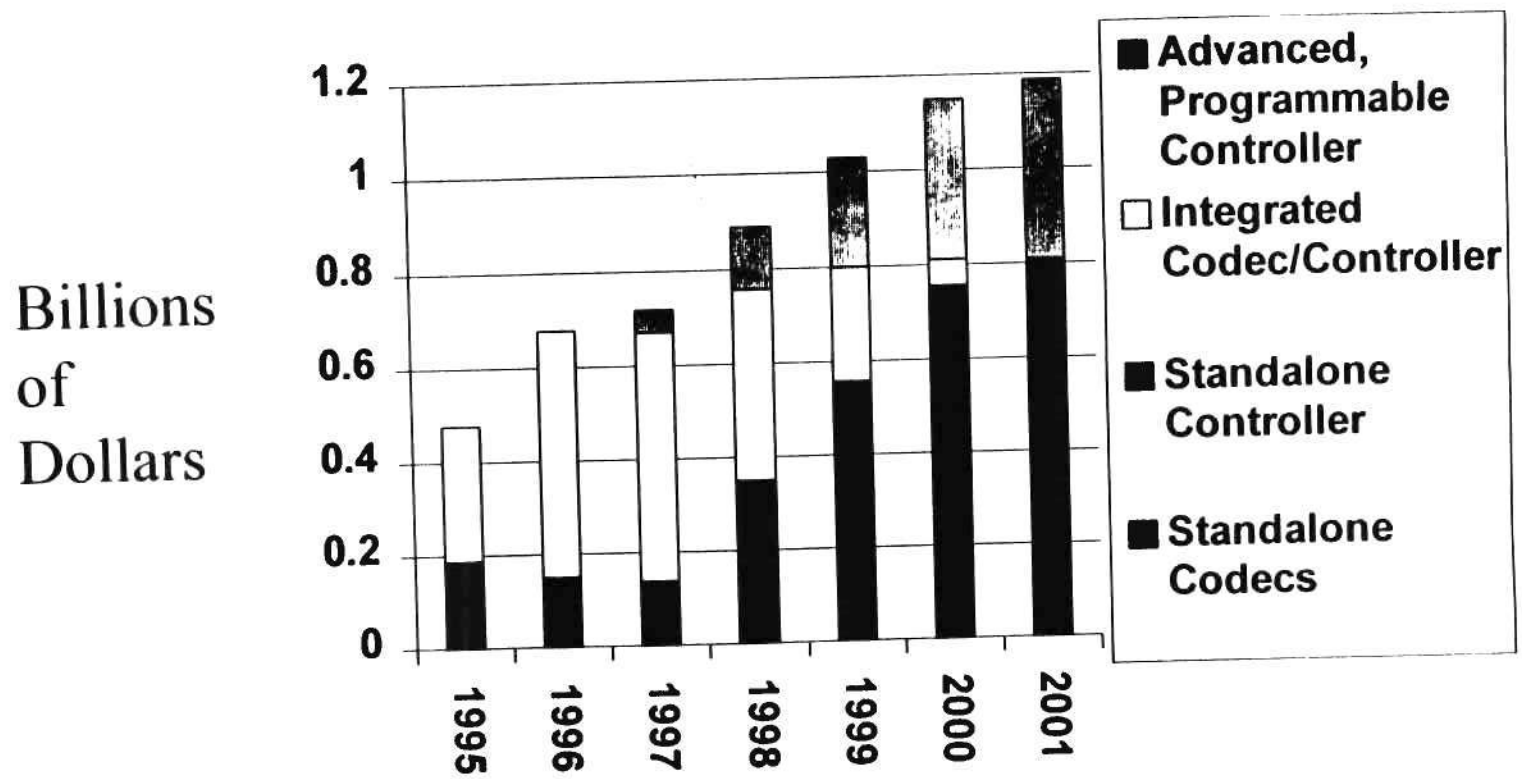


Data from Above Chart (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR 96-01
Total	1.08	1.34	1.52	1.66	2.11	2.77	3.57	4.41	23 8%
Year-to-Year Growth		24.0%	13 5%	9.0%	27 2%	31.6%	28.7%	23 6%	

Source: Dataquest May 1997

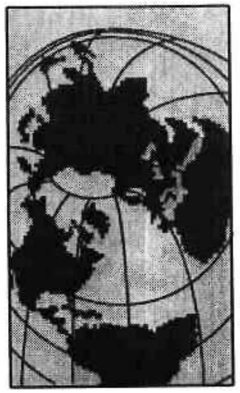
PC Audio Chip Forecast



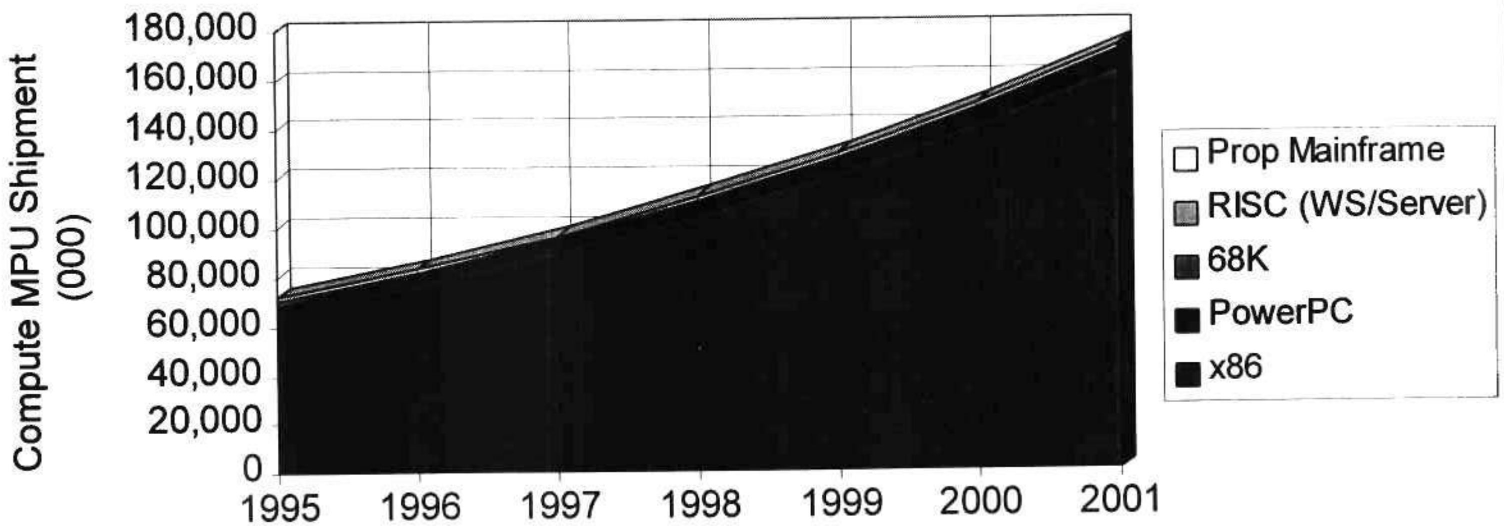
Data from Above Chart (Billions of Dollars)

	1995	1996	1997	1998	1999	2000	2001	CAGR 96-01
Total	0.48	0.68	0.72	0.89	1.04	1.15	1.18	11.8%
Year-to-Year Growth		39.6%	6.4%	24.2%	16.0%	11.0%	2.9%	

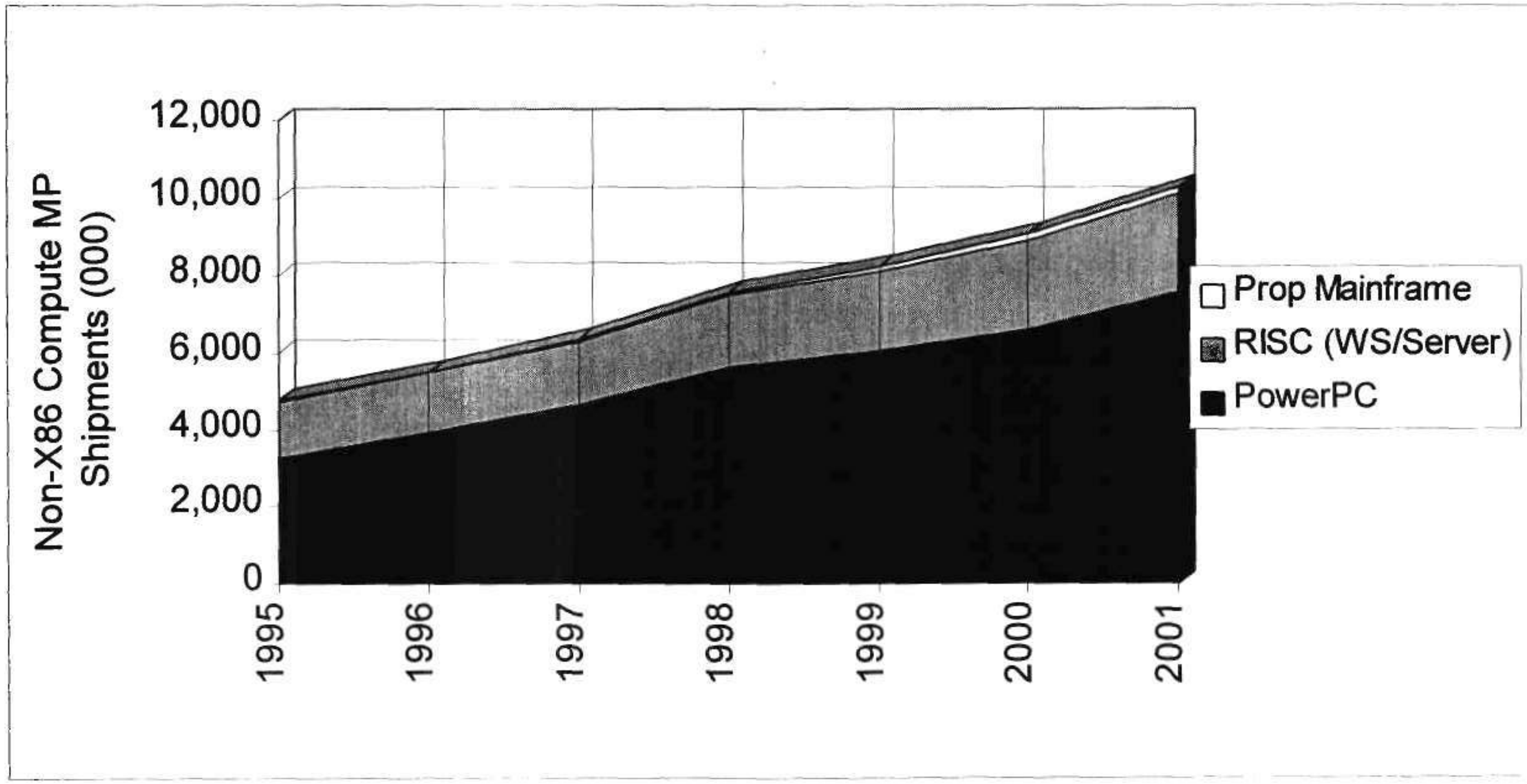
Source: Dataquest May 1997



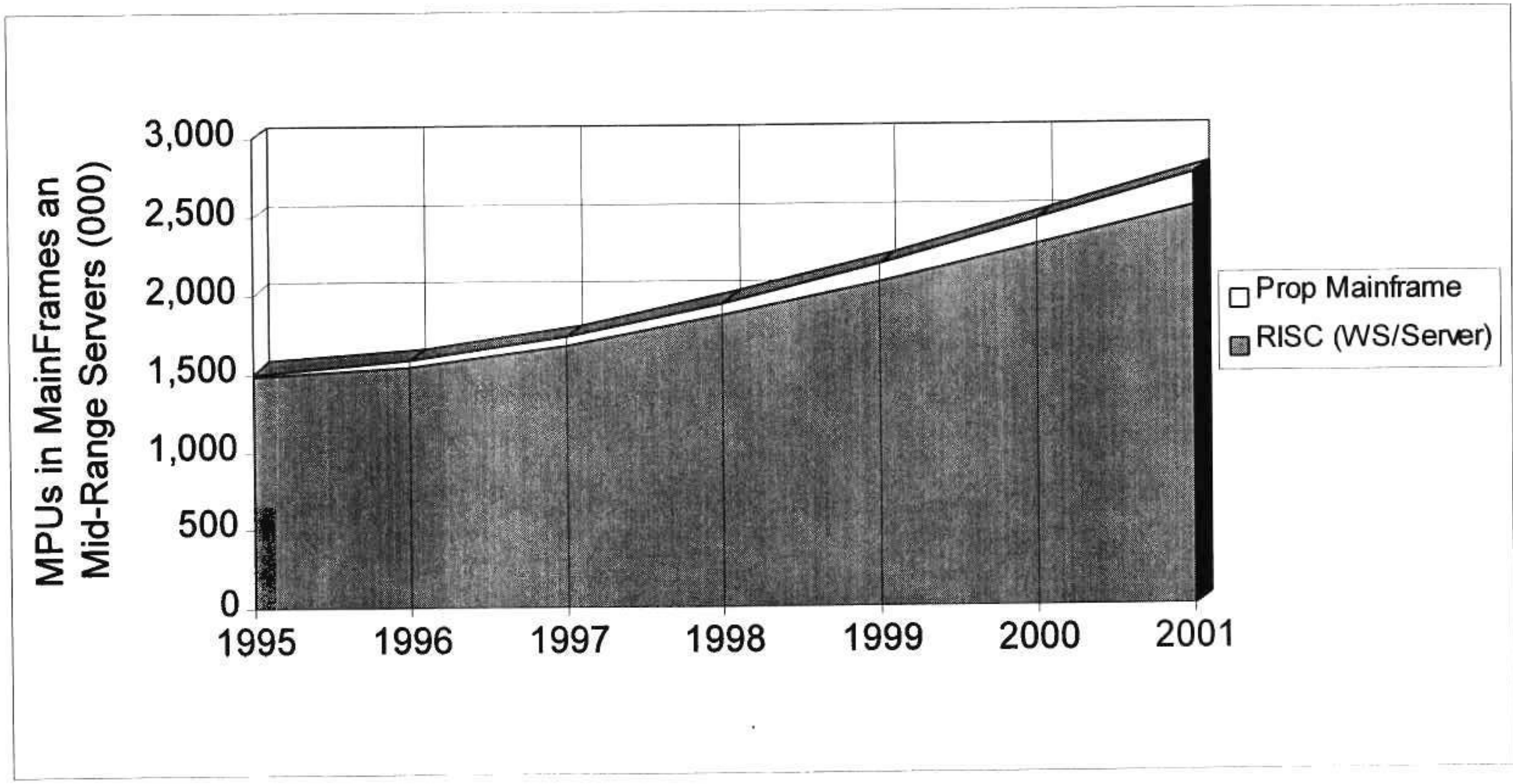
Compute MPU Unit Shipments to Double by Year 2001



Non-x86 Compute MPU Unit Shipments Growing Too



Mainframe and Mid-Range MPU Units Also Increasing



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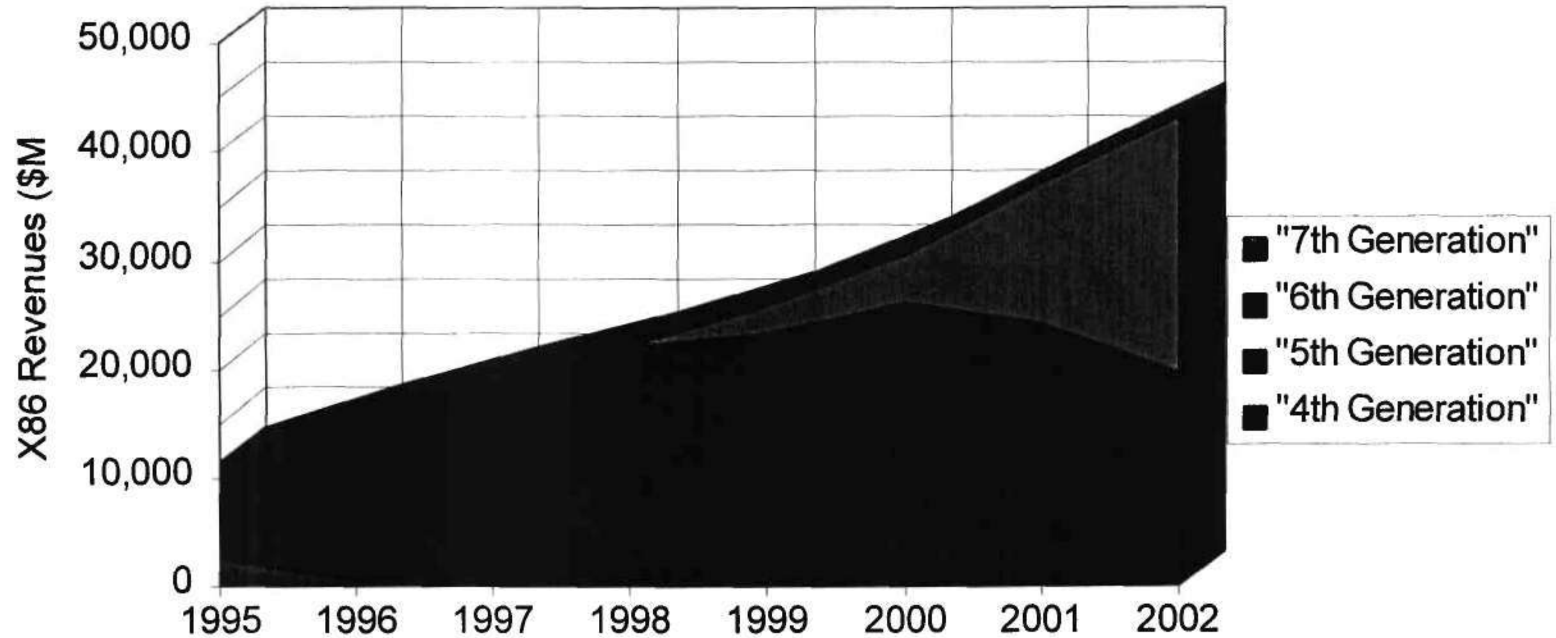
Compute x86 Revenue To Double To $30B By Year 2000



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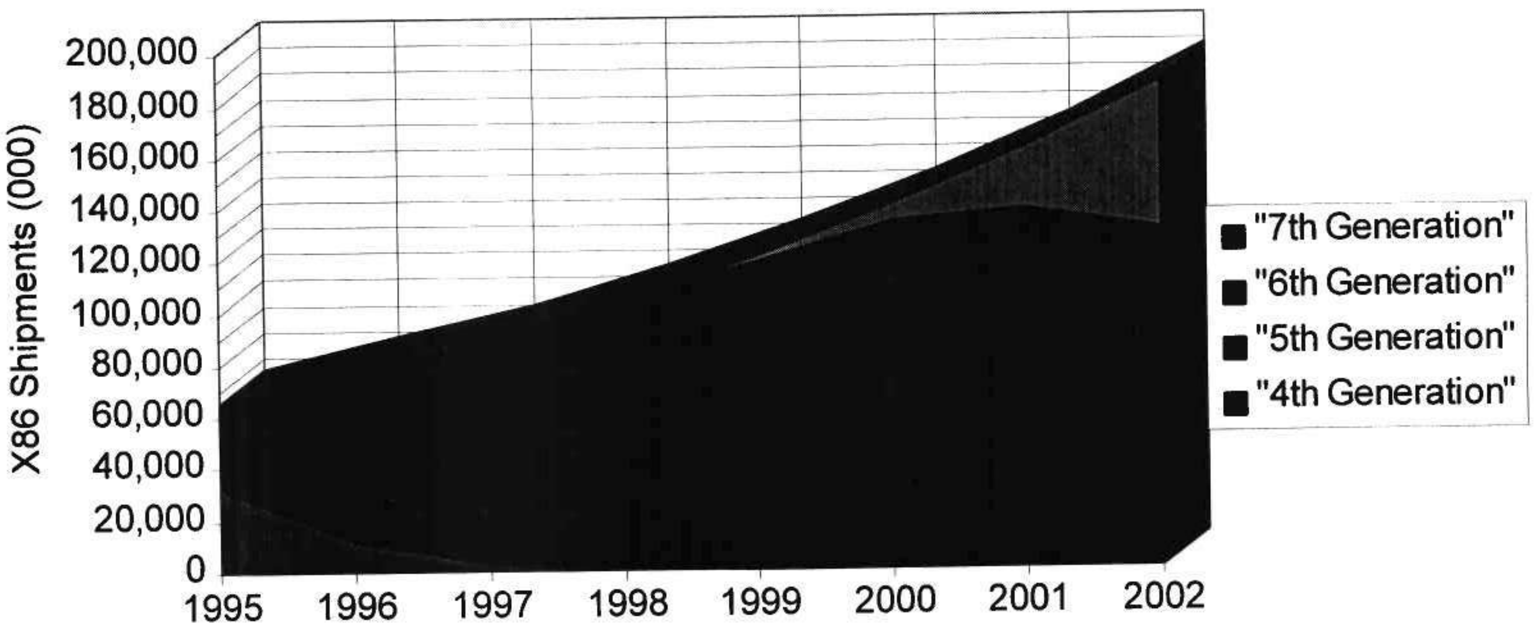
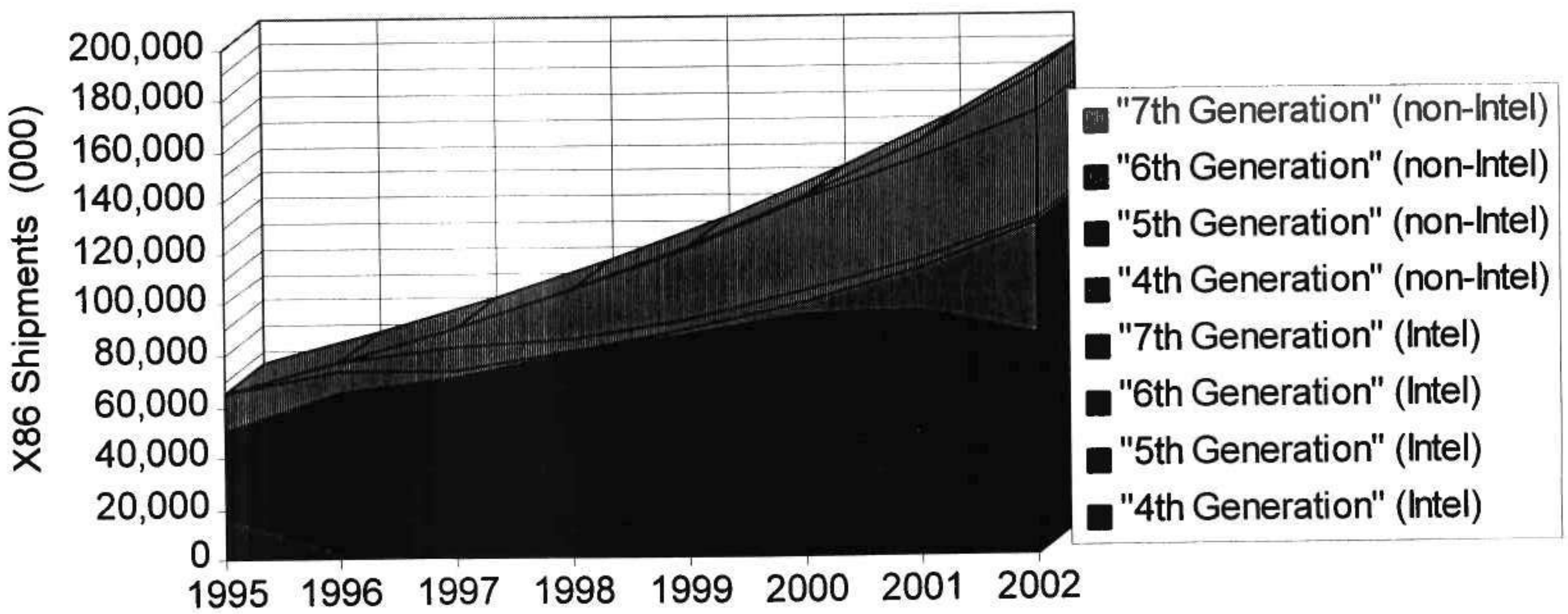
Compute x86 Shipment Grow From 77M Units in 1996 to 140M in Year 2000



x86 Clones Gain 25% Share by Year 2000



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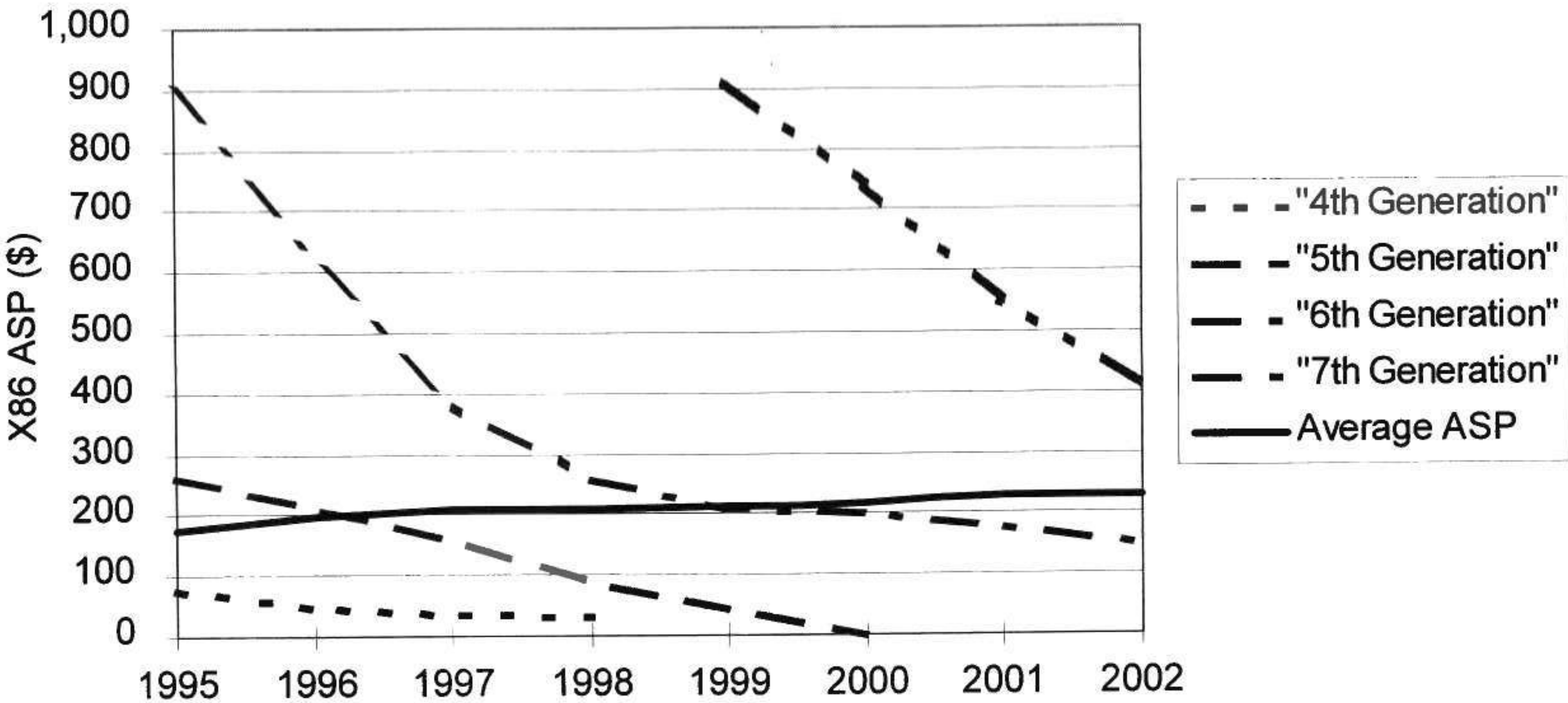
x86 ASP Continues Its Upward Creep



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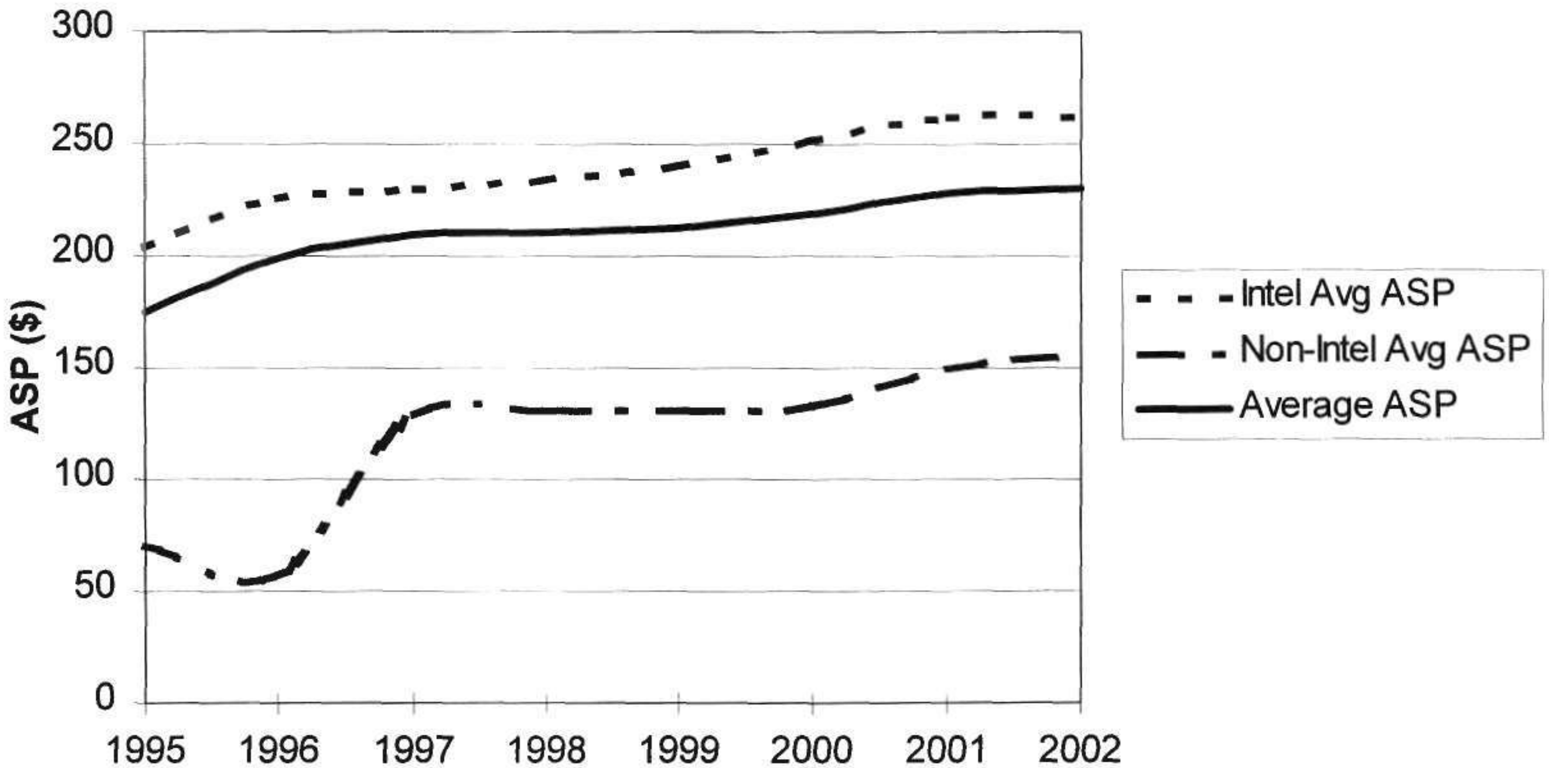
"Intel Inside" Continues to Command a Premium Price



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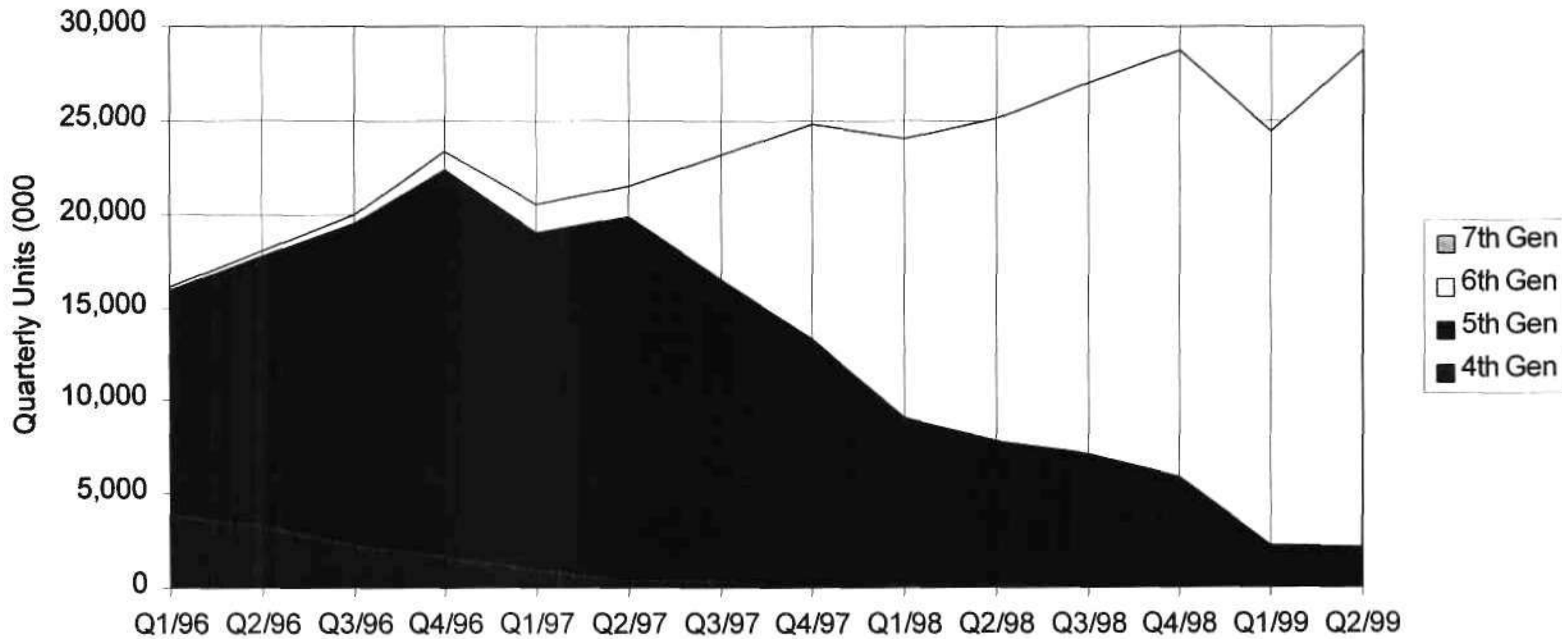
6th Generation x86 Will Reach 50% of Units by Q4/97



[6th Generation Includes PPro, P II, K6 and M2]

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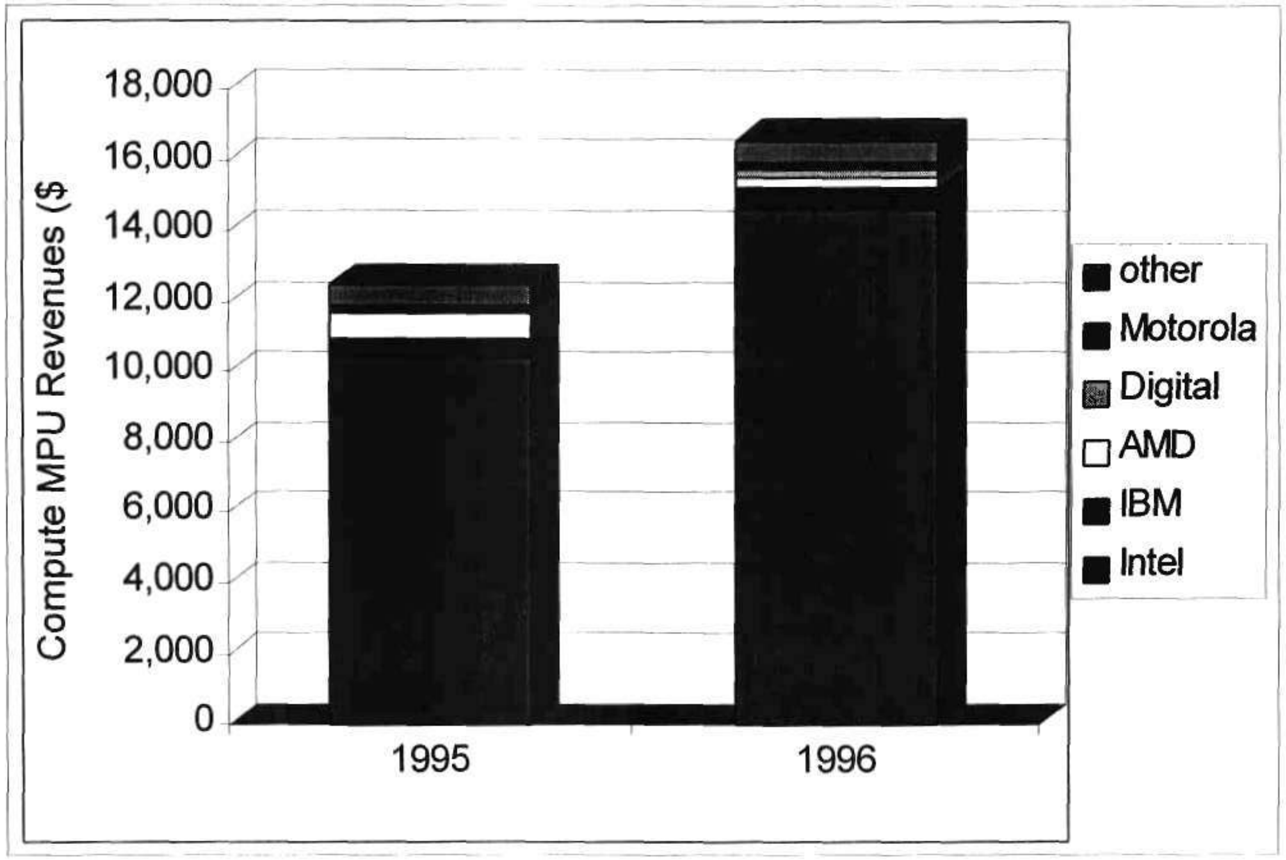
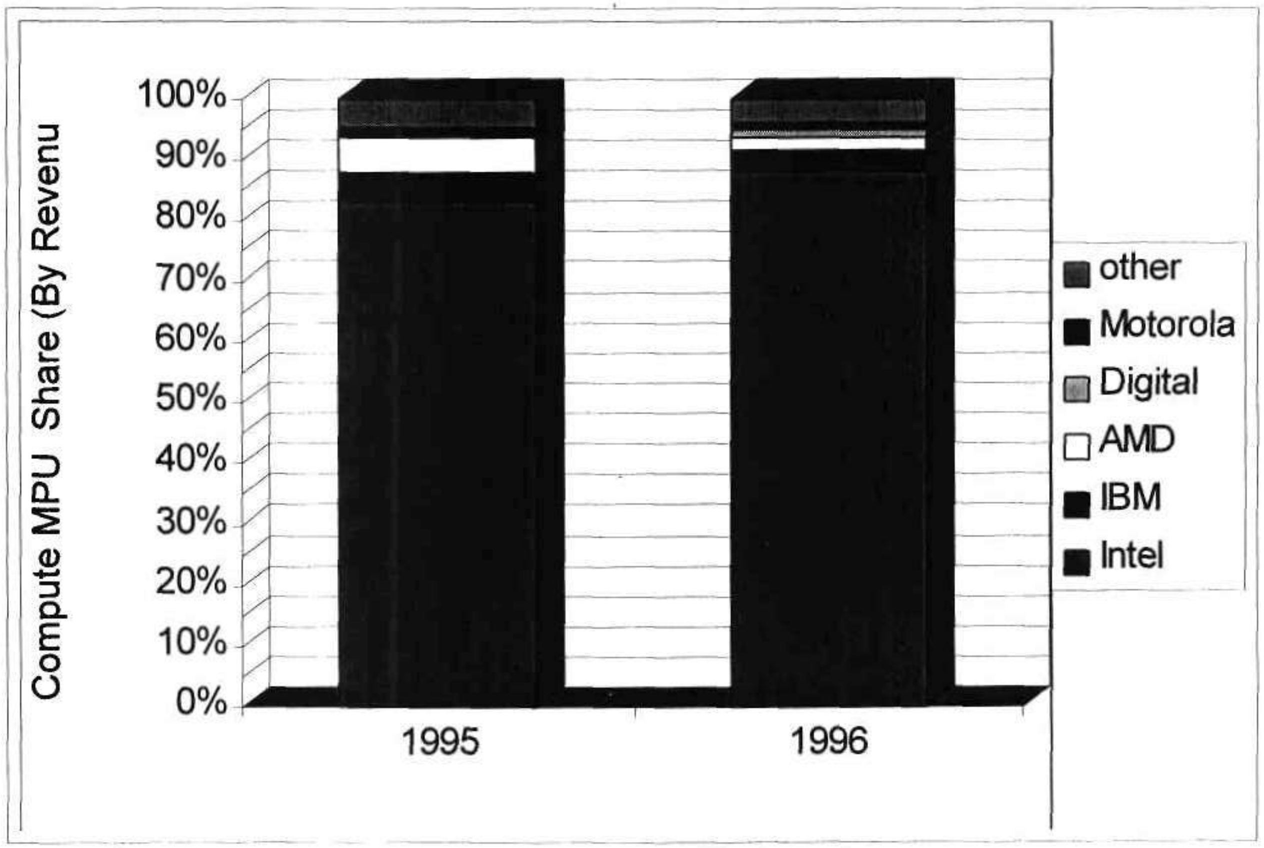
Compute MPU Market Exceeded $16.5B in 1996



Intel Captured 88% of Compute MPU Market in 1996



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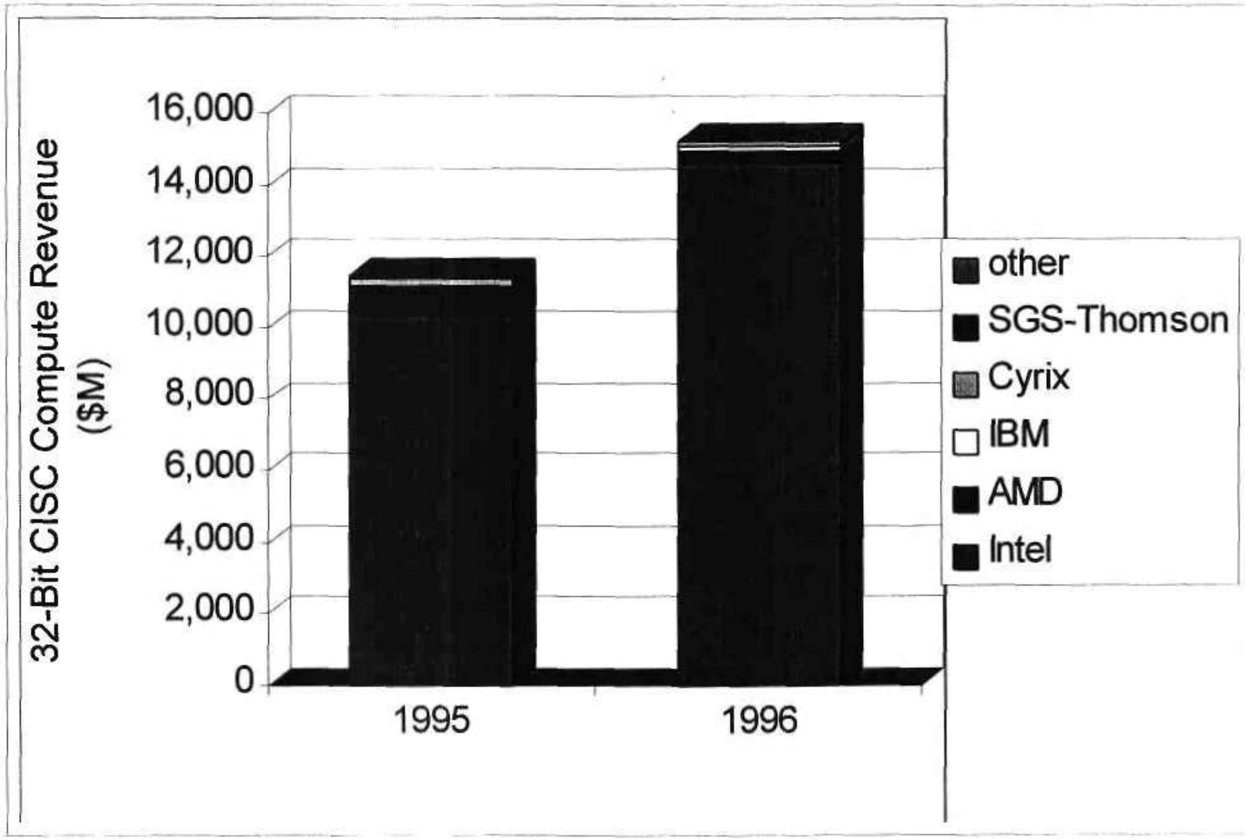
32-Bit CISC Market Exceeded $15B in 1996



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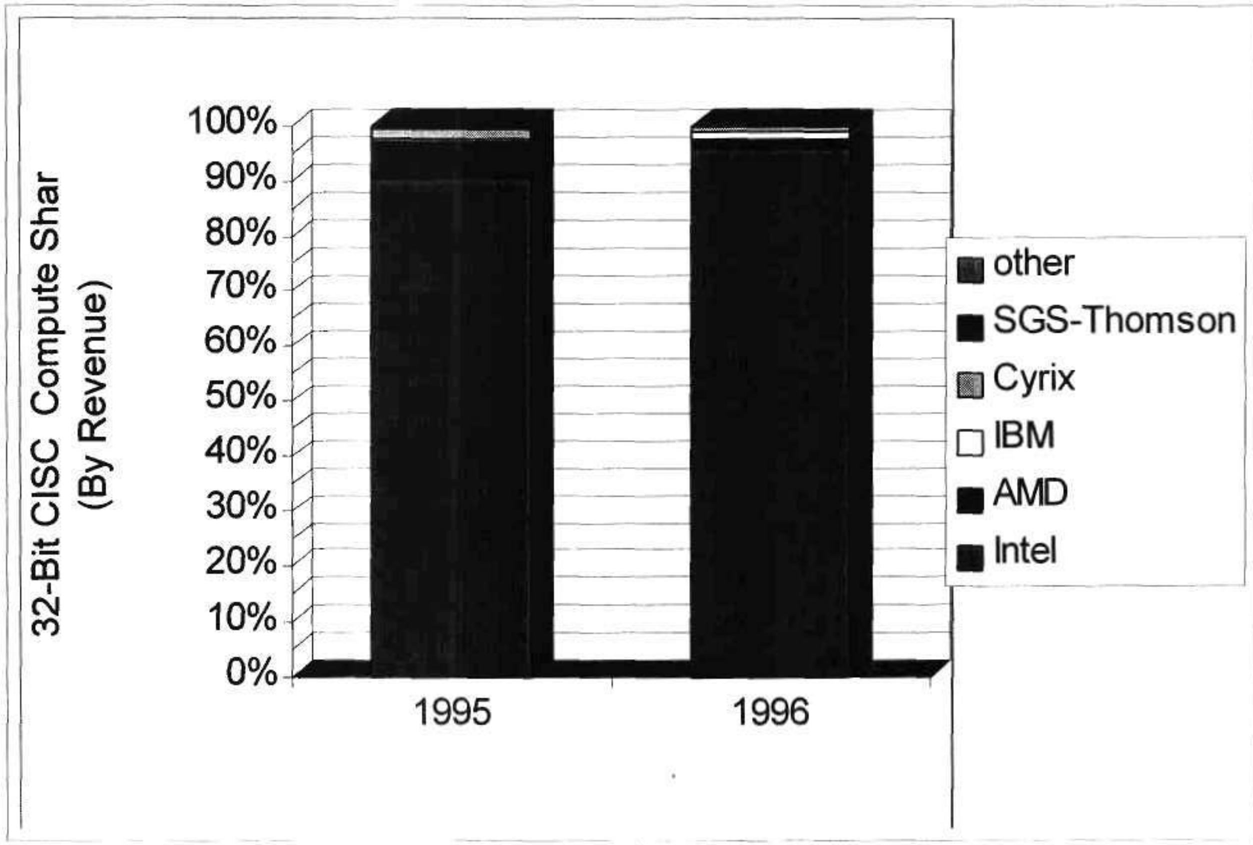
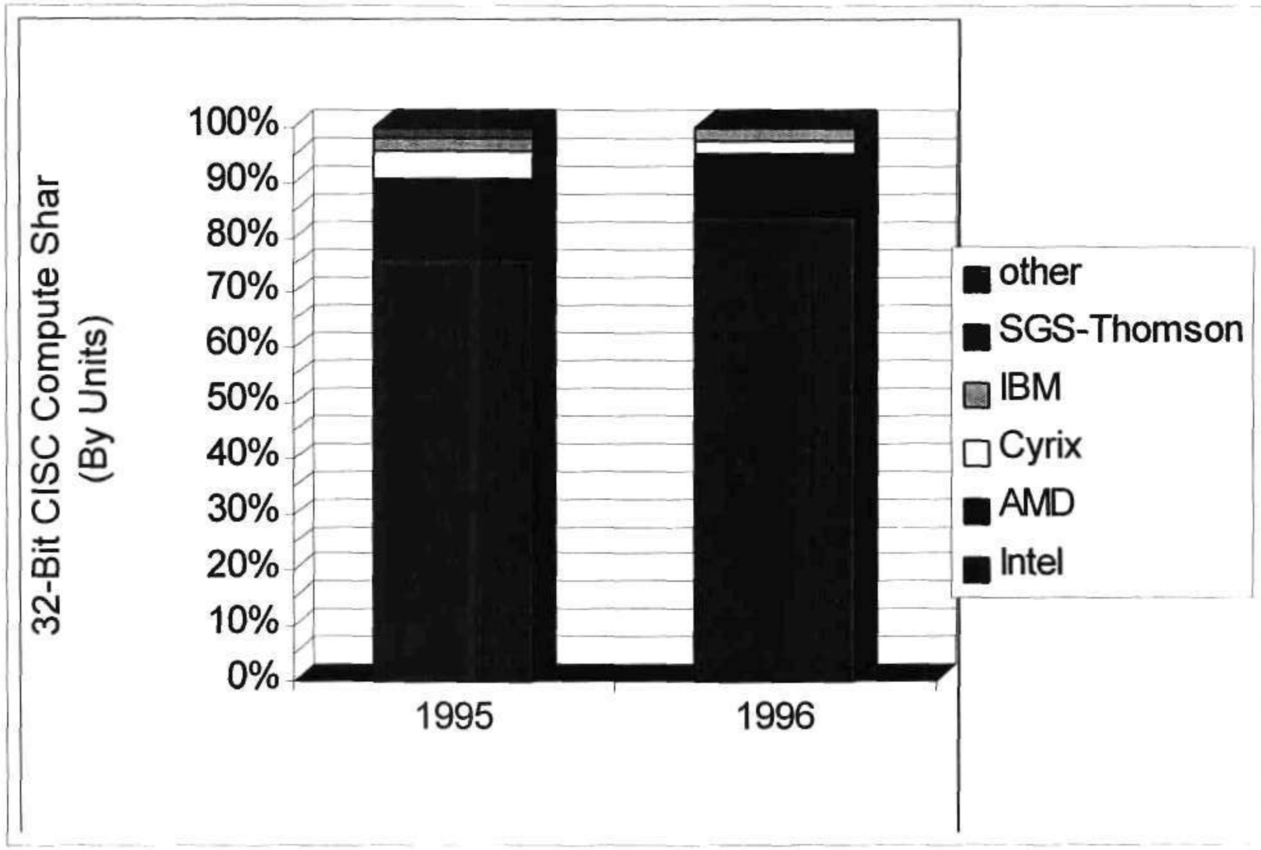
Intel Captured 96% of 32-Bit CISC Compute Market in 1996



But Only 84% of 32-Bit CISC Compute (I.e., x86) Units



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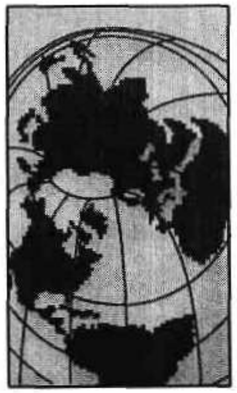
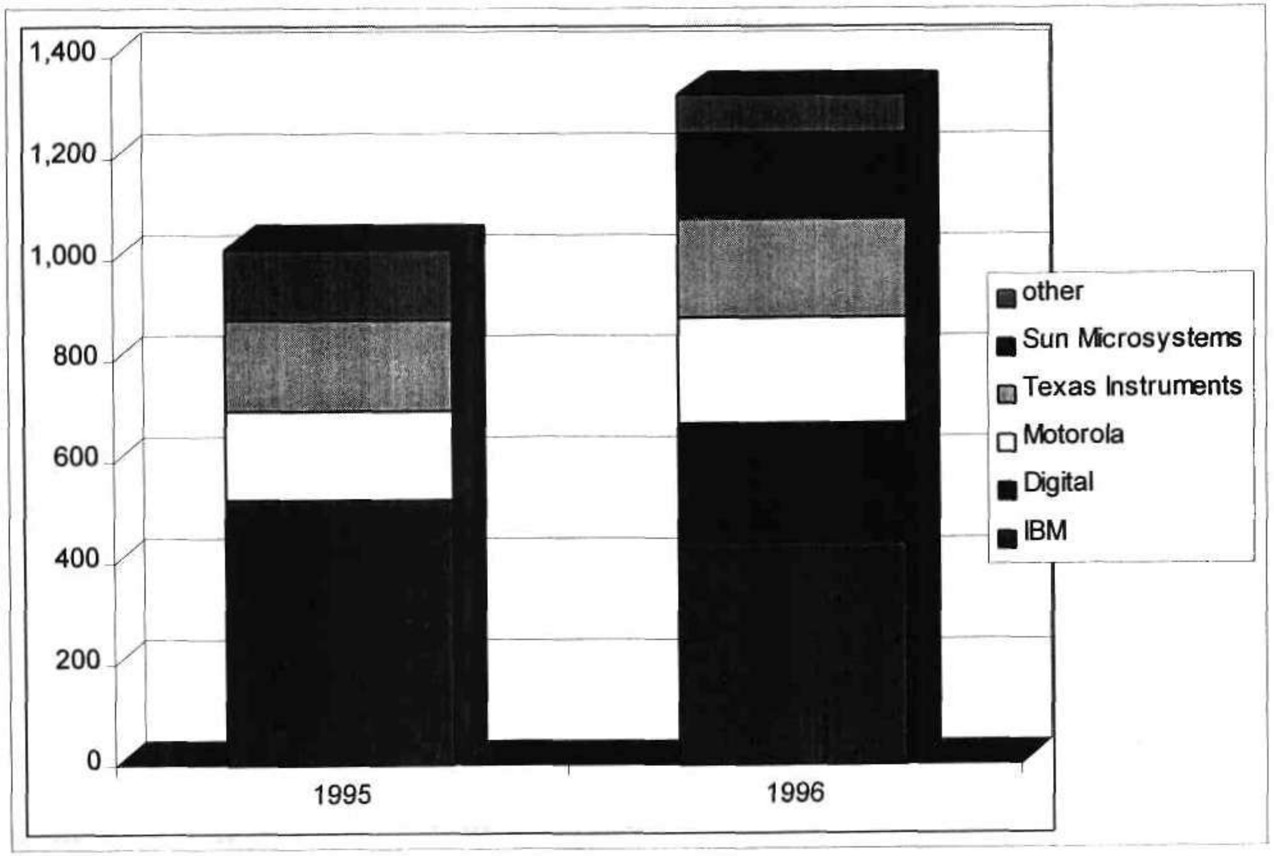
32-Bit RISC Compute Market Remains Fragmented





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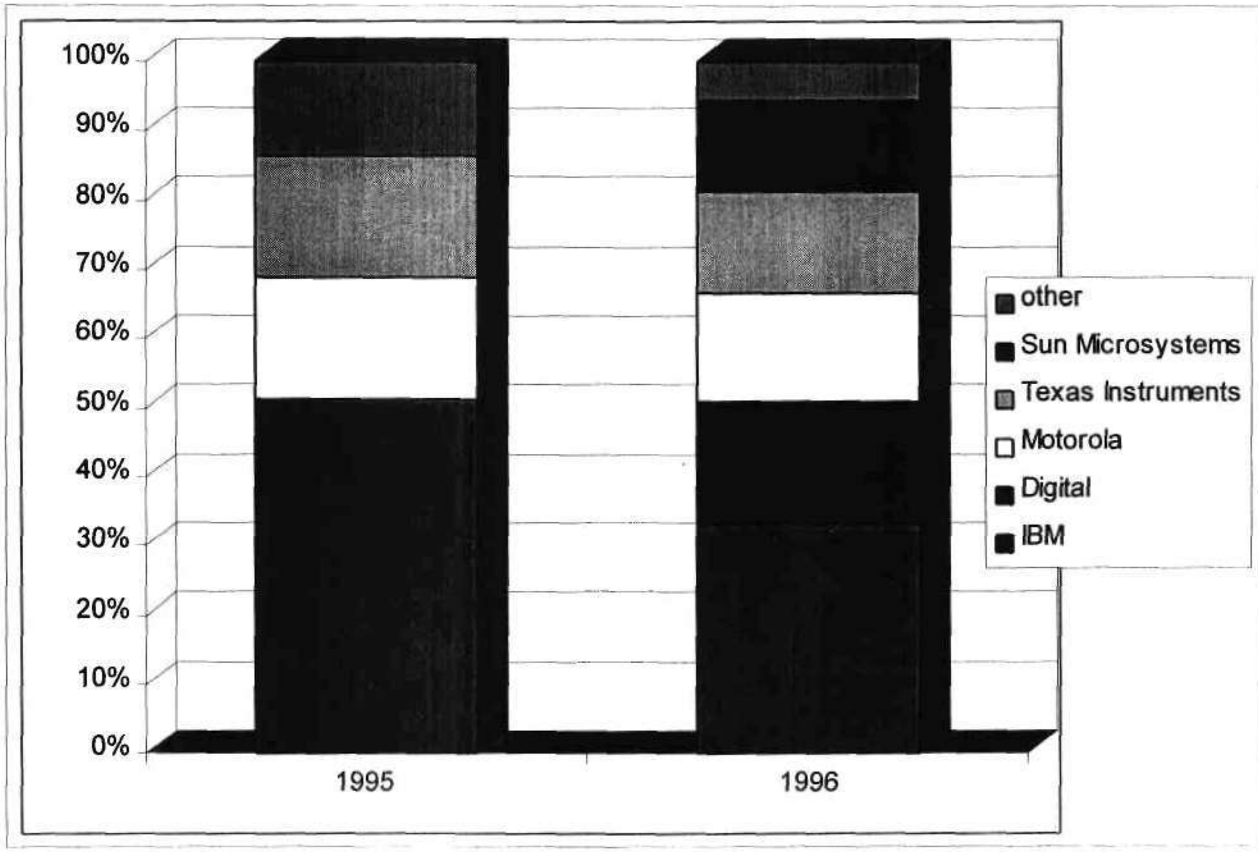
IBM Continues to Lead in 32-Bit Compute RISC



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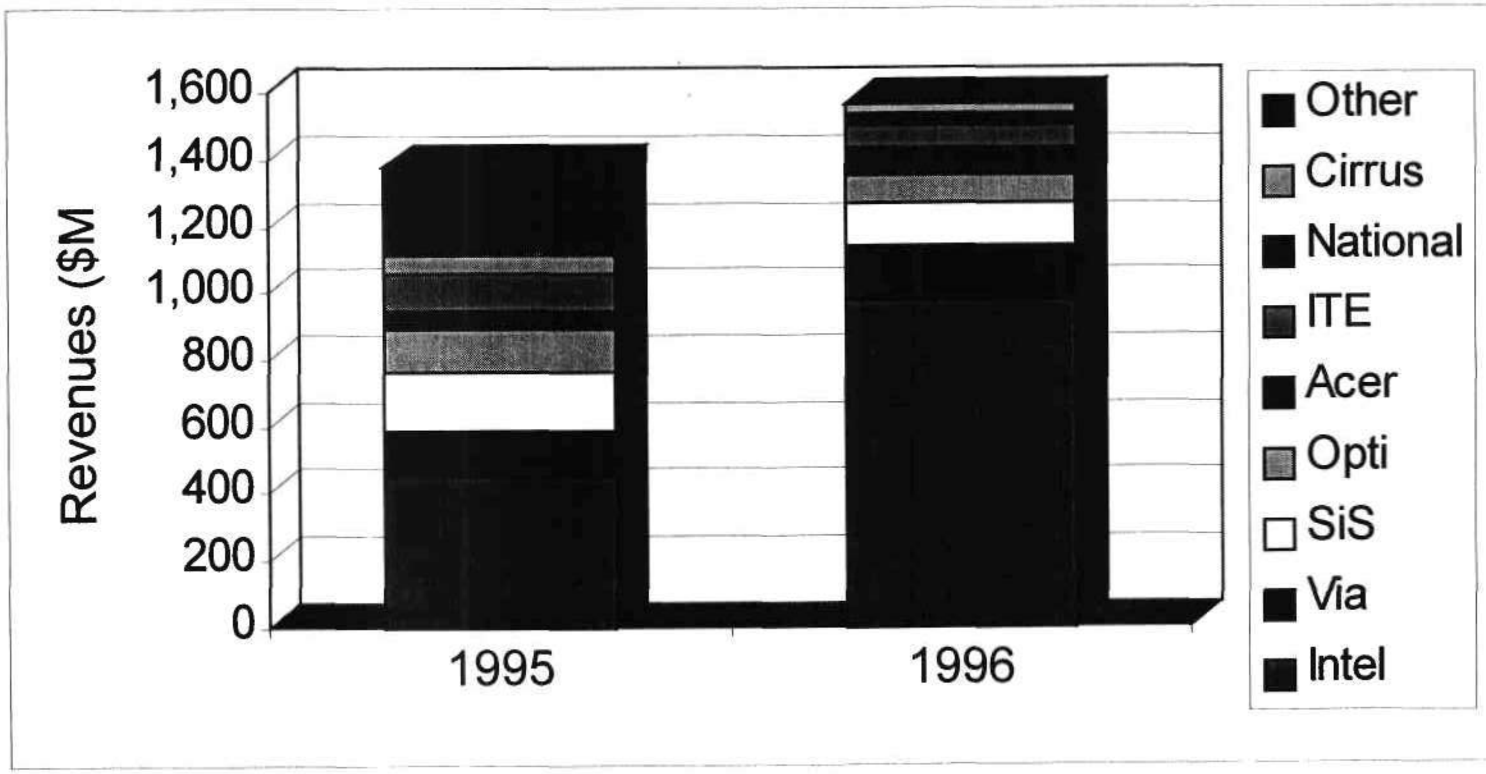
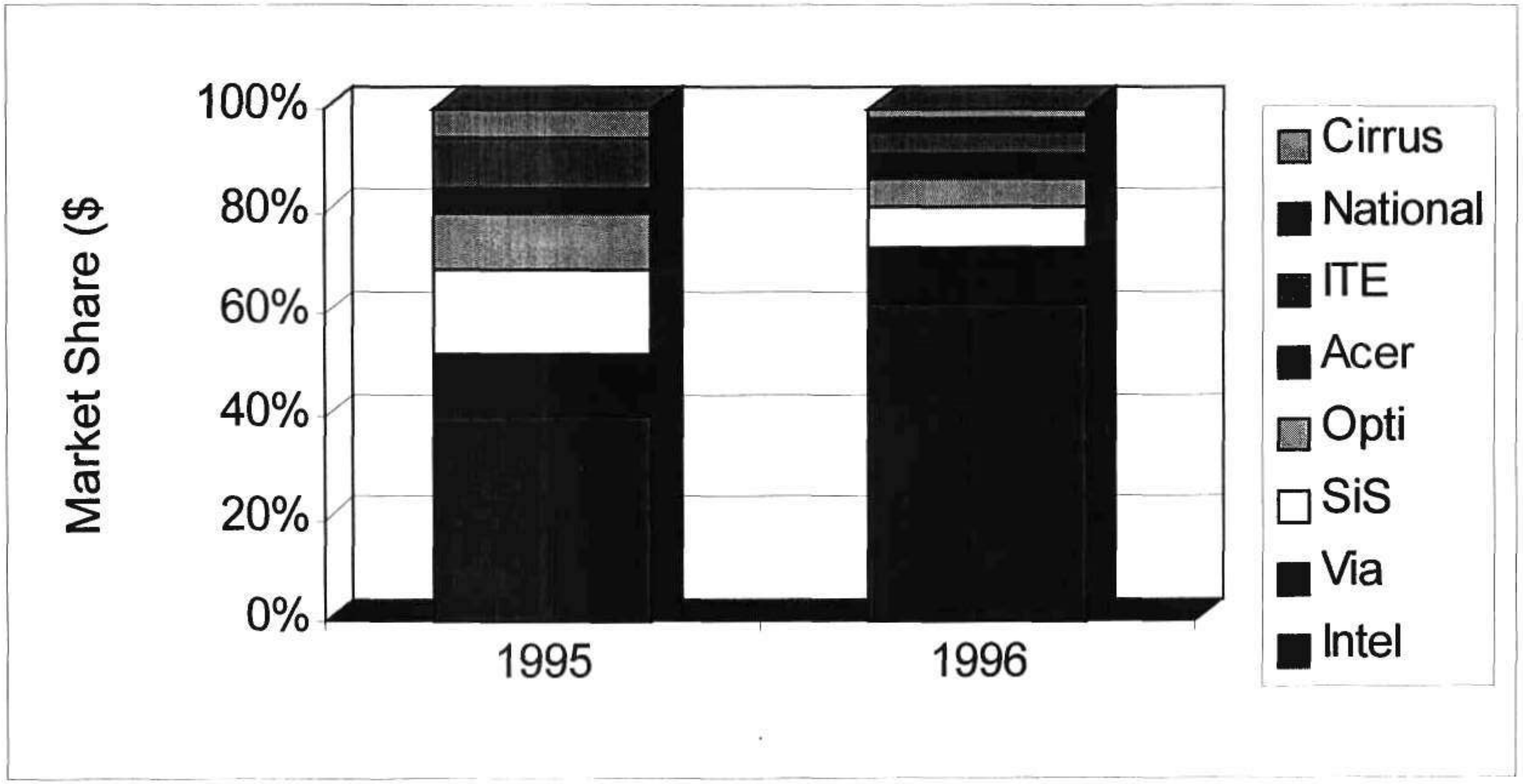
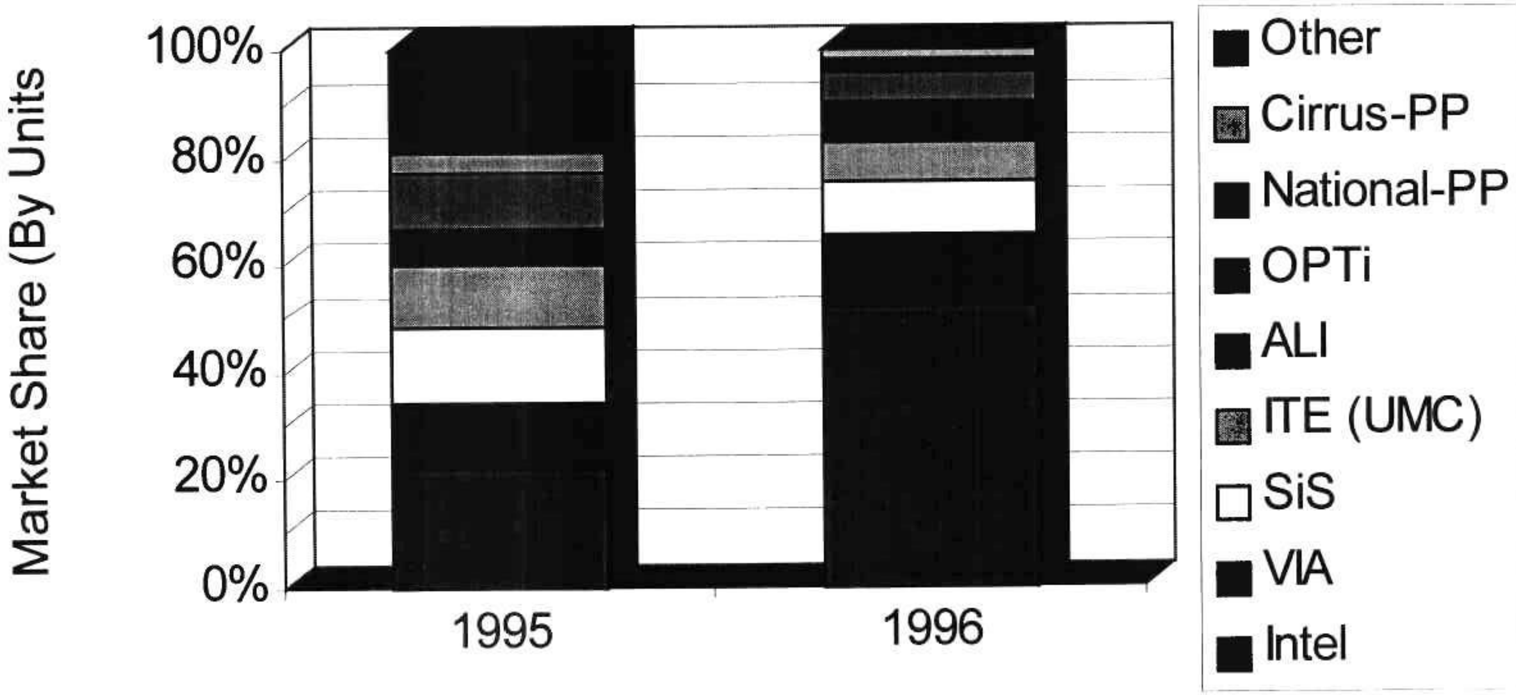
x86 Core Logic Market Exceeded $1.5B in 1996



Intel Captured 62% of Core Logic Revenues in 1996



But Only 52% of Units



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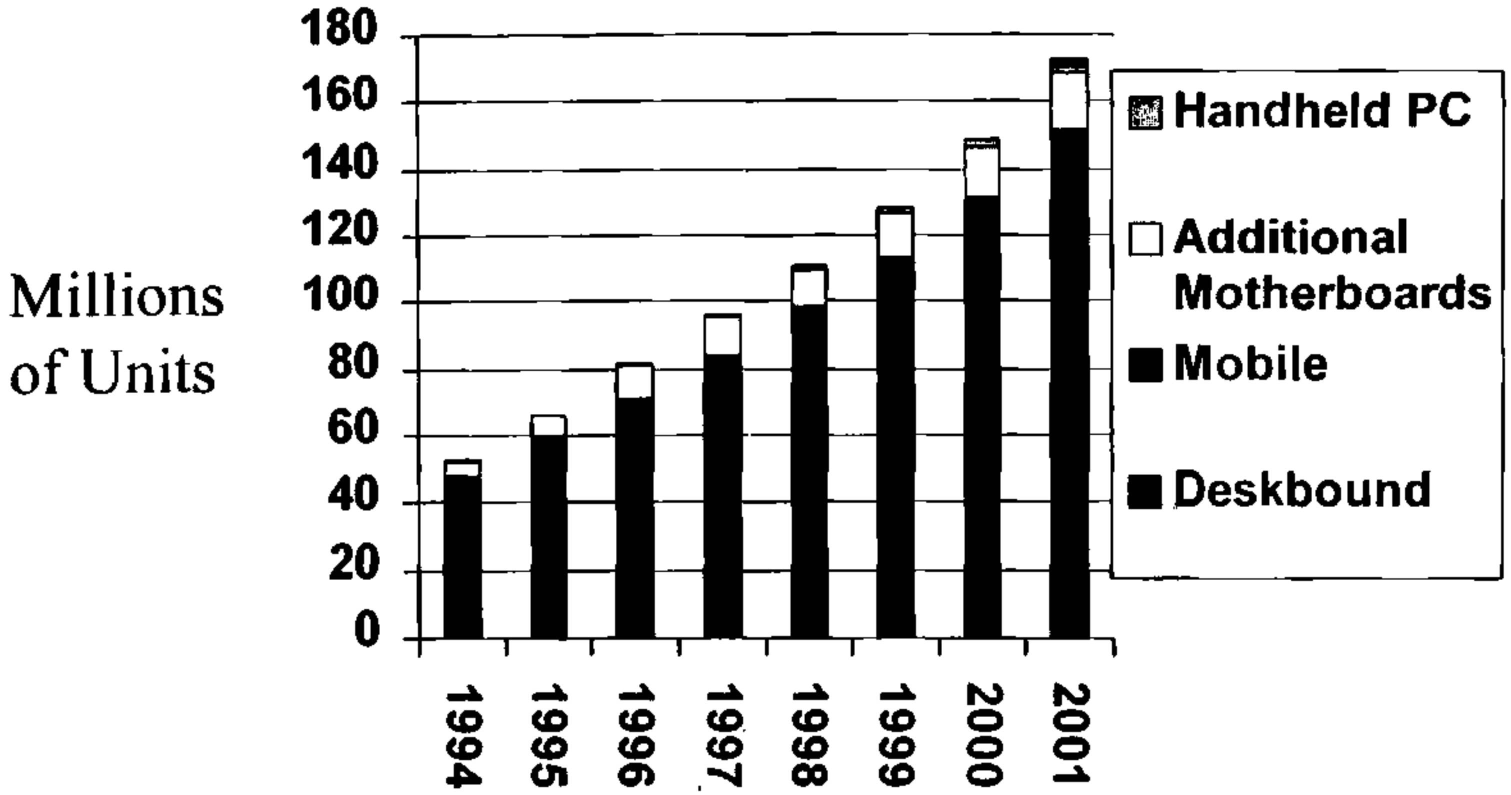
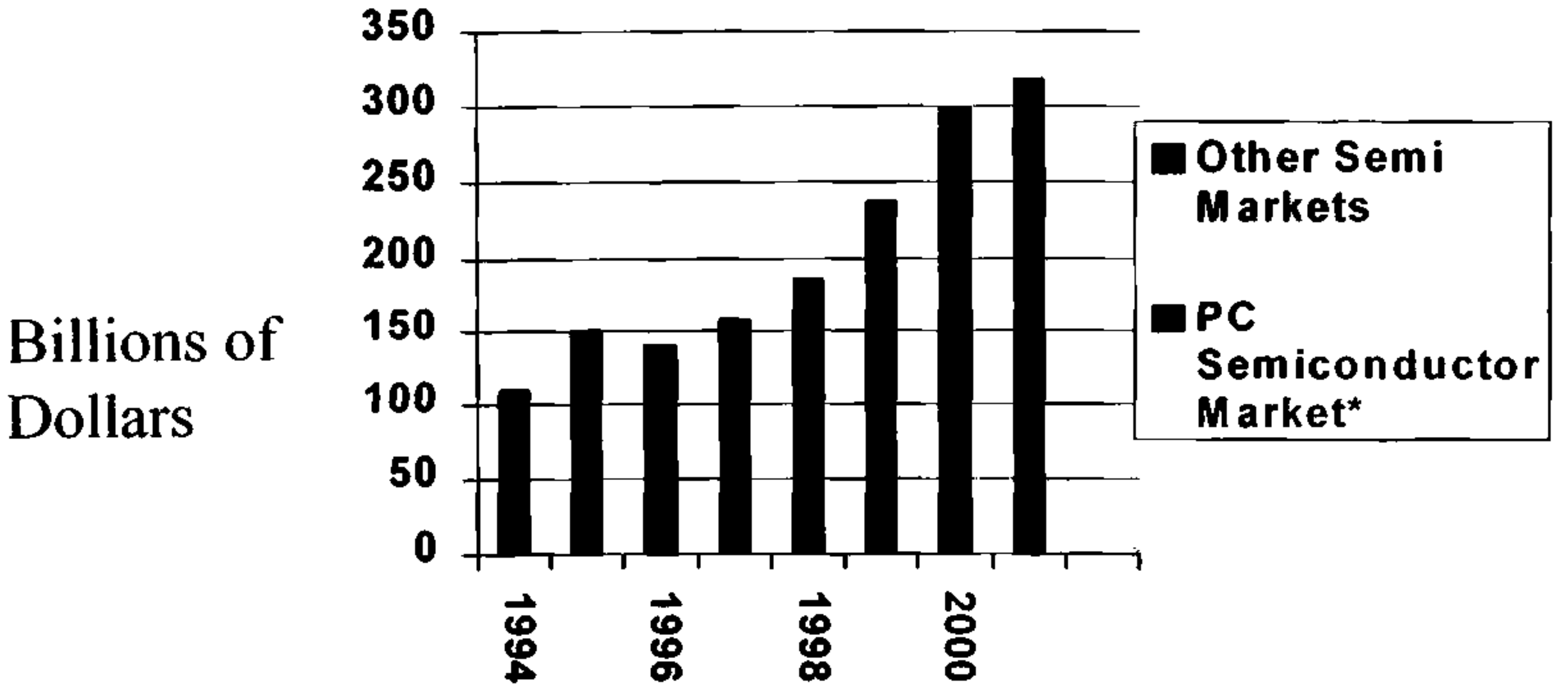
PC Unit Shipment Forecast



Source: Dataquest April 1997

PC Semiconductor Revenue

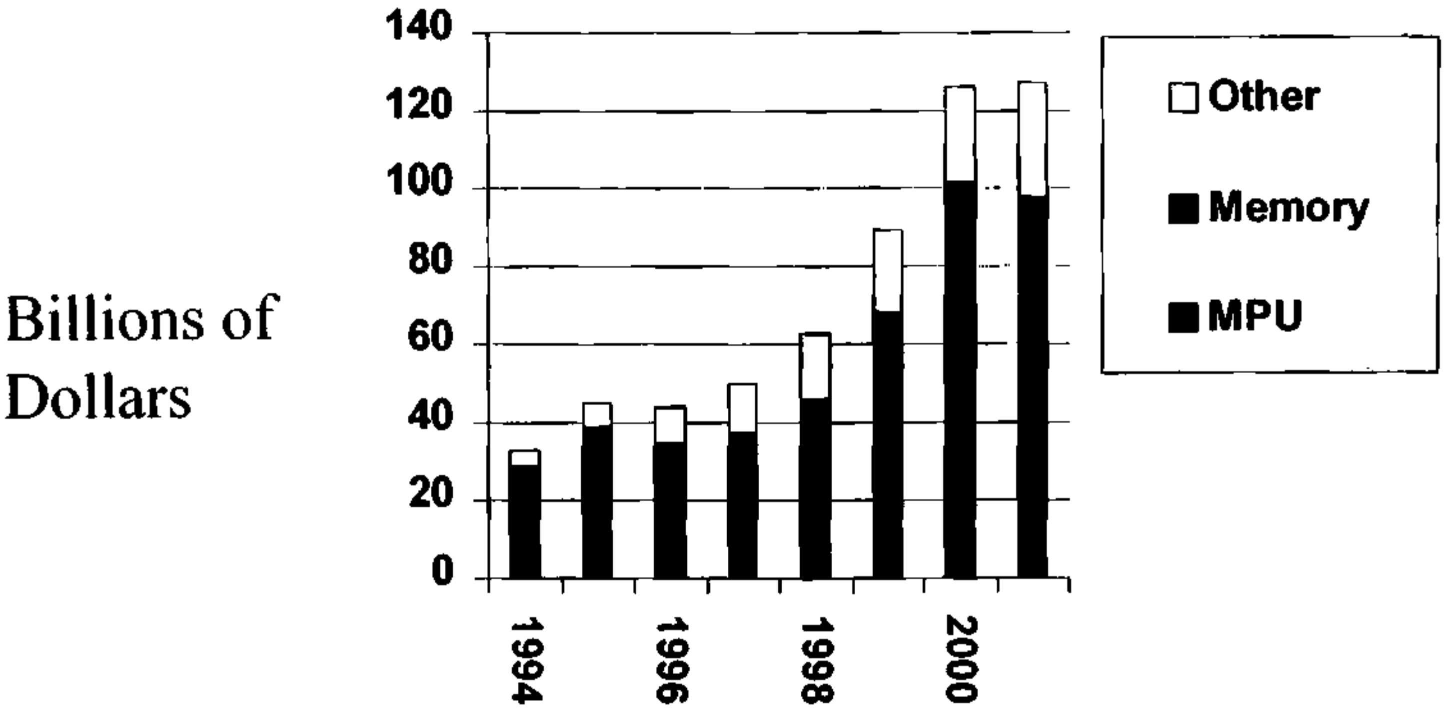


Data from Above Chart (Billions of Dollars)	1994	1995	1996	1997	1998	1999	2000	2001	CAGR 96-01
PC Semiconductor Market*	33.01	45.20	43.99	50.07	63.10	89.29	126.42	127.09	23.6%
Year-to-Year Growth		36.9%	-2.7%	13.8%	26.0%	41.5%	41.6%	0.5%	
Other Semi Markets	77.51	106.07	97.70	108.72	123.99	147.37	172.98	191.20	14.4%
Total Semiconductor Market	110.51	151.26	141.69	158.79	187.09	236.66	299.40	318.29	17.6%

*Includes semiconductor content of all PC categories: deskbound, mobile, handheld and additional motherboards

Source: Dataquest June 1997

PC Semiconductor Consumption By Major Category

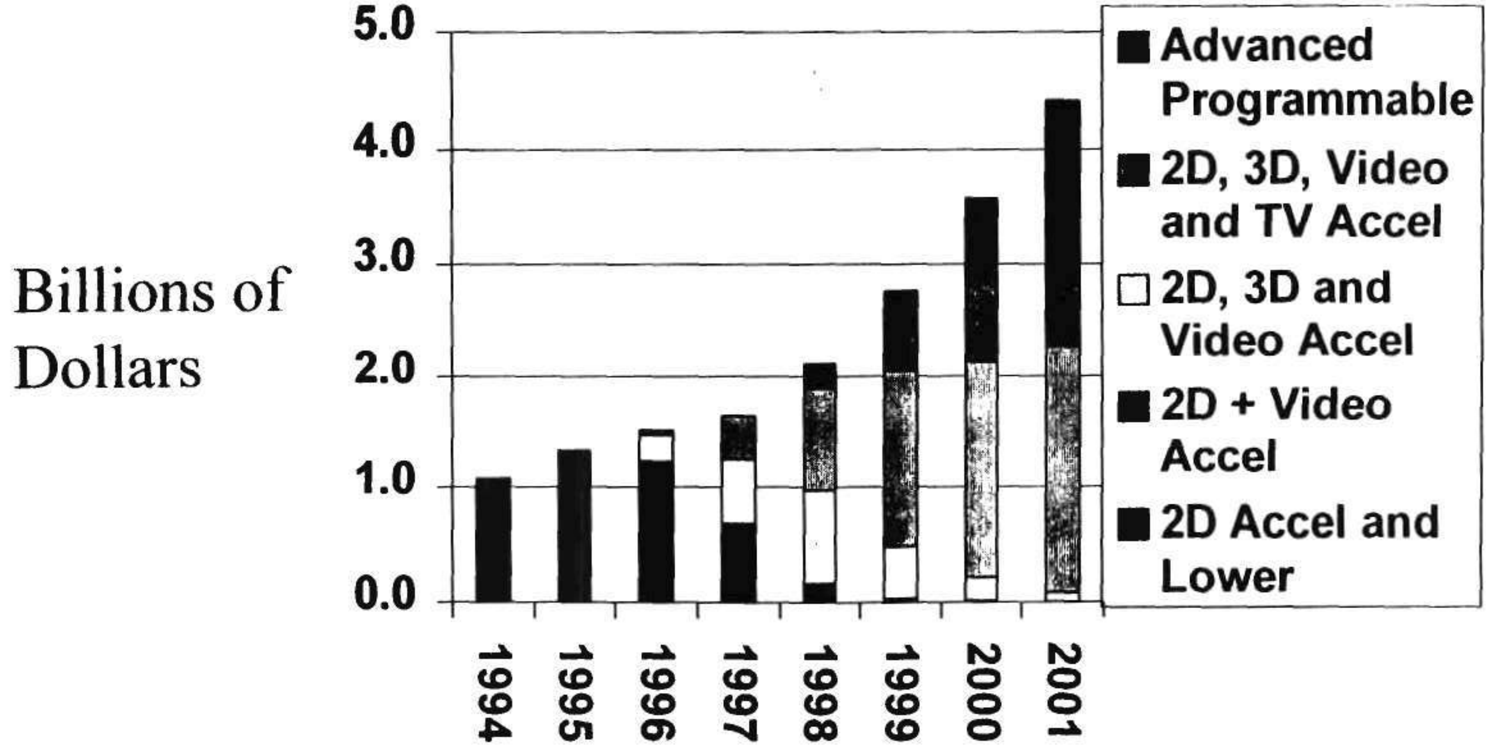


Data from Above Chart (Billions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR 96-01
Microprocessor (MPU)	9.25	10.96	14.16	16.77	20.94	29.11	36.98	43.17	25.0%
Memory	19.44	28.09	20.90	20.73	25.12	39.11	64.24	54.51	21.1%
Other	4.32	6.15	8.94	12.57	17.04	21.08	25.20	29.42	26.9%
Total	33.01	45.20	43.99	50.07	63.10	89.29	126.42	127.09	23.6%

Source: Dataquest June 1997

PC Graphics Controller Forecast

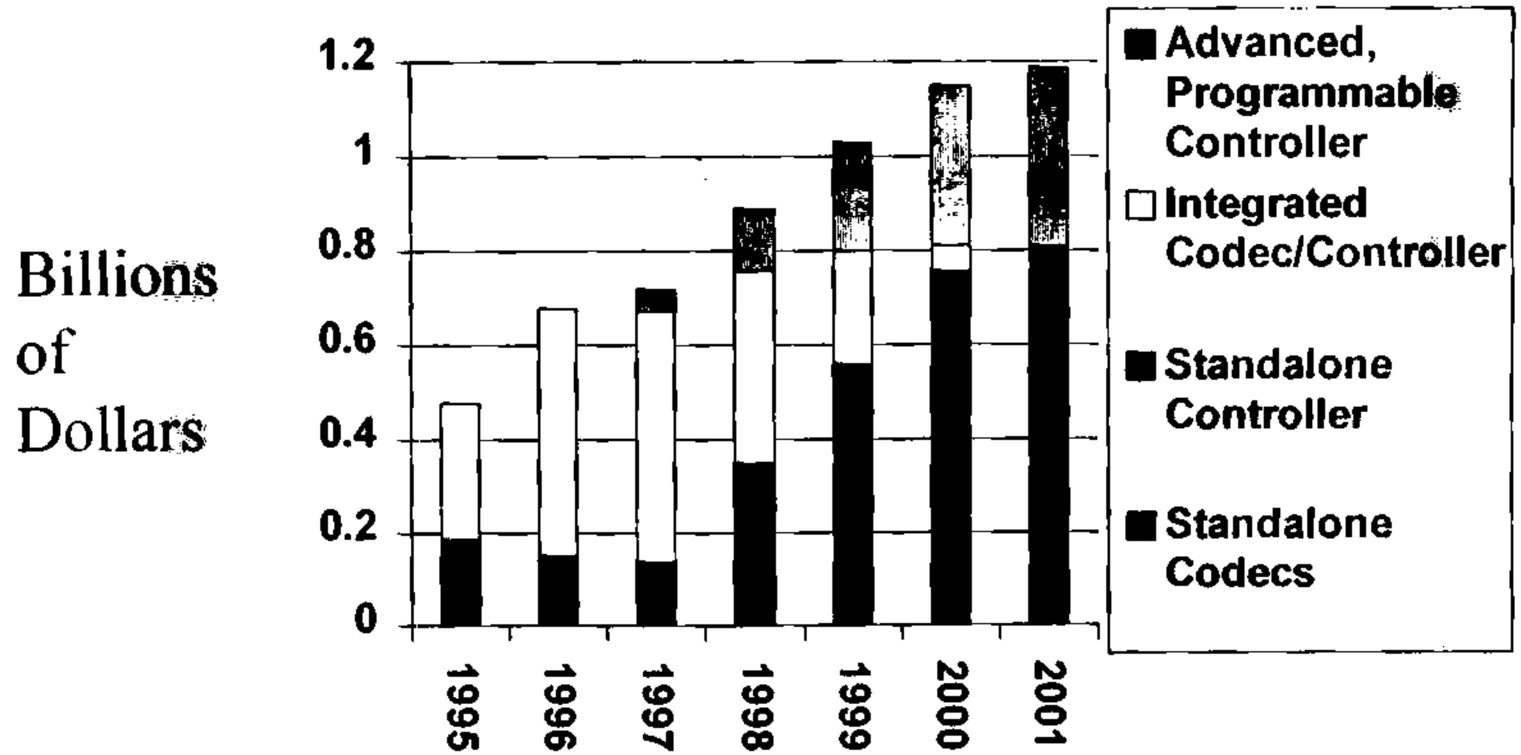


Data from Above Chart (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR 96-01
Total	1.08	1.34	1.52	1.66	2.11	2.77	3.57	4.41	23.8%
Year-to-Year Growth		24.0%	13.5%	9.0%	27.2%	31.6%	28.7%	23.6%	

Source: Dataquest May 1997

PC Audio Chip Forecast



Data from Above Chart (Billions of Dollars)

	1995	1996	1997	1998	1999	2000	2001	CAGR 96-01
Total	0.48	0.68	0.72	0.89	1.04	1.15	1.18	11.8%
Year-to-Year Growth		39.6%	6.4%	24.2%	16.0%	11.0%	2.9%	

Source: Dataquest May 1997

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Digital Uses AMD K6 Microprocessors to Launch Massive Marketing Experiment

On June 9, 1997, Digital Equipment Corporation introduced several new versions of its Venturis FX-2 personal computer system. Unlike earlier models that carried the "Intel Inside" logo, these new systems contain an AMD K6 microprocessor that sits in the socket normally reserved for an Intel Pentium Processor with MMX™ Technology. In all other regards, Digital's AMD-based configurations mirror the earlier Intel-based ones. A low-end system with a 166 MHz processor, 16 MB of synchronous DRAM (SDRAM), and a 1.2 GB disk goes for $1,249 with an MMX-enabled K6—$63 less than the same system with an Intel MMX-enabled Pentium, which sells for $1,312. Upscale customers can save $94 by purchasing a K6-based 200 MHz version (with 32 MB SDRAM and 2 GB disk) for $1,670, instead of a Pentium-based system for $1,764.

Even a professional market researcher would be hard-pressed to devise a better experiment to test the value of the "Intel Inside" logo. The brand of the microprocessor is the *only* independent variable and impacts both price and performance. All other variables (vendor reputation, channel, salesperson, color of box, bundled software, and so on) remain constant. Every Digital customer who purchases either of these systems gets to participate in the experiment, voting with dollars as to which offers the more compelling solution. Regardless of the outcome, this will be a fascinating experiment to watch over the remainder of the year and will provide material for unknown numbers of future MBA candidates and doctoral dissertations. (Of course, as professional market researchers, Dataquest would have preferred that Digital vary the price differential between the Intel and AMD configurations in different geographical regions, to assess whether the magnitude of the cost savings has any impact on the outcome. But Dataquest will save that for another consulting project.)

Like all good researchers, Digital slyly attempts to bias the experiment in favor of its own preferred outcome. The AMD-based systems cost about 5 percent less and perform about 5 percent faster than comparable Intel-based systems at the same clock frequency. To make the deal even more tempting, Digital sets the price of the 200 MHz AMD systems very close to that of the 166 MHz Intel configurations. This means a customer can purchase a 200 MHz AMD system that performs 5 percent faster than a 200 MHz Intel system for the price of a 166 MHz Intel system. For typical configurations, this amounts to savings of $200, not including taxes and license. In essence, Digital is asking its customers, "Will you sacrifice 'Intel Inside' to save 15 percent on your system's purchase cost?"

For AMD, Digital's move comes at a most opportune time. Although Digital falls 13th in worldwide rankings of personal computer vendors, it always gets high marks for technical achievement in personal computers as in microprocessors. Its K6 endorsement certainly speaks well for that chip's technical merit. Digital's unit volume requirements will provide AMD with a healthy revenue stream, but this won't saturate AMD's manufacturing capacity unless the experiment produces startling results.

Dataquest suspects that Digital failed to consult with Intel prior to the structuring of this grand marketing experiment, just as it failed to consult prior to filing last month's lawsuit for patent infringement. Had such consultation taken place, Intel might have suggested a more restricted geographical test—in cities like Billings, Montana or Reno, Nevada—in order to minimize the expense of analyzing the results. Given that Digital decided to skip the pilot program and roll the campaign out on a more massive basis, everyone gets to participate in and observe this grand experiment. The results of this test could have a dramatic impact on the future structure of the computer industry. Stay tuned for further developments—Jerry Sanders and Andy Grove will be watching closely.

By Nathan Brookwood

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Intel Finally Announces the Processor Formerly Known as Klamath

In the least surprise-packed announcement since January's launch of the Pentium Processor with MMX™ Technology, Intel today launched Pentium II (formerly known as Klamath), the cute and imaginative name it has created for its new flagship processor. Although Intel officially launched its sixth generation of x86 processors with Pentium Pro in November 1995, the introduction of Pentium II, along with the new name, suggests that this time, Intel means business.

Unless you have spent the past year on the space station *Mir*, you have probably known all about this device long before today. Intel has presented almost every detail associated with this product over the last few months; it's almost as if *they* forgot it had not yet been announced. The new Pentium II weighs in at 7.5 million transistors,36 percent more than the Pentium Pro it will someday replace. Its larger on-chip caches (dual 16KB, versus dual 8KB on the Pro) consume most of the additional transistors. It runs at 233 MHz, 266 MHz and 300 MHz. Table 1 summarizes the price and performance figures for the new CPU. Table 2 looks at the Pentium II's price and performance relative to the earlier Pentium Pro. Alert readers will note that the integer performance of these devices (as measured by SPECint95) scales closely with regard to clock frequency while floating point performance (as measured by SPECfp95) scales less closely, a consequence of the cache-intensive nature of the SPEC floating point benchmark.

Table 1
Pentium II Price and Performance

Chip	SPECint95	SPECfp95	Price ($)
Pentium II at 233 MHz	9.49	6.43	636
Pentium II at 266 MHz	10.80	6.89	775
Pentium II at 300 MHz	12.18	7.77	1,981
Pentium Pro at 200 MHz	8.20	6.21	514

Source: Intel

Table 2
Pentium II Price and Performance Relative to 200 MHz Pentium Pro

Chip	Relative Frequency (%)	Relative SPECint95 (%)	Relative SPECfp95 (%)	Relative Price (%)
Pentium II at 233 MHz	117	116	104	124
Pentium II at 266 MHz	133	132	111	151
Pentium II at 300 MHz	150	149	125	385
Pentium Pro at 200 MHz	100	100	100	100

Source: Dataquest (May 1997)

Given the initial prices Intel has set for these devices, they will likely appear in desktop configurations selling for $2,500 or more, an area previously addressed by the 200 MHz Pentium Pro and the 200 MHz Pentium with MMX technology. Dataquest anticipates that as production volumes ramp, Intel will reduce chip prices, resulting in system prices of $2,000 by the fourth quarter, and $1,700 by this time next year. Dataquest also expects that Intel will ship between 12 million and 15 million of these devices by year's end.

How the Pentium II Differs from the Pentium Pro

Intel's sixth-generation processors (Pentium Pro and Pentium II) utilize a dedicated bus to shuttle data between the external cache and the CPU chip. To avoid delays that would slow the chip down, this external cache must be located in close proximity to the processor. The Pentium Pro package included two chips—a processor die and a separate external cache die that contained either 256 KB or 512 KB of fast level-two cache. Intel designed and manufactured both devices internally. By sealing both chips inside a single package, Intel made the external cache operate at the same frequency as the processor—no mean feat at 200 MHz.

This design concept presented two major drawbacks. First, Intel had to manufacture the cache chip using the same state-of-the-art production equipment needed to make the CPU, but it could not charge as much for the cache chip as it could for a processor. This hardly mattered as long as it delivered Pentium Pro in (relatively) small volumes, but would have wreaked havoc with Intel's margins as the device moved into the mainstream. Second, the two dice needed to be mounted in a package, and then wired to each other and to the package itself. Intel never published data on its assembly yield through this process, but Dataquest imagines that it was not a pretty picture.

The Pentium II differs most dramatically from its predecessors in the approach Intel uses to provide the Pentium II's cache memory. Intel mounts the Pentium II processor chip and its associated caches on a small 6-layer card that is, in turn, mounted inside an aluminum and plastic housing that Intel calls the "single edge contact" (SEC) Cartridge. The SEC looks more like a Nintendo game cartridge than a microprocessor, and is decorated with a holographic image of the processor itself. Instead of a high-pincount socket, the SEC plugs into a motherboard connector dubbed "Slot 1."

The cartridge itself measures about 2 inches by 5 inches by 0.5 inches; a heat sink measuring 2 inches by 5 inches by 1.5 inches is normally attached to the cartridge, making the total assembly 2 inches by 5 inches by 2 inches. Together with the heat sink, it weighs close to one pound. (The Pentium II is the first microprocessor that could hurt you if you drop it on your foot.)

Given the new package and associated connector, the Pentium II requires a new motherboard. Boards designed for the earlier Pentium Pro "Socket 8" cannot accommodate the Pentium II, and vice versa. Intel will cite the new advanced Slot 1 as a technology advancement, while AMD and Cyrix will plug their sixth-generation MPUs into the familiar Socket 7 that Intel used for Pentium, and they will cite their continuity with existing standards as an advantage. For the first time in quite a while, system vendors and end users may have to do some homework to determine which approach better meets their needs.

The SEC allows Intel to revert to a far more conventional manufacturing process for Pentium II. It produces the processor die using its most advanced semiconductor processes, mounts this die in a plastic ball-grid array package, and tests this standalone package before subsequent assembly operations. Intel purchases 32K x 32 (128 KB) SRAMs from a number of memory providers and uses conventional printed circuit assembly techniques to mount the BGA processor and the cache chips on the SEC card. Dataquest's memory service estimates that Intel will rapidly become the world's largest purchaser of SRAM devices.

Of course, the electrical signals that traveled less than an inch in the cozy dual cavity Pentium Pro package are forced to travel several inches over more hazardous terrain (the printed circuit board) in the SEC, and they cannot complete their journey as quickly as they could in the Pentium Pro. Intel solves this problem by running the cache at one-half the frequency of the CPU core (that is, 116 MHz in the 233 MHz version, and 150 MHz in the 300 MHz version). This change hinders the II's performance, relative to the Pro; to offset this slower cache access time, Intel beefed up the II's on-chip level-one caches from a dual 8 KB design to a dual 16 KB design. In theory, this means that the processor will access the external cache less often, and thus suffer less impact from the additional delays it encounters whenever it does so. The performance data presented in Table 1 suggests that this theory holds better for integer (fixed point) operations than for floating point calculations.

Along with the major overhaul of the cache design, (and the associated packaging changes), Intel's designers also enhanced two key aspects of the processor's logic. Best known are their efforts to incorporate the MMX functionality recently added to the Pentium processor. This feature should make the Pentium II far more useful in multimedia applications than the earlier Pentium Pro. Unfortunately, for instruction set extensions like MMX to do their work, software programs must know how to use them, and this means programmers must rewrite portions of their code. Consumers will need new MMX-aware programs to take full advantage of the chip's features. Such packages may be difficult to find today, but Dataquest expects their ranks to swell over the year. MMX significantly boosts the performance of image processing applications, so it is no surprise that Adobe's Photoshop and Microsoft's PictureIt are leading the pack in this regard. Intel's engineers also added some features to enhance the Pentium II's 16-bit performance, at least compared to the notoriously weak 16-bit performance of the Pentium Pro. These changes should appeal greatly to users that deploy the Pentium II in Windows 95 environments.

Pentium II and the Competitive Landscape

The Pentium II arrives on the scene just as Intel faces credible x86 competition for the first time. AMD's K6, based on the design procured by the NexGen acquisition, comes amazingly close to the 233 MHz Pentium II's performance in many benchmarks, but costs $180 less. The Cyrix M2 should hit the street within a month, and will also approach Intel's performance. AMD and Cyrix will sell their wares at a substantial discount to Intel's prices, and buyers will be forced to decide how much they are willing to pay for "Intel Inside."

Given the wide range of benchmark programs and operating environments available in today's personal computer market, Dataquest would be surprised if Intel, AMD, and Cyrix cannot each point to specific tests where they rate the highest. Performance data will be inconclusive at best. Intel will likely stress the Pentium II's "dual independent bus architecture" (DIBA)—its term for the dedicated cache bus described earlier—as the key to its performance, while AMD and Cyrix will argue that their larger (dual 32 KB) on-chip caches offset the need for new buses or form factors. The advantages of Intel's DIBA increase with increasing MPU core frequencies, a fact that AMD cannot refute, given that earlier NexGen designs used a similar approach. (NexGen abandoned this concept in order to gain compatibility with the Intel Socket 7 interface.) Consequently, Dataquest expects that the increasingly competitive environment will drive Intel to improve the clock rate of its processors as fast as it can, in an attempt to reach frequencies where the DIBA makes a real difference.

All-in-all, Dataquest expects to see Intel compete on the basis of its performance and manufacturing capacity, while AMD and Cyrix use price as their competitive weapon. Dataquest believes Intel will refrain from matching AMD or Cyrix prices, an expensive alternative because of its overwhelming market share. Thus, Dataquest regards the outbreak of a microprocessor price war as an extremely unlikely possibility.

Oh No! Not Another FPU Bug!

Just as Intel began to chill the champagne for Pentium II's gala New York coming-out party, an ugly reminder of one of Intel's darkest moments surfaced on the Internet. Rumors emerged regarding a Pentium II design error that could, in certain cases, produce faulty arithmetic results. Although clearly undesirable, problems like this can be found in most complex microprocessors; once they are known, software developers can often program "work-arounds" that avoid detrimental effects. Intel has indicated that it will need several days to study and "characterize" this problem, making any analysis here premature; but Dataquest is encouraged that the company's more open response to this issue (as contrasted with its handling of the original error a few years ago) bodes well for an uneventful conclusion to this episode. The $475 million Intel spent repairing the results of its last floating point bug appears not to have been spent in vain.

By Nathan Brookwood

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MPU Price War Ends Peacefully

Ever since Advanced Micro Devices Inc. launched its K6 microprocessor earlier this month, the industry has anxiously awaited Intel's May pricing moves to gauge just how bloody the impending price war might be. Yesterday, Intel Corporation finally let the cat out of the bag. If you were hoping to see Intel and AMD stage a repeat of the price war that decimated DRAM markets last year, Dataquest has some bad news for you. Peace and tranquillity reign supreme in microprocessor markets.

The media, in a desperate attempt to get some mileage out of this nonstory, have trumpeted "cuts of up to 48 percent," which certainly would have been exciting, had they been applied across the board. Unfortunately, they apply only to the 200-MHz Pentium without MMX, a product that accounts for a relatively small portion of the market. Intel needed to drop this product's price more sharply than most in this cycle, primarily because it reduced it less than most others in the previous round of cuts, and the chip's price-performance drifted out of line with the rest of Intel's processors.

In prior reports, Dataquest argued that the concept of a microprocessor price war made little sense, given that Intel was already producing at capacity and that AMD, now that it has a respectable product, soon would also be at its limits. Furthermore, a 25 percent across-the-board reduction on Intel's part, which would have been needed to match AMD's quoted prices, would have deprived Intel of about $4.5 billion in revenue—far more than would have been lost to AMD via lost sales. Nevertheless, it is comforting to see that the Excel spreadsheets running on Pentium Pros inside Intel's headquarters yielded the same answer as Excel spreadsheets running on K6s within AMD.

The most remarkable aspect of this latest round of pricing moves is the degree to which Intel's planners accurately anticipated these prices at least nine months ago. To facilitate the planning process for customers like Compaq and IBM, Intel generally provides large OEMs with a rolling four-quarter forecast of anticipated microprocessor prices. Dataquest recently had the opportunity to compare the prices Intel projected *last summer for this May*, with the prices announced yesterday. Back then, AMD was struggling to produce 100-MHz K5s, and the K6 design had yet to be completed, much less tested or manufactured; if Jerry Sanders knew then what his pricing strategy for this part would be, he wasn't saying. Nevertheless, the prices announced yesterday (with the exception of the aforementioned P200 catch-up reductions) precisely match those projected. On Intel's railroad, even the price reductions arrive on time.

Tables 1, 2, and 3 provide the details of Intel's latest revision to its microprocessor prices, effective May 1, along with the prices it published last fall and in February.

Table 1
Revised Desktop Pentium Pricing (Dollars, for 1,000 Units)

Pentium	Fourth Quarter 1996	February 1997	May 1997	Reduction (%)	May Projection
200 MHz with MMX 2.8V	550	539	492	-9%	492
166 MHz with MMX 2.8V	407	356	270	-24%	270
200 MHz 3.3V	509	498	257	-48%	407
166 MHz 3.3V	402	295	209	-29%	209
150 MHz 3.3V	214	161	150	-7%	198
133 MHz 3.3V	204	134	134	0%	134
120 MHz 3.3V	106	106	106	0%	106
100 MHz 3.3V	106	106	106	0%	106

Source: Intel

Table 2
Revised Mobile Pentium Pricing (Dollars, for 1,000 Units)

Mobile Pentium	Fourth Quarter 1996	February 1997	May 1997	Reduction (%)
166 MHz with MMX 2.5V	550	539	498	-8
150 MHz with MMX 2.5V	443	336	326	-3
133 MHz with MMX 2.5V	-	-	284	-
150 MHz 2.9V	329	249	230	-8
133 MHz 2.9V	244	174	166	-5
120 MHz 2.9V	144	106	106	0

Source: Intel

Table 3
Revised Desktop Pentium Pro Pricing (Dollars, for 1,000 Units)

Pentium Pro	Fourth Quarter 1996	February 1997	May 1997	Reduction (%)
200-MHz Pentium Pro/512K	1,072	1,035	1,035	0
166-MHz Pentium Pro/512K	664	627	412	-34
200-MHz Pentium Pro/256K	562	525	514	-2
180-MHz Pentium Pro/256K	482	418	407	-3

Source: Intel

By Nathan Brookwood

last week

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Intel Dominates x86 Processors Market in 1996, but Clones Will Make Progress, According to Dataquest

San Jose, Calif., April 2, 1997—Demand for more powerful x86 processors to handle complex PC programs continues to grow, driving the worldwide x86 processor market to $15.4 billion in 1996, according to Dataquest. Intel continues to be the preeminent leader with 95 percent market share. While Intel will continue to lead the market through the year 2000, x86 clones will make inroads into the marketplace. Dataquest projects that x86 clones will account for 25 percent of unit shipments and 15 percent of revenue by the year 2000.

"Unlike prior incursions, when AMD arrived with too little fab capacity or too late with competitive performance, this time, bolstered by the technology boost it received via its NexGen acquisition, AMD's gun may shoot real bullets," said Nathan Brookwood, principal analyst for Dataquest's Personal Computer Semiconductors and Applications Worldwide program. "Over the next few quarters, the market will measure AMD's skill as a marksman, while Intel gets to discover whether the 'Intel Inside' shield it has created can fend off the invading hordes."

"Historically, Intel led its competitors by several years in ramping production volume for each generation, but this gap shrinks significantly with the sixth-generation processors," said Mr. Brookwood. "In the past, the clones' late arrival to the market restricted their ability to charge the same type of premium prices as Intel. The average selling price of x86 clones will significantly increase with their improved products, although they will still sell at a discount to Intel's offerings."

The Dataquest Perspective titled "Quarterly x86 Forecast: Send in the Clones" provides further analysis of x86 marketplace. This document has a detailed forecast by both shipments and revenue through the year 2002. A forecast for the average selling price of both Intel and non-Intel x86 processors is also included.

-MORE-

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Dataquest ALERT

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The Presario 2100: Not Your Father's Compaq, But Maybe Your Grandmother's

Yesterday Compaq introduced its $999 Presario 2100, the first member of a new line of consumer-oriented desktop computers targeted at the first-time buyer and multiple PC household markets. Unlike other attempts to meet this price point by combining dated technology with thinner-than-usual profit margins, the Presario 2100 achieves its low price via new technology that repartitions the PC's internal elements in order to achieve genuine cost reductions. The system includes a Cyrix 133 MHz MediaGX processor, 24 MB memory, 2.0 GB storage, 33.6 Kbps modem, and an 8x CD-ROM drive. The MediaGX, a new design, incorporates the microprocessor itself, its core logic, a midrange graphics accelerator, a frame buffer for that accelerator, and has "Soundblaster-compatible" audio capability. This all fits in two BGA packages, mounted on a tiny motherboard inside a matte-black chassis that looks more like a VCR than a computer (although it lacks the clock blinking 12:00). Compaq offers the systems with a full one-year warranty and 7x24-hour technical support.

Benchmarks suggest the Cyrix MediaGX provides a respectable level of performance, comparable to a 133 MHz Pentium; that is, slightly better than the 120 MHz models typically included in low-end systems (including the recently-introduced Packard Bell C115). Consequently, the new system is unlikely to cannibalize sales of faster and more expensive Presarios based on the traditional components. The consumer electronics approach, low price, and ease of installation (with built-in speakers, the user merely plugs in the keyboard, mouse, monitor and line cord), should appeal to first-time buyers and multiple PC households.

Dataquest Perspective

The message Compaq and Cyrix convey is that they used engineering skill and innovation to break the price barrier. Tradeoffs not withstanding, this will not be perceived as a de-featured system or one based on old technology. Rather, the Presario 2100 will be seen as a value, with the customer being thrifty, not cheap.

Two factors have retarded the growth of the home PC market: relevance and affordability. Vendors began to address the relevance issue in the second half of 1996, via lifestyle marketing and advanced industrial designs. The Internet's increasing popularity certainly aids this cause as well. However, to reach critical mass, PCs must become part of the social fabric, and this, in turn requires inexpensive systems. Cost is a big deal to the 65 percent of U.S. households, many with annual incomes in the $30,000 to $40,000 range, which still have not purchased a personal computer. Until recently, price-sensitive buyers have been forced into the used computer market, where support is "chancy" at best. Although sub-$1,000 systems comprise just 2 percent of the total PC market, used systems make up 16 percent of the U.S. home installed base. With just over 100 million households in the United States alone, there is great potential for a system that cracks the code.

Our primary concern with Compaq's new product is its lack of upgradeability. Unlike traditional systems that come with many empty slots and bays for future upgrades, the Presario's cabinet is fully packed. Its one 8-bit ISA expansion slot comes filled with a 33.6 Kbps modem, presumably so Compaq can drop in the appropriate version for various international destinations. Although most slots and bays remain unoccupied throughout the system's lifetime, their presence provides flexibility and comfort. Over the next two years, Dataquest expects that the industry will shift even more toward "sealed box" PCs, but these new designs will incorporate USB (universal serial bus) and IEEE 1394 ("firewire") ports for out-of-box expansion. The 2100 lacks both in-box and out-of-box expansion. Consumers wanting a simple and utilitarian PC may accept this new fixed-configuration model, especially at the price, but Dataquest hopes that Compaq can add USB and 1394 features soon in order to appeal to a broader set of purchasers.

Of lesser concern is the lack of MMX support. For most of 1997, software titles will not be optimized for MMX. We do not think that the primary target for these systems will be swayed by marginal Quake performance relative to a P55C systems, and that the use experience in more mainstream applications will be compromised before Cyrix supplies its own MMX implementation. However, if this solution is not in place by early 1998, sales will begin to reflect its absence.

For Cyrix, Compaq's use of the MediaGX processor represents a new degree of acceptance within the OEM community. The company's inability to sign up major OEM customers for its advanced 6x86 processor represents one of the major disappointments of 1996, and contributed to its poor financial showing. The win at Compaq demonstrates that major system vendors are not afraid to purchase microprocessors that lack the "Intel Inside" logo, as long as those other vendors supply components that make valid technical and business sense. Dataquest hopes that Compaq's recent announcement marks the beginning of a turnaround for Cyrix.

For Compaq and the industry, the lasting impact of the Presario 2100 may be that it legitimizes the sub-$1,000 PC category. It does this because the marketing story is clean—not old technology at bargain basement prices—and because it is Compaq. This is the first inexpensive PC we would recommend to our grandmothers.

By Nathan Brookwood and Scott Miller

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Intel's Amazing New Disintegrating Processor Module

Intel today introduced a new mobile system partitioning scheme intended to let notebook vendors more quickly assimilate and bring to market advances in microprocessor technology. The new scheme places the microprocessor and its associated level 2 (external) cache, along with core logic components associated with cache and memory control, all on a single 8-layer daughtercard that measures 4 inches by 2.5 inches. The new scheme has the potential to impact many aspects of the mobile PC market.

The performance gap between desktop and mobile systems has grown larger over the past few years as vendors have rushed to incorporate Intel's latest microprocessor technology into their desktop systems, while mobile introductions lag. Mobile systems prices have remained high, due largely to the high cost of LCD displays and the slightly less competitive nature of the mobile market, where the small size of the product usually precludes the use of "off-the-shelf" components, and thus requires greater investments in proprietary designs. Users were forced to pay higher prices for systems with lower performance: not a happy situation.

Most desktop systems feature a processor socket into which the system assembler can drop a wide range of Pentium (or even Pentium-socket compatible) CPUs immediately prior to system shipment. The space constraints in mobile systems force vendors to use Intel's Tape Carrier Package (TCP) processors that are soldered onto the motherboard early in the assembly process and virtually impossible to remove for rework or reconfiguration. Vendors lacked the ability to reconfigure CPU or cache to respond to tactical market conditions and typically needed to redesign the board for each new version of the Intel CPU, thus retarding Intel's ability to rapidly transition the market to newer and faster models. The desktop socket also permitted the ability to upgrade the system to higher performance levels as future products emerged. This reassured system purchasers, although relatively few ever bothered to exploit this feature following the system's purchase.

The mobile module changes all this. From a design standpoint, it eliminated the need for system vendors to redesign the motherboard in order to introduce products with faster CPUs; they can now incorporate a new processor module (almost) as easily as desktop vendors plug in a new processor. From a system assembly perspective, they will be able to emulate the desktop model and add the processor at the end of the assembly line, instead of at the beginning, thus increasing their ability to respond to swift market shifts, and decreasing their WIP inventory.

The processor module encapsulates the electrical characteristics of the microprocessor's interface to its cache and chipset; the module communicates with the rest of the system via a PCI bus and a standard memory control bus. This gives Intel enormous flexibility with regard to changes it might want to make down the road in the areas of processor packaging, buses, and cache implementation. They could, for example, modify the Pentium design to include a dedicated "backside cache bus" like that found on the Pentium Pro; such a change would be transparent to the rest of the system. Or, they could swap out the Pentium and substitute a Pentium Pro; this type of change would also be transparent, and could facilitate a transition from Pentium to Pentium Pro in the mobile space.

The new module also permits Intel to create an "overdrive" product line for mobile markets. As noted earlier, until now users have been forced to regard notebooks as expensive but disposable systems—you use them for a year or two, and throw them away. The overdrive concept typically forces vendors to add flexibility to their initial designs in order to accommodate the downstream processors, and this adds cost and complicates the design. Given the relatively small portion of users who follow through and purchase overdrive processors, combined with the relatively small portion (under 20 percent) of the market that mobile units comprise, Dataquest would not be surprised if Intel forgoes the creation of such a program.

The new module also presents one of those rare instances where what is good for Intel may also be good for Intel's competitors. Although the dimensions of the Intel processor module are unique, there appears to be little else proprietary in the manner in which the module interfaces with the rest of the system. Thus, it should be possible for AMD, Cyrix, or other potential competitors to adopt this new module format, and thus gain easy technical entry to the mobile market. It will be interesting to see if any pursue such a path.

Along with the new mobile module, Intel also introduced a new core logic chipset with the cute and subtle designation "430TX." Like earlier members of the Triton family, the TX includes a "north bridge" that controls the PCI bus, the cache and main memory, and a "south bridge" that interfaces to the traditional ISA bus, along with enhanced Integrated Drive Electronics (IDE) and Universal Serial Bus (USB) controllers. The north bridge supports synchronous DRAM capability, a feature its predecessor (the 430HX) lacked. Intel's Pentium Pro chipsets (440FX and 450GX) still lack SDRAM capability, but this situation will change in the second half of the year with the expected launch of the 440LX chipset. Following that introduction, system vendors have the ability to use SDRAM with all configurations: low end Pentium systems with the earlier 430VX; mid-range Pentium systems with the 430TX; and high-end Pentium Pro configurations using the 440LX. This should pave the way for a massive shift from EDO to SDRAM memory technology by the end of the year.

By Nathan Brookwood

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Intel Finally Announces the Processor Formerly Known as "The As-Yet-Unannounced P55C"

In one of the least surprise-packed announcements thus far in 1997, Intel yesterday launched the Pentium Processor with MMX™ Technology, the catchy new name it assigned to its P55C microprocessor. Intel moved the introduction date of this product from October to January in order to assuage fears that the earlier launch might confuse consumers and stall the market during the all-important Christmas season. Of course, the media did a good job of informing consumers that the chip was coming. Now we can all wonder what effect, if any, this information had on actual buying decisions. Any vendor that misses its Wall Street consensus results can and will blame Intel for softness in fourth quarter PC sales. (Sorry, Gil, this might not work for you.)

Unless you spent most of 1996 on the space station *Mir*, you probably knew all about this device long before today. The latest Pentium weighs in at 4.5 million transistors, 40 percent more than its predecessor. Its larger on-chip caches (dual 16KB, versus dual 8KB before) consume most of the additional transistors and boost overall computational performance by more than 15 percent. It runs at 200 MHz and 166 MHz in its desktop configuration and 166 MHz and 150 MHz in the lower-voltage mobile version. Table 1 summarizes the price and performance figures for the new CPU.

Table 1
Pentium Processor with MMX Technology Price and Performance

	SPECint95	SPECfp95	Price ($)
P55C at 166 MHz	5.6	4.3	407
P55C at 200 MHz	6.4	4.7	550
P55C at 200 MHz/P55C at 166 MHz (%)	14	9	35

Source: Intel

Intel basically intends to slide these new models into the line at the same price points as their similarly clocked P54 predecessors. Once the dust settles, Dataquest expects to see prices for systems assembled with these chips fall into the same price bands as earlier systems at the same clock speeds. Table 2 compares the price and performance of the old (P54) and new (P55C) chips; it doesn't take a Pentium PC to figure out that the new models offer better value.

Table 2
New Pentium/Old Pentium Price and Performance Comparisons

	SPECint95	SPECfp95	Price ($)
P54 at 166 MHz	4.8	3.7	402
P55C at 166 MHz	5.6	4.3	407
P55C at 166 MHz/P54 at 166 MHz (%)	17	16	1
P54 at 200 MHz	5.5	3.9	509
P55C at 200 MHz	6.4	4.7	550
P55C/P54 at 200 MHz (%)	16	21	8

Source: Intel, Dataquest (January 1997)

The new processor's larger caches make its performance at 166 MHz superior to the old model's 200-MHz performance. This anomaly will force those who have foolishly been confusing clock speed with performance to clean up their acts. Rational consumers should prefer the new 166-MHz part at $407 over the old 200-MHz model at $509; it will be interesting to see if sellers present it this way and if buyers buy the argument. Were Intel to adopt the "P-rating" system, it could refer to its 166-MHz P55 as a "P200+." (But then, what would it call its 200-MHz P55?)

Table 3
Warning: Confusing Megahertz with Delivered Performance Can Be Dangerous to Your Health

	SPECint95	SPECfp95	Price ($)
P54 at 200 MHz	5.5	3.9	509
P55C at 166 MHz	5.6	4.3	407
P55C at 166 MHz/P54 at 200 MHz (%)	2	10	-20

Source: Intel, Dataquest (January 1997)

While the larger caches do most of the work, the 57 new multimedia instructions get most of the glory; it's tough to get today's sophisticated customers excited about bigger caches. The new instructions follow a supercomputer single instruction, multiple data (SIMD) model; a single instruction can manipulate eight separate 8-bit numbers, four separate 16-bit numbers, or two separate 32-bit numbers. Without MMX, a program must convert the 8-bit numbers into 32-bit numbers and then perform eight separate instructions to accomplish the same work. The chip needs little additional logic to support MMX operations, and the performance gains can be impressive. This provides a clear example of designers and silicon working smarter, rather than harder.

Unfortunately, for instruction set extensions like MMX to do their work, software programs must know how to use them, and this means programmers must rewrite portions of their code. (One of the reasons why Intel went public with the MMX extensions so long ago was to give software developers time to complete these modifications before the chip's general availability. Intel last made software-visible changes to the x86 architecture in 1985, with the 386, and

Microsoft's support for those enhancements showed up 10 years later in Windows 95.) Consumers who buy these new systems will see some performance improvements stemming from the improved caches but will need new MMX-aware programs to take full advantage of the chip's features. Such packages may be difficult to find today, but Dataquest expects their ranks to swell over the year. MMX significantly boosts the performance of image processing applications, so it is no surprise that Adobe's Photoshop and Microsoft's PictureIt are leading the pack in this regard.

Longer term, MMX will allow developers to build less-expensive hardware options that rely more on the processing power of the microprocessor and less on special-purpose (and thus expensive) hardware options. At the MMX unveiling, Motorola showed a "software-driven" modem that eliminates the need for a dedicated signal-processing chip, and Yamaha displayed a wave table sound synthesis package that provides richer, higher-quality musical tones at a lower cost than the traditional "FM synthesis" approach used in conventional low-end sound cards. These features provide little benefit to users who already own modems and sound cards, but future systems may cost less as vendors substitute lower-cost software for more expensive hardware solutions.

Intel demonstrated a new version of its ProShare videoconferencing package that uses MMX features to double overall performance, from 8 frames per second to 18 frames per second, over ordinary dial-up phone connections. At 8 frames per second, this was at best a marginal solution. At 18 frames per second, there is still room for improvement, but this will certainly satisfy more users and will thus popularize this technology. The ability to use laptop computers as low-cost, mobile videoconferencing devices may prove to be an important driver of future demand.

The launch of the Pentium Processor with MMX Technology marks the first appearance of MMX in 1997, but it is hardly likely to be the last. Look for Intel to introduce its next-generation P6 with MMX, known to its friends as Klamath but known to Intel's adroit product-naming department as the Pentium Pro Processor with MMX™ Technology, in the second quarter. By year's end, only the lowest-end Intel processors will lack MMX technology, and it is likely that the vast majority of the x86 computational processors Intel ships this year will include this feature.

Advanced Micro Devices and Cyrix both plan to introduce new products (K6 and M2) that will be compatible with MMX technology, although the names might be changed to keep Intel's lawyers at bay. Neither plans to add MMX to the earlier products (K5 and M1) that that they have positioned against Intel's Pentium. The addition of MMX to high-end and midrange Pentiums forces the M1 and K5 to the lower end of the market, where chips usually sell for less than $100. To climb back up to the higher part of the market, AMD and Cyrix must successfully launch their new MMX-compatible products in the first half of the year.

It's only the second week of the year, and vendors have already introduced more new technology than they did in all of 1996. The year 1997 should be interesting.
By Nathan Brookwood

Dataquest

Perspective

Personal Computer Semiconductors and Applications Worldwide

Market Analysis

PC Semiconductor Quarterly Outlook: Third Quarter Results Provide Little Encouragement for a Strong Fourth Quarter

Abstract: *Third quarter results can provide insight into fourth quarter market conditions as semiconductor vendors ramp up for seasonal business growth. This year's third quarter results indicate that moderate growth for the PC semiconductor market is likely for the next quarter, but those same results temper expectations for a robust ending to the year. This Perspective includes selected financial data from semiconductor vendors and PC OEMs, with analysis of that data.*
By Geoff Ballew

Steady as It Goes

The third quarter results of calendar 1997 show little to indicate a strong fourth quarter. Key market segments grew both on a year-to-year and sequential quarter basis, but the revenue growth is sluggish. Table 1 shows selected financial data.

The peripherals group barely grew at all on a revenue basis for either the quarter-to-quarter or year-to-year comparisons. Unit growth outpaces revenue growth because of lower average selling prices (ASPs) for many PC semiconductor markets. Prices for memory and multimedia chips continue to reflect the relative supply/demand imbalance and high levels of competition. PC system ASPs are under pressure, too, because of the rapid expansion of the sub-$1,000 market segment.

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Table 1
PC Semiconductor and PC System Vendor Financial Performance for Calendar Q3/97

Category	Company Name	Ticker Symbol	Fiscal Year	Revenue CA Q3/96	Revenue CA Q2/97	Revenue CA Q3/97	Q2/97 to Q3/97 Revenue Growth (%)	Q3/96 to Q3/97 Revenue Growth (%)	Q3/96 Gross Margin (%)	Q2/97 Gross Margin (%)	Q3/97 Gross Margin (%)	Q3/96 Days of Inventory	Q2/97 Days of Inventory	Q3/97 Days of Inventory
Microprocessors	Advanced Micro Devices Inc.	AMD	Dec-97	457,000	594,561	596,644	0	31	26	37	28	44	40	35
Microprocessors	Intel Corporation	INTC	Dec-97	5,142,000	5,960,000	6,155,500	3	20	57	61	58	57	56	53
Microprocessors	SGS-Thomson Microelectronics B.V.	STM	31-Dec	988,401	963,900	981,000	2	-1	40	38	40	89	85	90
Overall Microprocessors				**6,587,401**	**7,518,461**	**7,733,144**	**3**	**17**	**53**	**56**	**53**	**61**	**59**	**57**
Peripherals	Cirrus Logic Inc.	CRUS	Mar-97	236,030	201,623	223,960	11	-5	38	39	40	89	73	63
Peripherals	ESS Technology Inc.	ESST	Dec-97	60,138	45,142	52,172	16	-13	51	40	33	97	98	94
Peripherals	LSI Logic Corporation	LSI	Dec-97	300,195	332,004	326,847	-2	9	42	49	50	57	51	56
Peripherals	National Semiconductor Corporation	NSM	May-97	566,100	599,200	600,800	0	6	30	44	42	70	49	50
Peripherals	S3 Inc.	SIII	Dec-97	119,440	108,892	120,349	11	1	39	35	33	66	60	64
Peripherals	Texas Instruments Inc.	TXN	Dec-97	2,841,001	2,559,000	2,500,000	-2	-12	27	38	39	44	42	45
Peripherals	VLSI Technology Inc.	VLSI	Dec-97	182,959	182,472	181,181	-1	-1	40	45	45	52	49	51
Peripherals	3Com Corporation	COMS	May-97	1,250,060	1,506,000	1,600,900	6	28	47	29	48	56	53	45
Overall Peripherals				**5,555,923**	**5,534,333**	**5,606,209**	**1**	**1**	**34**	**37**	**43**	**52**	**47**	**48**
Systems	Compaq Computer Corporation	CPQ	Dec-97	4,481,002	5,012,000	6,474,000	29	44	24	25	27	40	39	39
Systems	Gateway 2000 Inc.	GTW	Dec-97	1,202,933	1,504,851	1,504,851	0	25	19	17	13	20	37	26
Systems	IBM	IBM	Dec-97	18,062,002	18,872,000	18,605,000	-1	3	40	39	38	27	25	25
Overall Systems				**23,745,937**	**25,388,851**	**26,583,851**	**5**	**12**	**36**	**35**	**34**	**30**	**29**	**29**

Source: Company reports and Dataquest (December 1997)

Inventories Remain Historically Low

One of the bright spots in the third quarter financial results is the fact that inventories of key vendors remain historically low. Hopes for strong fourth quarter PC system sales must be tempered by the economic concerns of several Asian economies and by lower system ASPs in the United States. If chip vendors' inventories were growing in terms of days of sales outstanding (DSO), the risk of an inventory overhang from fourth quarter into 1998 would be much higher. The chip vendors listed in Table 1 appear to be managing their inventories effectively to prevent such an overhang, even if PC unit shipments do not meet industry expectations.

Semiconductor Vendors Assume Greater Risk as Inventories Shrink

Many PC OEMs this year have focused on reducing their inventories relative to their sales volume. Dell Computer Corporation made this a fundamental part of its business plan with tight controls on inventory and quick turnaround of orders. Dell is able to lead the industry in terms of inventory turns because of its direct sales model and build-to-order (BTO) manufacturing practices. This necessarily impacts component suppliers because they have less forward visibility regarding new chip orders. As more PC OEMs focus on reducing inventory relative to sales, semiconductor vendors will need to adapt. Many top-tier OEMs have introduced variations of the BTO model, and each has coined its own term for it. Regardless of whether an OEM offers BTO, channel configuration, or channel assembly, the impact on component suppliers is one of less forward visibility for demand.

A potential problem with the shift to more just-in-time (JIT) delivery of components to system OEMs or other assembly houses is the fundamental mismatch of lead times for semiconductor device fabrication compared to PC assembly. Although the time it takes to build and test a PC is measured in hours, semiconductor production must be scheduled weeks in advance. The time a single wafer takes from start to finish is measured in weeks for a fabrication facility running at or near capacity. PC OEMs can push the risk of inventory back up the supply chain, but the ability of semiconductor vendors to react quickly to changing orders is limited by the relatively long fabrication time for semiconductor devices compared to assembly time for PCs.

Dataquest Perspective

The positive signs that Dataquest hoped to see in the third quarter financial results simply did not materialize in the PC semiconductor segment. Semiconductor growth may continue to be sluggish for the next quarter. System demand in the United States continues to be strong, but system ASPs are under pressure because of robust unit growth in the sub-$1,000 segment. Demand in many Asian countries is limited by economic woes throughout Asia, especially Japan and Korea.

Peripheral chip vendors are advised to pay close attention to the sub-$1,000 PC segment. The growth of less expensive PCs could change the dynamics in the PC semiconductor market. There simply isn't budget for a $250 microprocessor in a sub-$1,000 PC, so the success of these PC products somewhat blunts the megahertz marketing that has been effectively used to sell PCs in the past.

Dataquest believes that megahertz will continue to be a differentiator in most PC market segments, but peripheral chip vendors could find new opportunity to add value in the lowest tier of the PC market. PC OEMs need more than just a low price on yesterday's peripheral chips to make sub-$1,000 PCs continue to grow. They need innovative solutions that help them minimize costs without severely compromising multimedia performance. One example is Cyrix Corporation's Media Center reference design. It uses an inexpensive Cyrix MediaGX processor but boosts multimedia performance with dedicated chips for DVD playback and 3-D graphics. Dataquest expects to see more designs that trade CPU power against peripheral power as the sub-$1,000 PC segment continues to evolve.

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Perspective

Personal Computer Semiconductors and Applications Worldwide

Product Analysis

Yet Another Pentium Bug—The Poison Pill

Abstract: *Early November saw the discovery of another Pentium bug, which can halt the operation of a Pentium processor, even in a secure environment. The bug is irrelevant to all reasonable use of a computer (and much use beyond reason). However, the bug creates the opportunity for malicious users to halt the operation of a multiuser system, or to create ActiveX controls able to halt a single-user system. Dataquest believes that the bug can be addressed with a software fix and expects to see a swift resolution to the problem.*
By Martin Reynolds

A Simple Bug

The Pentium bug is relatively simple and involves the improper use of a 64-bit compare and exchange instruction in a 32-bit mode while having a locked bus. The operation naturally fails, but the exception is not properly handled by the processor and the bus lock is never released. Therefore, unlike some previous Pentium errata that returned incorrect results (about which there was much learned—and otherwise—discussion as to relevance), this latest discovery puts a final halt to all system activity.

It turns out that the processor core is working well behind the bus interface, but that the bus interface is locked up until it receives a hardware reset. No other information—including externally generated interrupts—can cross the barrier. Speculating further, Dataquest believes that the processor is simply waiting for access to its exception routine, which will never come because the bus is busy.

In terms of impact of the bug, the issue here is not one of accidental occurrence. Compilers and assemblers will flag the code as an error, and any amount of testing of code that slips past the compiler will turn up a rather

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solid crash. In other words, there is no chance of a user running into this problem by accident, running any existing code available as of last week.

The key issue, therefore, is one of overall security against malicious intent; if a "malfeasant" can slip the four bytes to a processor in executable form, then the system will hang until the processor receives a hardware reset. In a single-user system, there are plenty of ways to fool a user into running malicious code: Viruses are a great example of how this can happen. Furthermore, there are far more malicious things to do to a single user than stop the processor (erasing the hard drive directory, for example), so the single-user case is not relevant.

It is Dataquest's belief, however, that it is possible to build a relatively simple software fix that requires minimal changes to the operating system.

Recommendations to System Manufacturers

The bug is unlikely to affect the vast majority of users of Pentium systems. However, there are locations that provide execute capability to multiple users running under a multiuser operating system such as Linux or UNIX, or the Citrix extensions to Windows NT. Many of these systems are in higher education, which is also a place to find an above-average number of active pranksters. Therefore, it is likely that there will be some instances of system stoppages as word of the bug gets out. Some of this will stem from curiosity, some from malice.

The easiest fix, in many cases, is to replace the system with a Pentium II system. These machines are quite inexpensive and offer a useful performance boost to multiuser systems. Therefore, any commercial provider of multiprocessor access on Pentium systems is either likely to have upgraded already, or be prepared to make the change to minimize exposure. MIS departments with a heavy investment in Pentium servers will find this change unpalatable, but such organizations are at least risk because of the controlled nature of their user base.

Dataquest is also optimistic that Intel will deliver a software-based fix in the near term, which will take care of the cost-conscious users running, for example, Linux on a clone box. Therefore, Dataquest makes the following recommendations:

- Server manufacturers should prepare to discuss the bug with their clients, helping them to understand its ramifications.
- Desktop and mobile system manufacturers should wait for a response from Intel Corporation.

Though this is outside of Dataquest's normal sphere of coverage, vendors providing commercial multiuser accounts should warn their users off of trying out this feature. Such action is not consistent with good citizenship in the multiuser world, and "malfeasants" may be liable to civil penalty should they succeed in bringing down a system. Dataquest also notes that these incidents may become detectable in the near future, so there is no guarantee of anonymity for users who decide to compromise the work of their fellows. Commercial users of Pentium-based multiuser systems should also ensure that users have appropriate execute privileges; in particular, DOS commands such as DEBUG, LINK, and others capable of generating executable objects should be generally unavailable.

Scaling the Risk

As discussed later in this document, the risk is primarily constrained to systems that meet the following conditions:

- Pentium-based
- Supporting multiple users
- Permitting users to have execution privileges for personal code
- Undisciplined or uncontrolled user base

Systems that meet these criteria typically do not include servers (no user execution), but do include Intel-based multiuser systems. The prime example of this type of system is those based on The Santa Cruz Operation (SCO) UNIXware. For example, although many of SCO's many small multiuser systems run video stores, dentist's offices, or other small businesses, SCO has in recent years achieved some corporate success. Typical users of small business systems do not have execute privileges of any kind and likely lack the interest and skill necessary to cause a crash.

The potential for real damage is in those sensitive commercial environments where the security has been based on the belief that OS-based security was enough of a control. For these users, it will be important that SCO, and SCO's OEMs and value-added resellers (VARs), take immediate action to suggest to their customers that they review their security arrangements to radically minimize the number of users with execute privileges for unknown applications (for example, restrict the privileges to known-good applications).

The market segments SCO targets are retail, telephony, government, and small and medium-size business. Telephony and government are segments that have strong security concerns and will need a strong message to make sure that administrators are made aware of the risks.

A second class of users at risk is those educational users that provide a combination of access and temptation, to users with the ability and interest. These establishments will likely spend several days over the next couple of weeks crashing as users get into the joke.

Introducing the Poison Pill

There are two mechanisms that could be used to cause a processor to run the dreaded instruction sequence: ActiveX controls for single-user systems, and simple execution for Ring-3 enabled multiuser systems.

ActiveX Controls

ActiveX controls are one pathway that a miscreant might use to slip the poison pill to an unwary user. This particular method is of interest because it can come across the Internet under the guise of a neat experience of sound or sight. However, the principle of greater malice holds: ActiveX controls can be very damaging to a system, which is why users are supposed to check them for a valid signature before running them. Nonetheless, there will doubtless be instances of malicious ActiveX controls appearing on Web pages, particularly those intended primarily for UNIX users.

The Principle of Greater Malice and Single-User Systems

This thought deserves a little explanation and pertains to the risk of single-user systems being affected by the bug. In general, a user will not knowingly run the poison pill code on his or her machine unless the desired result is to stop the processor, or unless it is out of curiosity. Therefore, Dataquest would expect the experiment to be tried in a controlled fashion with all open documents saved.

However, should a malicious third party somehow bamboozle the user into running poisoned code, the user might lose open documents. Though if the bamboozler really wanted to cause damage, there are many more exciting things to do with even simple code fragments: One would be changing the contents of the hard drive. In other words, there are actions of greater malice that a "malfeasant" can visit upon users of single-user systems, once the user's defenses are compromised.

The Multiuser System

Multiuser systems, however, are vulnerable to attack. Ring 3 systems refer to systems in which the user's code is totally isolated from the core of the machine. A user is generally unable to perform any action that could affect other users, as the operating system will receive an exception should the user's session in some way cross the bounds. The poison-pill bug allows a user to circumvent these defenses, bringing all users to a grinding halt and disposing of all unsaved work in progress.

Systems that do not implement Ring 3 protection are also at risk, but they are at risk from a great many other directions.

Any Internet service provider (ISP) providing a shell account to its users is therefore vulnerable to a rude stop, should one user choose to run a poison-pill program. There will no doubt be a certain amount of disruption as users try to test this one out. Inexpensive Linux and UNIX systems found in educational establishments are particularly vulnerable, and Citrix-enhanced Windows NT systems are at risk.

Defenses

The poison-pill sequences can be treated as a virus, and executable code could be scanned for them. However, Dataquest must assume that the code is malicious in nature and therefore expects the poison pill sequence to be generated at run time, rather than being a static sequence visible to scanning and filtering programs. As the code fragment is so small, Dataquest believes that it will slip past the virus scanners that might otherwise provide a defense. Virus scanners depend on multiple hits of small signatures in a file, and the poison pill is four bytes long in its entirety.

Fixing the Bug in Software

Despite the apparent total isolation of the processor, Dataquest believes that there are techniques that can reactivate the processor from within. This optimism stems from the fact that the problem lies in the bus interface, not the processor core itself. Therefore, if Intel can encourage the processor to generate a second exception after the invalid instruction, the second exception may well clear the bus lock. There are several possible ways of achieving this result.

One method would be to place the invalid opcode exception vector in a memory segment designated as data, forcing a type exception and clearing the bus lock. In this case, the operating system exception handler would have to be able to figure out that the exception was initialized by an invalid opcode exception and pass control back to the "real" invalid opcode exception handler. Another possibility would be to lock the exception handler routine into the cache and include a code sequence that clears the bus.

Dataquest believes that these approaches offer the opportunity to solve the problem, requiring relatively minor tweaks to the operating system. The key parameters are that the fix must:

- Leave the processor in a defined state (as viewed by the operating system)
- Prevent the user session from bypassing Ring 3 security
- Flag and identify the malicious process

The first two are essential the third feature will allow system administrators to locate and identify wrongdoers, with the objective of taking appropriate punitive action. The impending arrival of such a facility should assist in discouraging users from attempting system crashes while they believe themselves to be anonymous.

Distributing the fix is another issue. However, Dataquest believes that at-risk sites will be aggressive in pursuing the code necessary, which will ease the problem.

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Perspective

Personal Computer Semiconductors and Applications Worldwide

Dataquest Predicts

Quarterly x86 Forecast: When the Clones Go Marching In

Abstract: *Dataquest extends its x86 forecast to the year 2002 and anticipates that the market will grow slightly faster than our previous forecast. The change stems primarily from an increase in average selling prices during the forecast period.*
By Nathan Brookwood

Forecast Overview

Dataquest forecasts that the market for x86 microprocessors (MPUs) used in personal computers, workstations, and servers will grow from 77.6 million units in 1996 to 188 million units in 2002. The revenue associated with these processors will grow from $15.4 billion to $44.2 billion over the same period. Although we have not altered our overall unit shipment forecast from the previous quarterly forecast (included in *1997 Trends in Computational Microprocessors and Core Logic*, PSAM-WW-MT-9702), we have adjusted the processor mix, average selling prices (ASPs), and revenue compared with the prior estimates. These changes increase the size of the market, as measured in revenue, from the earlier forecast.

The Dataquest Personal Computers Worldwide program tracks and forecasts personal computer shipments by system generation. Until recently, a simple and straightforward mapping between microprocessor generations and PC generations could be used, but the vagaries of clever marketers and clever lawyers force Dataquest to take a more complicated approach in our latest forecasts.

The clever marketers named their products so as to suggest they were one generation more advanced than their architecture would suggest; thus there were Advanced Micro Devices Inc.'s 5x86 and Cyrix Corporation's 5x86,

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both of which provided high-end 486 performance and fit into 486 CPU sockets (hereinafter referred to as Socket 3). Dataquest counts systems containing these devices as fourth-generation systems and tallies the processors as fourth-generation MPUs.

Further complicating matters, Cyrix named its Pentium-equivalent processor the "6x86," suggesting that it corresponds in meaningful ways to Intel's Pentium Pro line. Dataquest assumes that if it's priced like a Pentium, performs like a Pentium, and plugs into a Pentium socket, then it should be classified as a fifth-generation part, and we have proceeded on this basis. To make things even more complicated, AMD and Cyrix have positioned their parts (the K6 and 6x86MX, respectively), which compete with Intel's Pentium II and Pentium Pro offerings, as sixth-generation parts, although they plug into Pentium-style sockets (hereinafter referred to as Socket 7). The Dataquest Semiconductor research group assumes that if it's priced like a Pentium II and performs like a Pentium II (which several magazine reviews have suggested is the case), then it should be classified like a Pentium II, even if it plugs into a Socket 7. We have therefore classified these devices as members of the sixth generation of computational MPUs.

The Dataquest Personal Computers Worldwide program measures the generation of a personal computer based on its motherboard, and thus classifies all Socket 7 PCs as fifth-generation systems, even if they contain AMD K6 or Cyrix 6x86MX processors. Alert users may notice that Dataquest's forecasts for Personal Computer systems and our forecasts for microprocessors may not always line up precisely when cut by generation. Dataquest does reflect these differences in its proprietary forecasting models, and therefore ensures that every forecast system will have an appropriate MPU assigned to it.

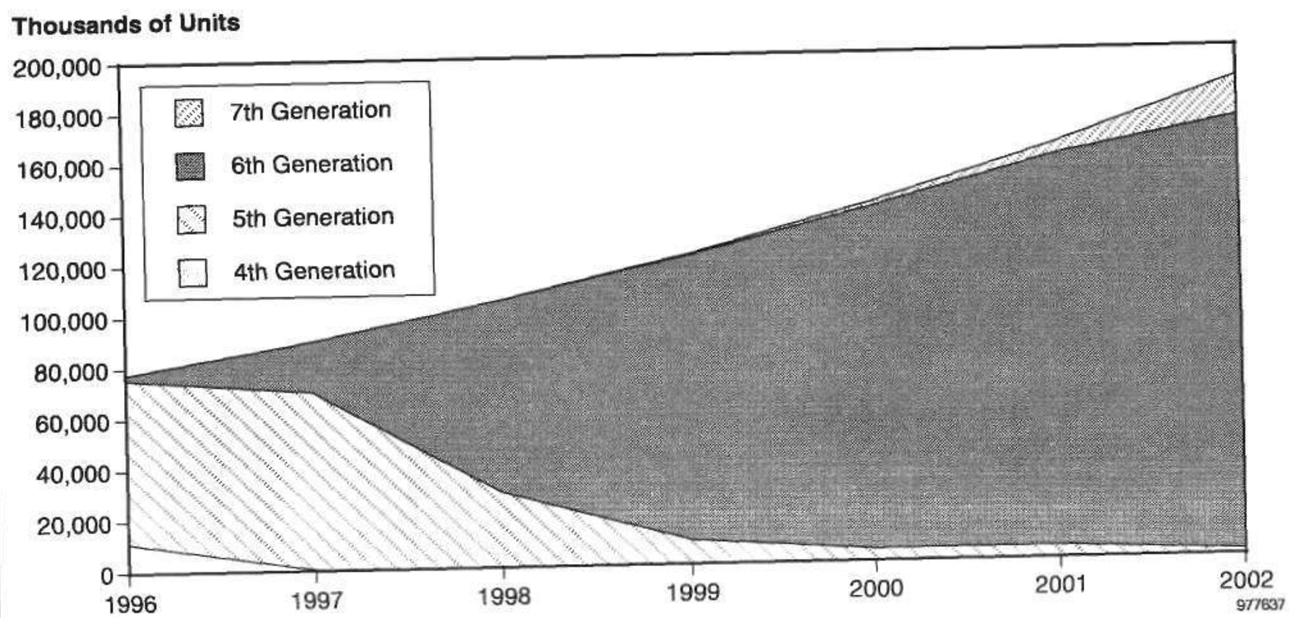
Table 1 and Figure 1 provide Dataquest's x86 shipment forecast by processor generation; Table 2 and Figure 2 translate these unit shipments into equivalent revenue, based on the average selling price (ASP) assumptions included in Table 3 and Figure 3. Compared with previous forecasts, ASP has increased, primarily as a result of Intel's increasing focus on workstation and server markets, where the company has introduced new versions of its MPUs, specifically enhanced for these segments and priced substantially above processors targeted at desktop personal computer markets. Dataquest anticipates that this marks the start of a trend wherein Intel will offer a greater variety of market-specific processors at widely varying price points. Although unit volumes sold into these market niches will pale compared with volumes in mainstream markets, the substantially higher ASPs (a factor of two or three times the PC processor prices) will positively impact overall x86 ASP. Vendors of x86 clones do not participate in these market niches and will not experience concomitant increases in their ASPs.

Table 1
Forecast of x86 Computational MPU Shipments by Generation, 1996-2002 (Thousands of Units)

Generation	1996	1997	1998	1999	2000	2001	2002	CAGR (%) 1997-2002
Fourth Generation	11,400	428	0	0	0	0	0	-100
Fifth Generation	64,200	69,611	29,509	9,452	4,661	4,559	1,881	-51
Sixth Generation	2,000	19,962	75,319	111,659	134,369	153,896	170,568	54
Seventh Generation	0	0	0	459	1,796	4,355	15,609	-
Total	**77,600**	**90,001**	**104,828**	**121,570**	**140,825**	**162,810**	**188,057**	**16**

Source: Dataquest (October 1997)

Figure 1
x86 Computational MPU Shipments by Generation, 1996-2002



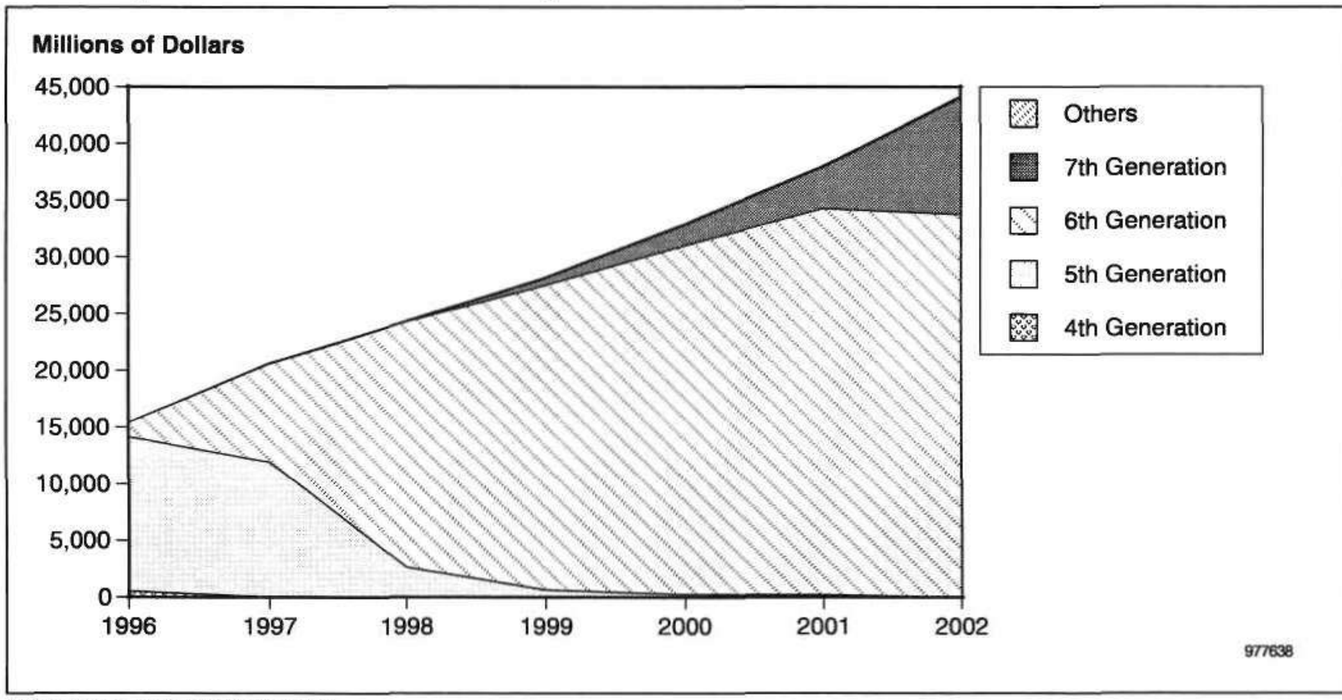
Source: Dataquest (October 1997)

Table 2
Forecast of x86 Computational MPU Revenue by Generation, 1996-2002 (Millions of Dollars)

Generation	1996	1997	1998	1999	2000	2001	2002	CAGR (%) 1997-2002
Fourth Generation	518	15	0	0	0	0	0	-100
Fifth Generation	13,629	11,902	2,647	641	244	220	0	-100
Sixth Generation	1,250	8,645	21,617	26,853	30,755	34,045	33,754	31
Seventh Generation	0	0	0	620	1,828	3,635	10,282	-
Others	15	68	79	91	106	122	141	16
Total	**15,412**	**20,630**	**24,343**	**28,205**	**32,932**	**38,023**	**44,177**	**16**

Source: Dataquest (October 1997)

Figure 2
x86 Computational MPU Revenue by Generation, 1996-2002



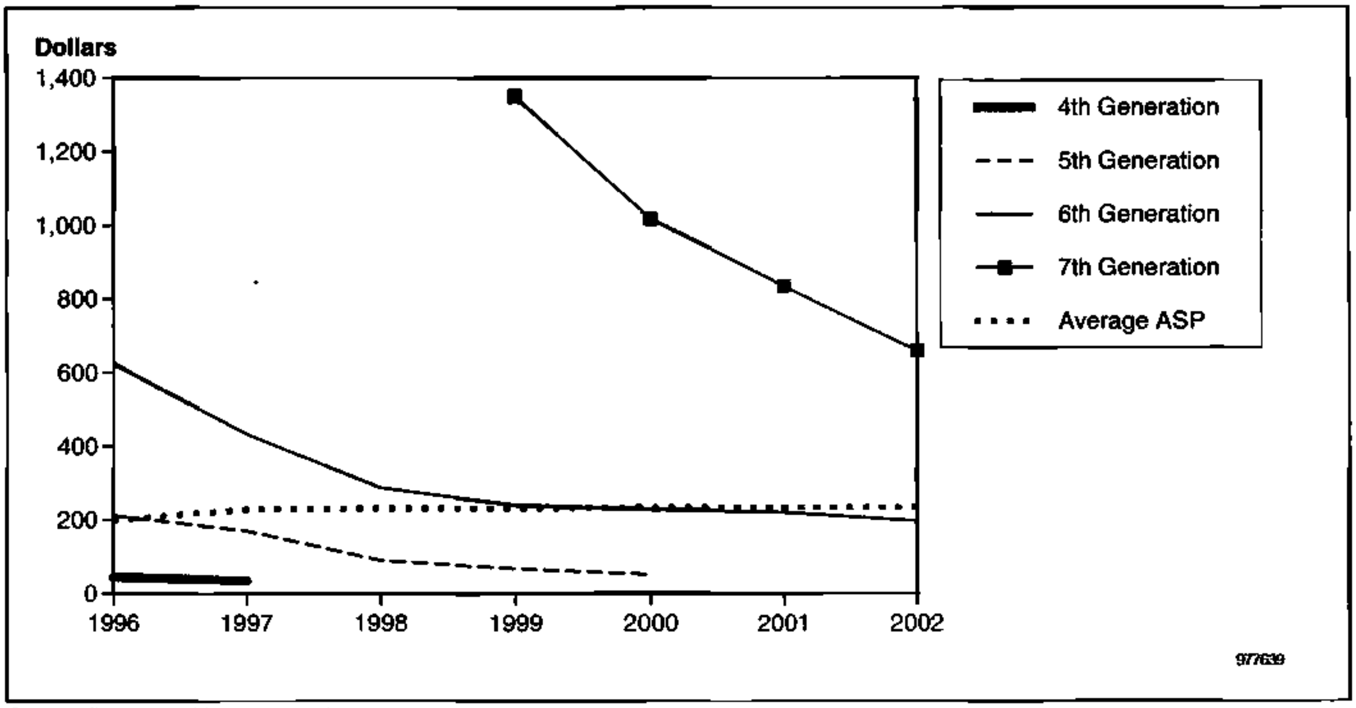
Source: Dataquest (October 1997)

Table 3
Forecast of x86 Computational MPU ASP by Generation, 1996-2002 (Dollars)

Generation	1996	1997	1998	1999	2000	2001	2002	CAGR (%) 1997-2002
Fourth Generation	45	35	-	-	-	-	-	-100
Fifth Generation	212	171	90	68	52	-	-	-100
Sixth Generation	625	433	287	240	229	221	198	-14
Seventh Generation	-	-	-	1,350	1,018	835	659	-
Average ASP	**199**	**229**	**232**	**232**	**234**	**234**	**235**	-

Source: Dataquest (October 1997)

Figure 3
x86 Computational MPU ASP by Generation, 1996-2002



Source: Dataquest (October 1997)

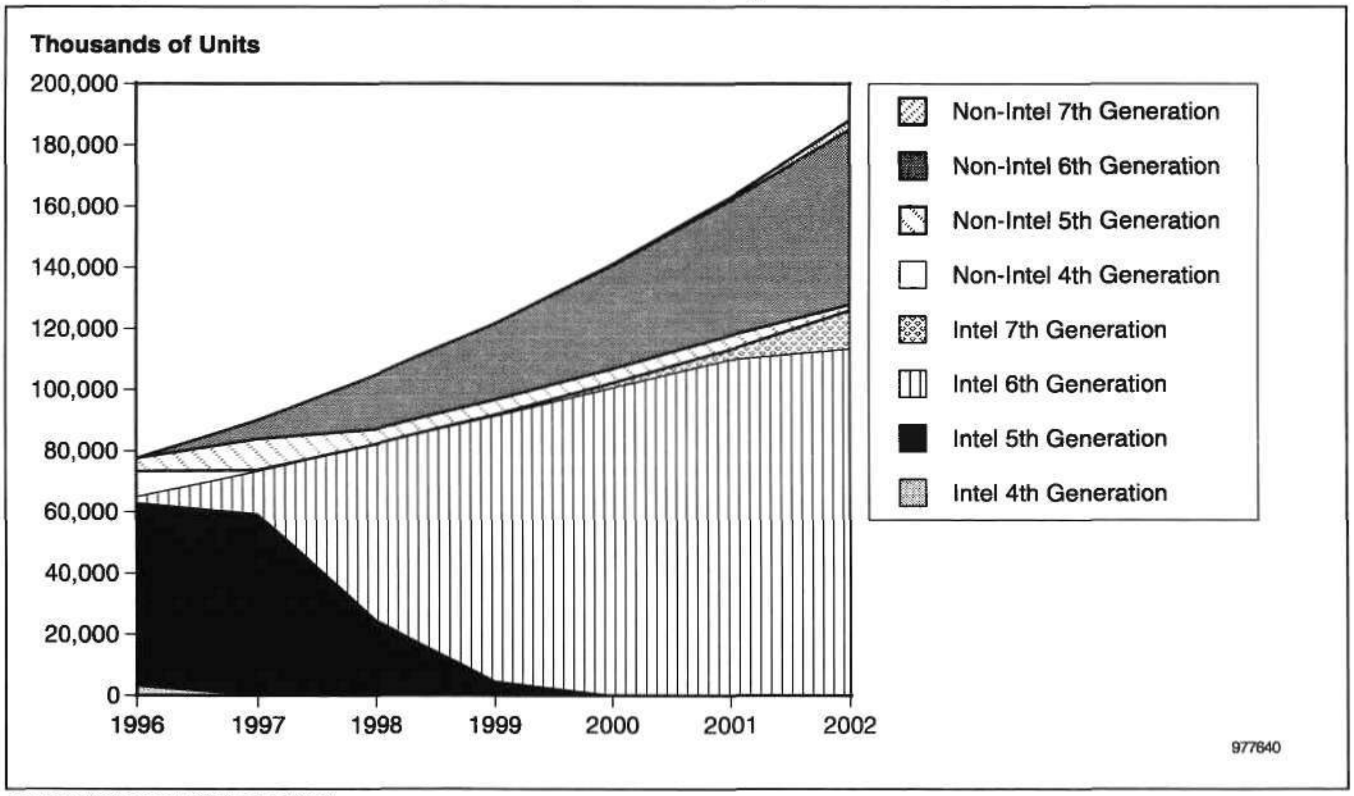
Although Dataquest normally forecasts markets rather than vendor market shares, the unique situation of Intel's enormous market share forces us to make an exception with regard to computational microprocessors. Tables 4 and 5 apportion the shipment forecast (presented earlier) into Intel and non-Intel (that is, clone) segments. Figures 4 and 5 present these shipment forecasts, grouped by vendor and by generation, respectively. Tables 6 and 7 translate these shipments into revenue, based on ASP assumptions contained in Table 8 (for Intel) and Table 9 (for other vendors). Figures 6 and 7 present these revenue forecasts, grouped by vendor and by generation, respectively.

Table 4
Forecast of Intel x86 Computational MPU Shipments by Generation, 1996-2002 (Thousands of Units)

Generation	1996	1997	1998	1999	2000	2001	2002	CAGR (%) 1997-2002
Fourth Generation	3,000	0	0	0	0	0	0	-
Fifth Generation	60,000	59,414	24,687	4,589	0	0	0	-100
Sixth Generation	2,000	13,937	57,603	86,737	100,567	109,758	113,398	52
Seventh Generation	0	0	0	459	1,531	3,395	12,600	-
Total	**65,000**	**73,351**	**82,290**	**91,785**	**102,098**	**113,153**	**125,998**	**11**

Source: Dataquest (October 1997)

Figure 4
x86 Computational MPU Shipments by Vendor, by Generation, 1996-2002



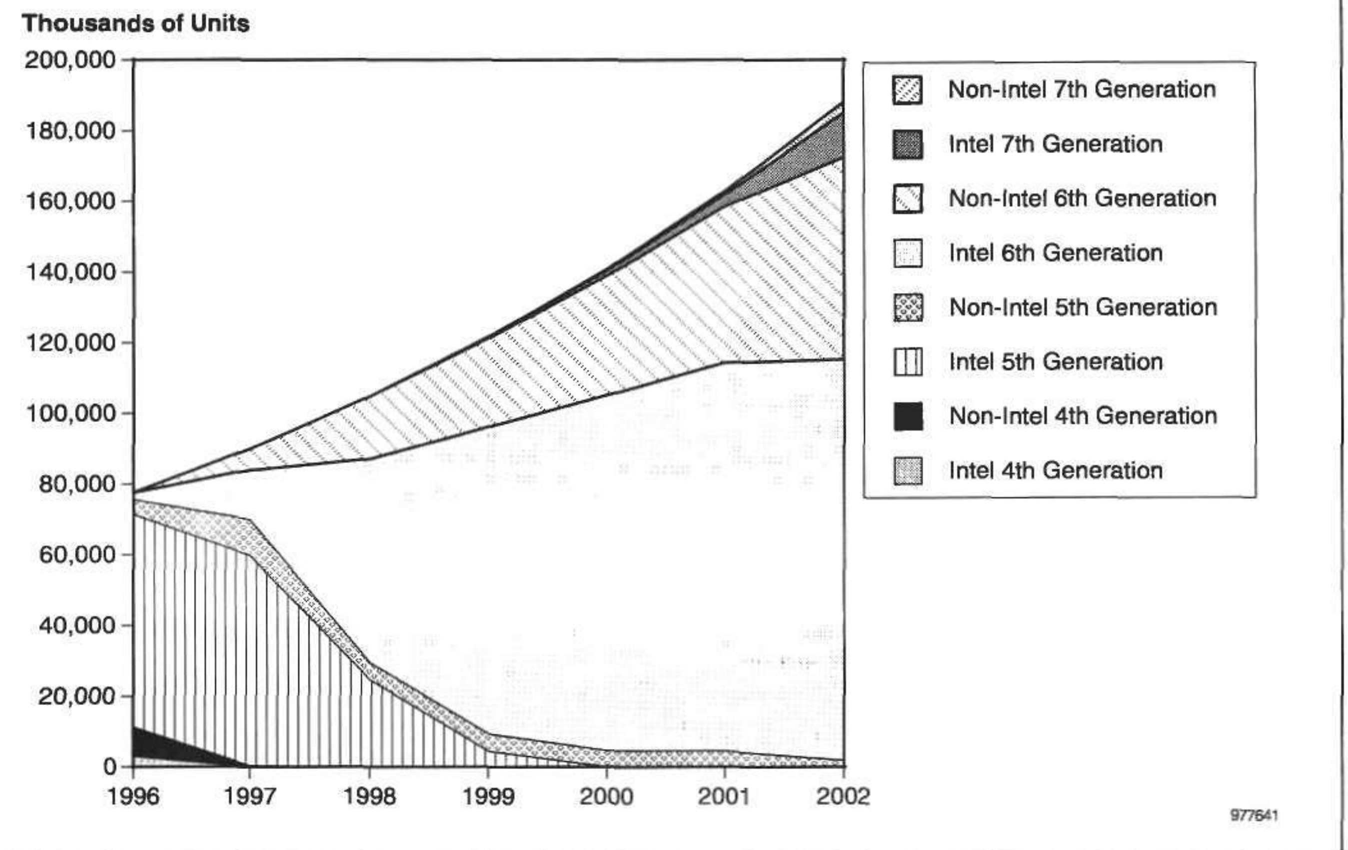
Source: Dataquest (October 1997)

Table 5
Forecast of Non-Intel x86 Computational MPU Shipments by Generation, 1996-2002 (Thousands of Units)

Generation	1996	1997	1998	1999	2000	2001	2002	CAGR (%) 1997-2002
Fourth Generation	8,400	428	0	0	0	0	0	-100
Fifth Generation	4,200	10,197	4,822	4,863	4,661	4,559	1,881	-29
Sixth Generation	0	6,026	17,716	24,922	33,802	44,138	57,169	57
Seventh Generation	0	0	0	0	264	961	3,009	-
Total	**12,600**	**16,650**	**22,538**	**29,785**	**38,727**	**49,657**	**62,059**	**30**

Source: Dataquest (October 1997)

Figure 5
x86 Computational MPU Shipments by Generation, by Vendor, 1997-2001



Source: Dataquest (October 1997)

Table 6
Forecast of Intel's x86 Computational MPU Revenue by Generation, 1996-2002 (Millions of Dollars)

Generation	1996	1997	1998	1999	2000	2001	2002	CAGR (%) 1997-2002
Fourth Generation	225	0	0	0	0	0	0	-
Fifth Generation	13,200	11,170	2,345	367	0	0	0	-100
Sixth Generation	1,250	7,177	19,009	23,246	26,047	28,318	27,216	31
Seventh Generation	0	0	0	620	1,685	3,225	9,135	-
Total	**14,675**	**18,347**	**21,354**	**24,232**	**27,731**	**31,542**	**36,351**	**15**

Source: Dataquest (October 1997)

Table 7
Forecast of x86 Computational MPU Revenue for Vendors Other Than Intel by Generation, 1996-2002 (Millions of Dollars)

Generation	1996	1997	1998	1999	2000	2001	2002	CAGR (%) 1997-2002
Fourth Generation	293	15	0	0	0	0	0	-100
Fifth Generation	429	732	302	274	244	220	0	-100
Sixth Generation	0	1,468	2,608	3,608	4,708	5,728	6,539	35
Seventh Generation	0	0	0	0	143	410	1,147	-
Total	**722**	**2,215**	**2,910**	**3,881**	**5,095**	**6,358**	**7,686**	**28**

Source: Dataquest (October 1997)

Table 8
Forecast of Intel x86 Computational MPU ASP by Generation, 1996-2002 (Dollars)

Generation	1996	1997	1998	1999	2000	2001	2002	CAGR (%) 1997-2002
Fourth Generation	75	-	-	-	-	-	-	-
Fifth Generation	220	188	95	80	56	-	-	-100
Sixth Generation	625	515	330	268	259	258	240	-14
Seventh Generation	-	-	-	1350	1100	950	725	-
Average ASP	**226**	**250**	**260**	**264**	**272**	**279**	**289**	**3**

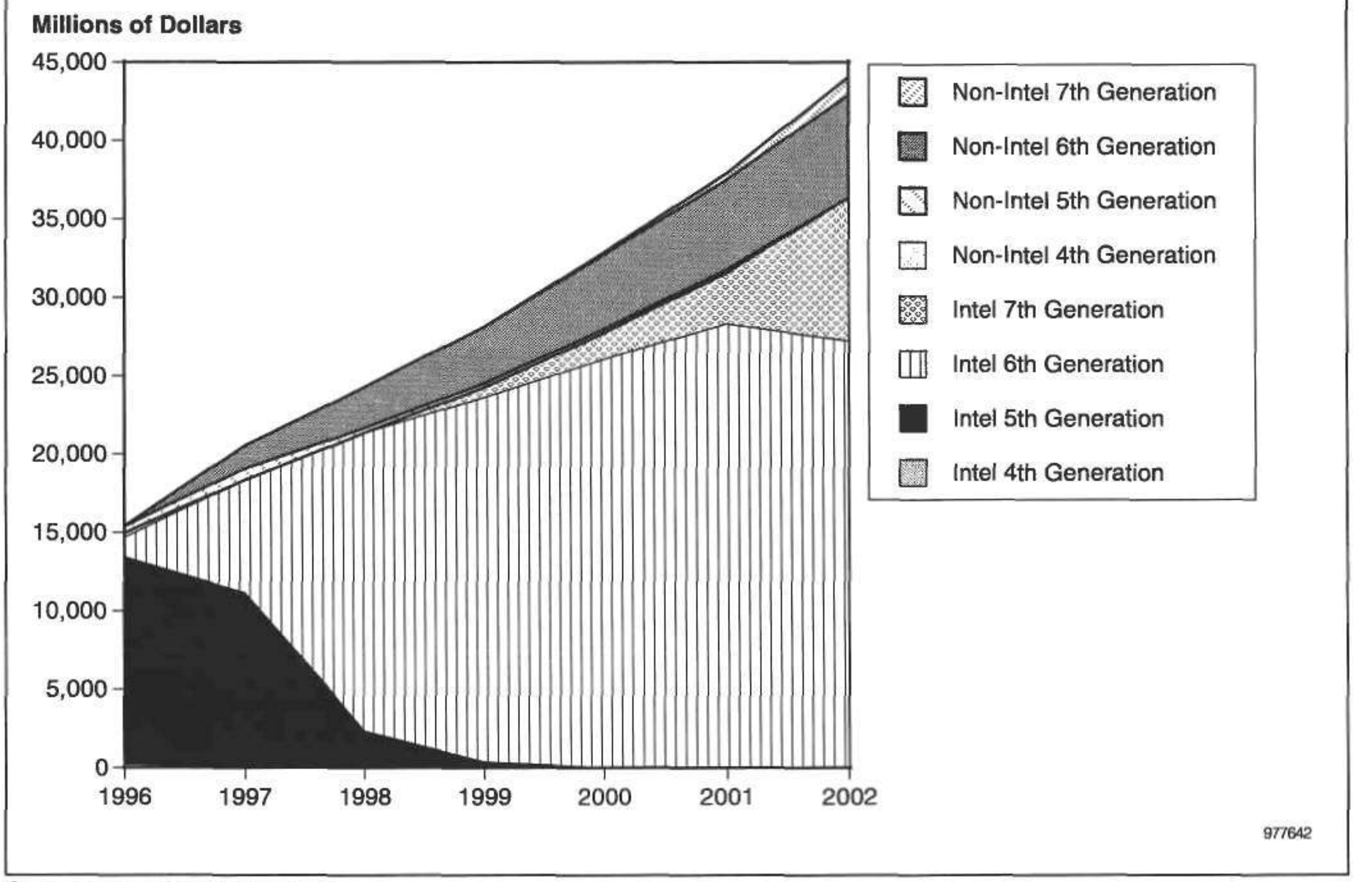
Source: Dataquest (October 1997)

Table 9
Forecast of Non-Intel x86 Computational MPU ASP, by Generation, 1996-2002 (Dollars)

Generation	1996	1997	1998	1999	2000	2001	2002	CAGR (%) 1997-2002
Fourth Generation	35	35	-	-	-	-	-	-
Fifth Generation	102	72	63	56	-	-	-	-100
Sixth Generation	-	244	147	145	139	130	114	-14
Seventh Generation	-	-	-	-	541	427	381	-
Average ASP	**57**	**133**	**129**	**130**	**132**	**128**	**124**	**-1**

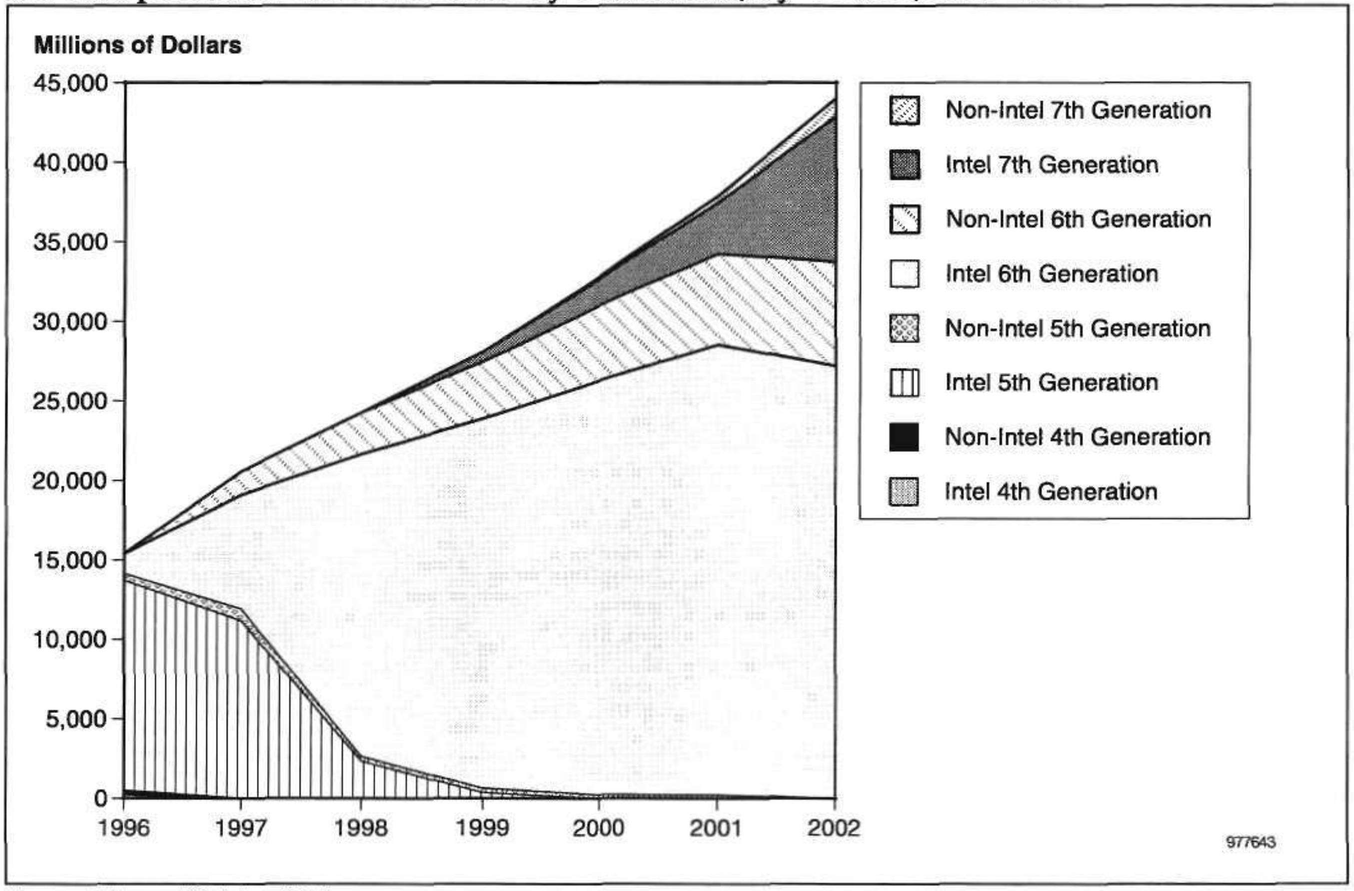
Source: Dataquest (October 1997)

Figure 6
x86 Computational MPU Revenue by Vendor, by Generation, 1997-2002



Source: Dataquest (October 1997)

Figure 7
x86 Computational MPU Revenue by Generation, by Vendor, 1997-2001



Source: Dataquest (October 1997)

Dataquest's model projects that, following a dismal showing in 1996, when non-Intel x86 processors captured only 5 percent of x86 revenue and 16 percent of unit shipments, these products will rebound and account for 11 percent of revenue ($2.3 billion) and 18 percent of shipments (16.7 million units) in 1997. By the year 2000, the non-Intel component of this market will capture 16 percent of revenue ($5.2 billion) and 27 percent of unit shipments (38.7 million units). We anticipate that Intel will only grudgingly cede this market share, and Intel's competitors will be forced to sell their wares at a steep discount to the prices offered by Intel. Our most likely scenario sees Intel abandoning the sub-$100 processor market to its competitors, which could then drive their own growth based on the increasing market for sub-$1,000 personal computers. Tables 10, 11, and 12 summarize the limited share erosion we anticipate Intel to experience over the next five years and the discount from Intel's prices that its competitors must offer to make these gains. Figure 8 displays our projections for Intel, non-Intel, and overall ASP over the period.

Table 10
Comparison of x86 Computational MPU Revenue for Intel and Other Vendors, 1996-2002 (Millions of Dollars)

	1996	1997	1998	1999	2000	2001	2002	CAGR (%) 1997-2002
Intel Revenue	14,675	18,347	21,354	24,232	27,731	31,542	36,351	15
Non-Intel Revenue	737	2,283	2,989	3,972	5,200	6,480	7,827	28
Overall Revenue	15,412	20,630	24,343	28,205	32,932	38,023	44,177	16
Intel Market Share (%)	95	89	88	86	84	83	82	-

Source: Dataquest (October 1997)

Table 11
Comparison of x86 Computational MPU Shipments for Intel and Other Vendors, 1996-2002 (Thousands of Units)

	1996	1997	1998	1999	2000	2001	2002	CAGR (%) 1997-2002
Intel Units	65,000	73,351	82,290	91,785	102,098	113,153	125,998	11
Non-Intel Units	12,600	16,650	22,538	29,785	38,727	49,657	62,059	30
Overall Units	77,600	90,001	104,828	121,570	140,825	162,810	188,057	16
Intel Market Share (%)	84	82	79	76	73	70	67	-

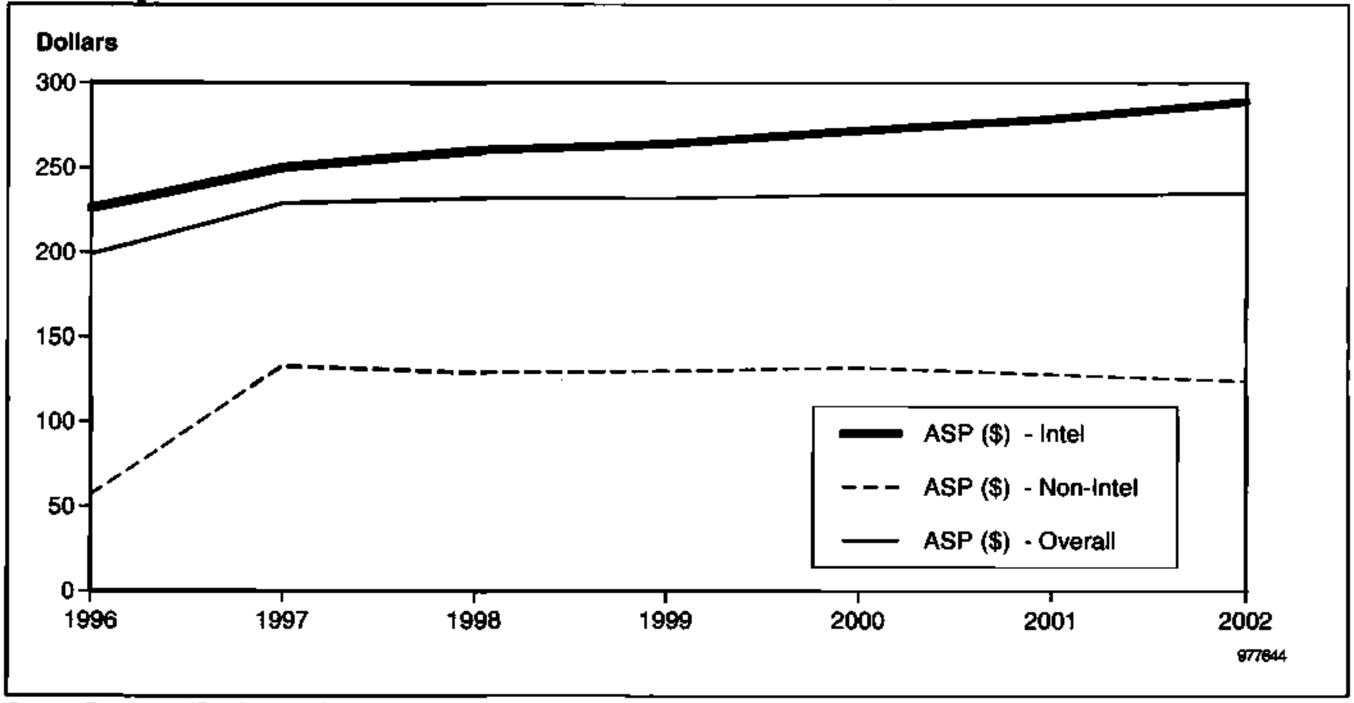
Source: Dataquest (October 1997)

Table 12
Comparison of x86 Computational MPU ASPs for Intel and Other Vendors, 1996-2002 (Dollars)

	1996	1997	1998	1999	2000	2001	2002	CAGR (%) 1997-2002
Intel ASP	226	250	260	264	272	279	289	3
Non-Intel ASP	57	133	129	130	132	128	124	-1
Overall ASP	199	229	232	232	234	234	235	0
Non-Intel Discount	75	47	50	51	52	54	57	-

Source: Dataquest (October 1997)

Figure 8
x86 Computational MPU ASPs for Intel and Other Vendors, 1996-2002



Source: Dataquest (October 1997)

Computational x86 Rolling Eight-Quarter Shipment Forecast, 1997 to 1999

At the speed with which performance evolves in today's personal computer market, generational transitions can be missed in annual forecasts. Dataquest provides an estimate of these transitions on a quarterly basis to assist our clients in their planning activities. In this forecast, we attempt to capture overall seasonality, along with anticipated product introductions from major vendors. When referring to Table 13 and Figure 9, the reader is reminded that Dataquest's definition of a sixth-generation microprocessor includes not only Intel's Pentium Pro and Pentium II lines, but also the AMD K6 and the Cyrix 6x86MX processors. Our model forecasts that shipments of fifth-generation microprocessors, after peaking in the recently completed second quarter of 1997, will fall slowly over the next six quarters. Dataquest anticipates that by the first quarter of 1998, AMD and Cyrix will have completed the volume ramp-up of their sixth-generation K6 and 6x86MX parts, and Intel will be well along in its own transition to Pentium II (including the mobile version of Deschutes), and all these changes will combine to dramatically shift the majority of PC consumption to systems powered by sixth-generation processors.

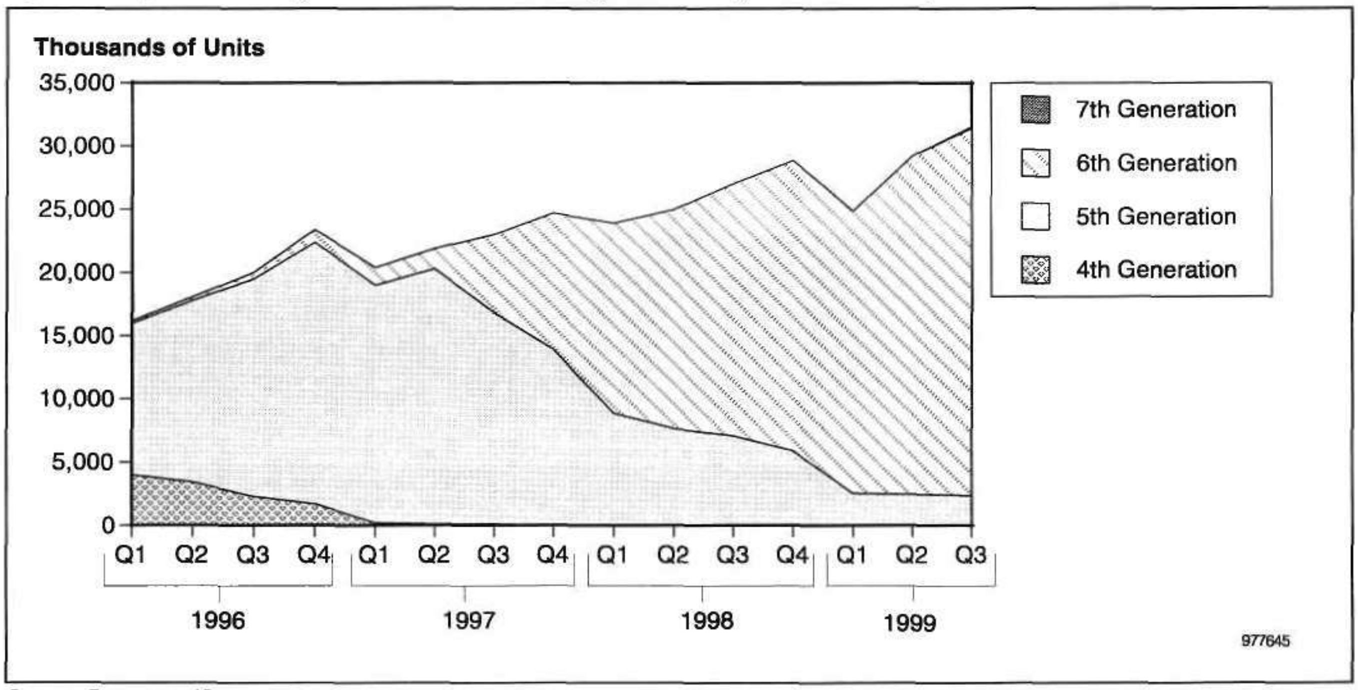
Also, the long-rumored Merced 64-bit MPU makes its first appearance in this quarterly forecast, showing up in the third quarter of 1999. As information regarding this new processor seeps into the public domain, it appears to Dataquest that the transition to Merced and 64-bit environments will be even slower than previously anticipated, and this in turn will prolong the period during which Pentium II designs (along with minor enhancements to the Pentium II) will account for the bulk of Intel's sales.

Table 13
Quarterly x86 Computational MPU Shipments by Generation, 1996-1999 (Thousands of Units)

Quarter	Fourth Generation	Fifth Generation	Sixth Generation	Seventh Generation	Total
Q1/96	3,990	11,960	200	0	16,150
Q2/96	3,420	14,352	300	0	18,072
Q3/96	2,280	17,222	500	0	20,002
Q4/96	1,710	20,666	1,000	0	23,376
Q1/97	214	18,795	1,397	0	20,406
Q2/97	107	20,187	1,597	0	21,891
Q3/97	107	16,707	6,188	0	23,002
Q4/97	0	13,922	10,780	0	24,702
Q1/98	0	8,853	15,064	0	23,916
Q2/98	0	7,672	17,323	0	24,996
Q3/98	0	7,082	19,959	0	27,042
Q4/98	0	5,902	22,972	0	28,874
Q1/99	0	2,552	22,332	0	24,884
Q2/99	0	2,458	26,798	0	29,256
Q3/99	0	2,363	29,031	138	31,532

Source: Dataquest (October 1997)

Figure 9
Quarterly x86 Computational MPU Shipments by Generation, 1996-1999



Source: Dataquest (October 1997)

The Emerging Proliferation of Processor Platforms

As the market for PC microprocessors heats up, life will become a bit more complicated for the vendors that integrate systems. For several years, there has existed.a high degree of interchangability for basic system components; chassis from vendors "A" and "B" could accommodate motherboards from vendors "X" and "Y," which, in turn, could accommodate processors from vendors "A," "C," or "I." Much of the spadework to create this infrastructure was originally performed to support Intel-branded CPUs, and this simplified the task for chip vendors that followed in Intel's wake. Clone vendors simply designed their chips to work in sockets designed for Intel's products, a practice known as "socket stealing." In its latest offerings, Intel employs a variety of intellectual property measures that preclude the continuation of this practice. Competitors and manufacturing managers will soon look at the period up to now as the good old days.

To cover the full range of Intel processors, vendors will need specific motherboards for Pentium and Pentium II (which uses the Intel-proprietary "Slot 1" design). The most recent iteration of this design incorporates the new accelerated graphics port (AGP), which greatly enhances system graphics performance in 3-D and video-intensive environments. Intel has positioned this AGP capability as one of the key benefits of its new Slot 1 architecture, although this feature in actuality depends more on the design of the chipset that supports the processor than on the microprocessor itself.

Cyrix and AMD plan to stay with the current Pentium scheme (known as "Socket 7"). System vendors should be able to stretch their current Pentium platforms to accommodate the clones for now, but AMD and Cyrix must provide a path to AGP support early in 1998 if their processors are to remain viable competitors to the Pentium II. Dataquest anticipates that several traditional (non-Intel) chipset vendors will introduce new Socket-7-class chipsets that support AGP. VIA Technologies Inc. has already announced such a product, and other announcements are anticipated for this fall.

Some x86 clones, notably the Cyrix MediaGX product, require unique motherboards, and this complicates the platform issue even more. Table 14 describes all these alternatives, and Table 15 provides Dataquest's forecast for the mix of these platforms over the next several years. Figure 10 displays these results graphically.

Table 14
Description of x86 Platform Alternatives, 1996-2002

Designation	MPUs Supported	Description
Socket 3	Intel 486, AM486, Cy486, AMx586, Cy5x86	ZIF socket for classic CPGA 486;AMD x586 and Cyrix 5x86 also used this pinout
Socket 7	Intel Pentium, Cy 6x86, Cy-M2, AMD K5, AMD K6	ZIF socket for Intel P54/P55. Dataquest includes the earlier Socket 4 and Socket 5 products in this category
Socket 8	Intel Pentium Pro	ZIF socket for Pentium Pro "Dual Cavity Package," incorporates Intel proprietary P6 Bus
Slot 1	Intel Pentium II	Single-Edge Connector (SEC) for cartridge that contains Pentium II and associated cache. Incorporates Intel proprietary P6 Bus
Proprietary	NexGen Nx586, Cyrix MediaGX	Unique pinout that requires custom-designed motherboard

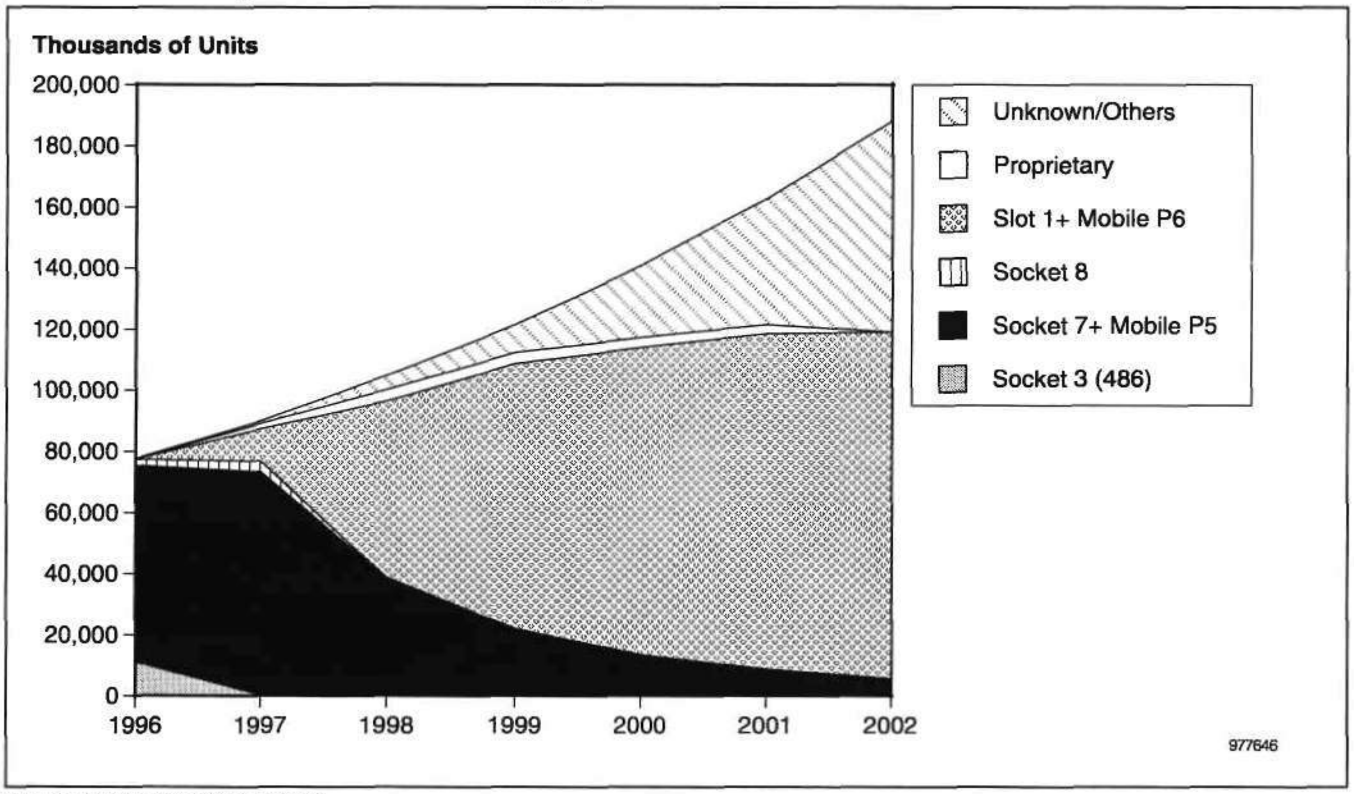
Source: Dataquest (October 1997)

Table 15
Forecast of x86 Platforms, 1996-2002 (Thousands of Units)

Platform	1996	1997	1998	1999	2000	2001	2002	CAGR (%) 1996-2002
Socket 3 (486)	11,200	428	0	0	0	0	0	-100
Socket 7+Mobile P5	64,200	72,937	38,860	22,035	13,521	8,828	5,717	-40
Socket 8	2,000	3,484	0	0	0	0	0	-100
Slot 1+Mobile P6	0	10,453	57,603	86,737	100,567	109,758	113,398	61
Proprietary	0	1,800	3,774	3,647	3,253	2,931	0	-100
Unknown/Others	200	900	4,591	9,151	23,485	41,293	68,942	138
Total	**77,600**	**90,001**	**104,828**	**121,570**	**140,825**	**162,810**	**188,057**	**16**

Source: Dataquest (October 1997)

Figure 10
x86 Platforms By Socket and Slot Type, 1996-2002



Source: Dataquest (October 1997)

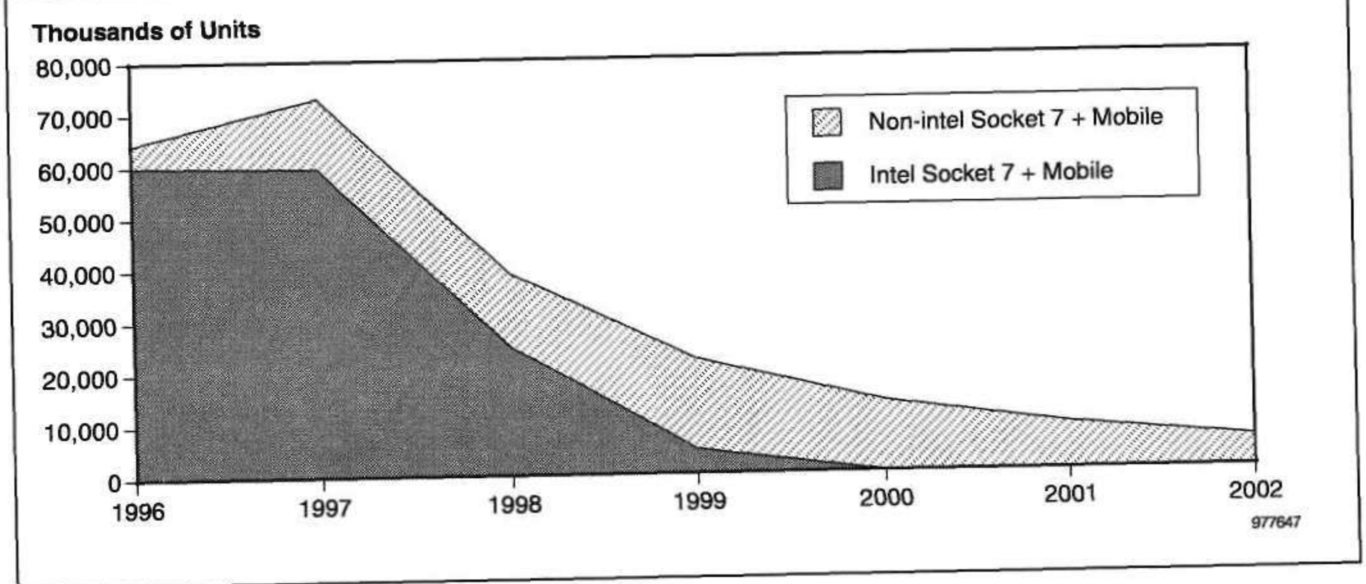
As 1998 progresses and Intel migrates more of its shipments toward Pentium II, Cyrix and AMD processors will occupy an increasing fraction of Socket 7 platforms, as noted in Table 16 and Figure 11. Traditional core logic vendors that have lost significant market share and sales to Intel may find temporary refuge in this market, as Intel focuses its efforts on chipsets to support its Pentium II architecture.

Table 16
x86 Clone Vendors Extend the Life of Socket 7 (Thousands of Units)

Platform	1996	1997	1998	1999	2000	2001	2002
Intel Socket 7 + Mobile	60,000	59,414	24,687	4,589	0	0	0
Non-Intel Socket 7 + Mobile	4,200	13,523	14,173	17,445	13,521	8,828	5,717
Total Socket 7 + Mobile	**64,200**	**72,937**	**38,860**	**22,035**	**13,521**	**8,828**	**5,717**

Source: Dataquest (October 1997)

Figure 11
x86 Clone Vendors Extend the Life of Socket 7



Source: Dataquest (October 1997)

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Perspective

Personal Computer Semiconductors and Applications Worldwide

Vendor Analysis

A Ride Down Intel's Pricing Escalator

Abstract: *For more than 10 years, Intel has lowered its list prices, but the average price for its products, along with its total revenue, keeps increasing. This Perspective sheds light on Intel's pricing strategies and offers an explanation for this apparent paradox.*
By Nathan Brookwood

Revenue Rides Up on a Downward Escalator

Every three months, like clockwork, Intel lowers its prices—usually by amounts ranging from 10 to 25 percent. Often the media seek a sinister motive, usually involving competition, to account for Intel's action. A few Wall Street analysts project the beginning of the end for the company's growth and profitability and recommend quick sales prior to the apocalypse.

Ten weeks later, Intel announces its quarterly results, often (although not lately) exceeding expectations and setting new records. This Perspective sheds light on Intel's pricing strategies and offers an explanation for the apparent paradox of ever-decreasing microprocessor (MPU) prices and ever-increasing MPU revenue—at least as far as Intel is concerned.

The magic behind this phenomenon is deceptively simple. *Despite Intel's price reductions, buyers continue to spend as much as they did before. They just buy faster processors.* Intel prices its PC MPUs from slightly less than $100 at the low end to almost $1,000 at the high end, but all these chips cost about the same to manufacture—between $40 and $80. From Intel's economic perspective, selling a 266-MHz Pentium II for $664 in August of 1997 differs little from selling a 66-MHz 486 DX2 for $682 in August of 1992.

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As shown in Figure 1, the prices for Intel's CPUs fall into eight broad bands. When its development programs hit their targets, every quarter Intel has a new, faster processor to place in the highest band. Its quarterly price reductions merely shift each of the other processors into the next lower price band. The oldest, slowest processor drops off the bottom—and life goes on.

Intel's pricing strategy resembles a conventional escalator running downward. Andy Grove stands at the top, and each quarter puts the latest model MPU on the first step. The escalator slowly descends, taking about eight quarters for the processor on the top to reach the bottom. At this point, the same MPU that set new speed records at its introduction is relegated to the technological trash heap. Figure 2 illustrates the state of Intel's escalator following its recent (November) pricing actions.

If most businesses lowered prices as predictably as Intel, customers would soon notice the trend and redirect their purchases toward the less expensive models capable of providing all the performance they thought they needed just a few months earlier. Two aspects of the current personal computer market minimize this effect. Most importantly, each major increase in computing power permits software developers to tackle new and more ambitious tasks that fully absorb the new level of hardware performance.

Figure 1
PC MPU Price Bands

Price Band
Above $600
$500-$599
$400-$499
$300-$399
$200-$299
$150-$199
$100-$149
Below $100

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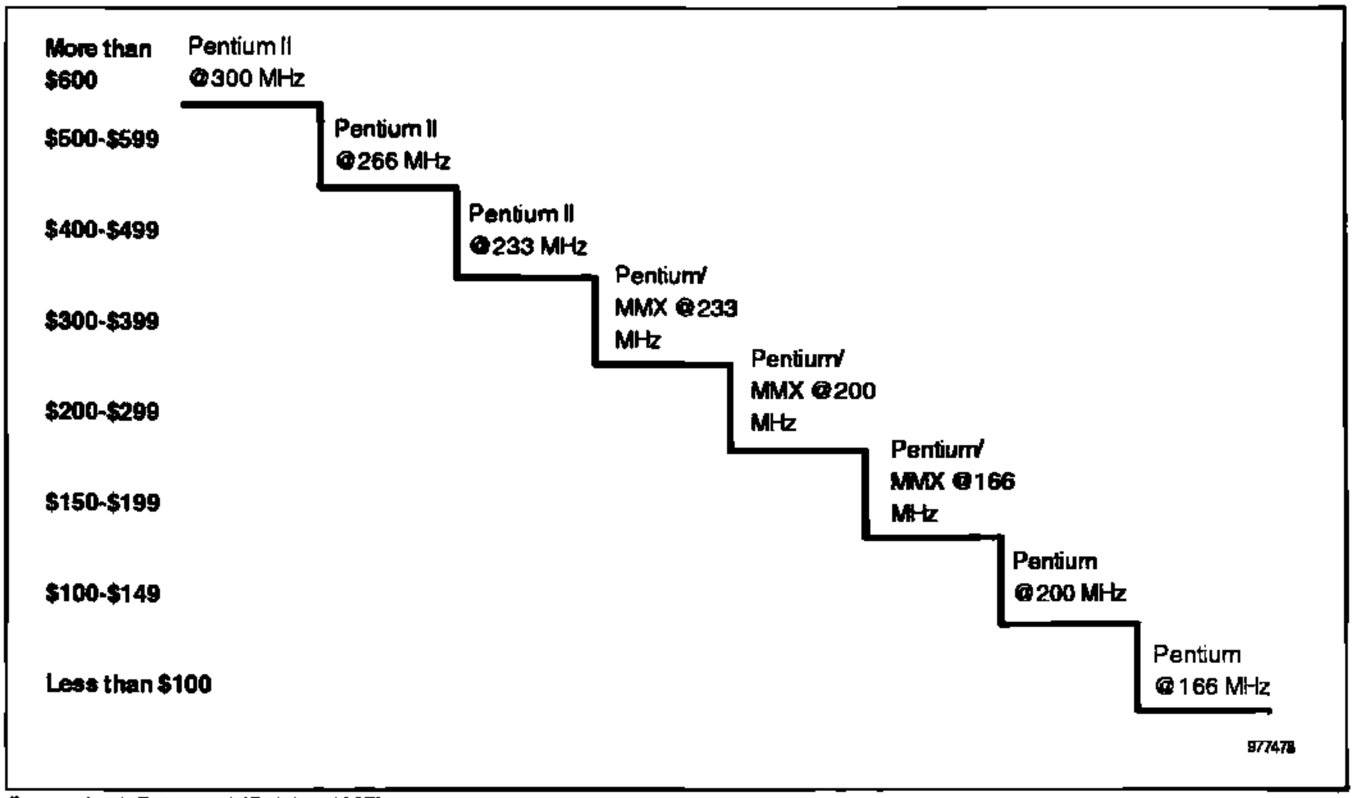
Source: Dataquest (October 1997)

Figure 2
Intel's MPU Escalator (November 1997)



Source: Intel, Dataquest (October 1997)

The desire to exploit some program's latest performance-intensive features offsets the purchaser's desire to spend fewer dollars for a constant level of performance. Even the slowest machines available today have more than enough capacity to reformat the largest document or recalculate the largest spreadsheet in the blink of an eye, but even the fastest machines still struggle to process images on the Internet, manipulate 3-D images, or analyze the complex patterns needed to understand natural language.

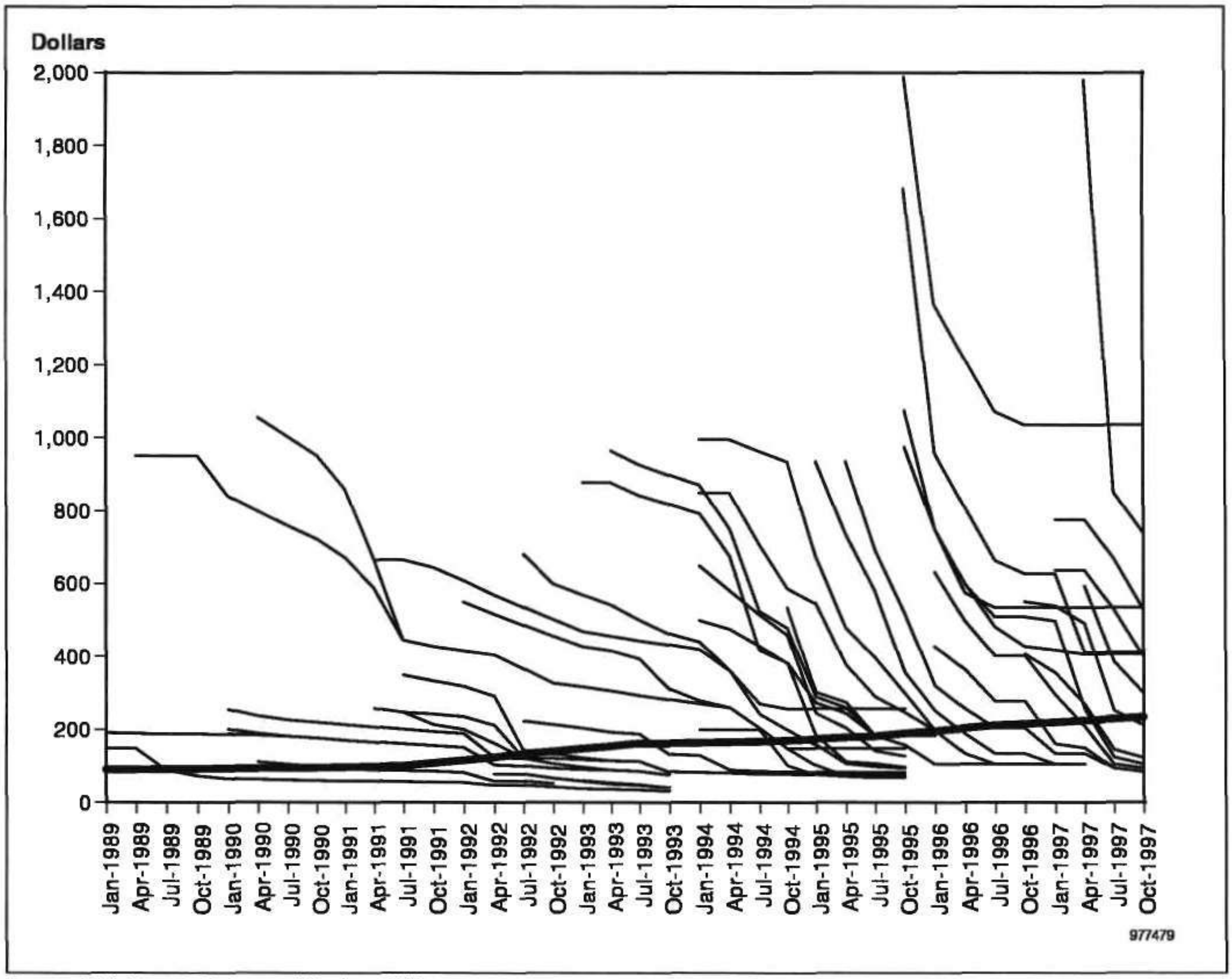
A second factor amplifies the buyer's desire to purchase at a constant or even increasing price level. Although a microprocessor typically accounts for only 10 percent to 20 percent of a system's overall price, it accounts for most, if not all, of the system's performance. The buyer who opts for a $1,000 system instead of a $1,500 system may shave one-third off the purchase price but sacrifices at least one-half of the potential performance. If the user fears that the performance not purchased may have even a minor impact on the user's productivity, the less expensive system loses much of its appeal.

Figures 3 and 4 chart the quarterly price progression of Intel's PC microprocessors since the days of the 386. Most start out at elevated levels, and sink to the bottom of the chart over time. (Figure 4 merely zooms in on the more interesting region below $600.) The prices plotted apply to low-volume (quantity 1,000) purchases. High-volume buyers obviously get large discounts, although Dataquest believes the discount curve has flattened somewhat over the years.

The thick, continuous line near the bottom of each chart represents the calculated average selling price (ASP) derived from our estimate of Intel's MPU revenue and shipments for each period, as shown in Table 1. This figure has doubled over the period, from $91 in 1989 to $235 at the end of 1997. The increase in ASP, accompanied by a huge increase in unit shipments over the period, accounts for the awesome financial results Intel has logged over the past few years. Dataquest would be hard-pressed to cite another market that has experienced dramatic unit growth in the face of increasing ASPs.

When its marketing, development, and manufacturing departments run in synch, Intel's escalator descends at its regular pace of one step per quarter. Occasionally, tactical issues force the company to simultaneously introduce several products in the same price band, as they did last spring when Intel launched its Pentium II series with three versions priced above $600.

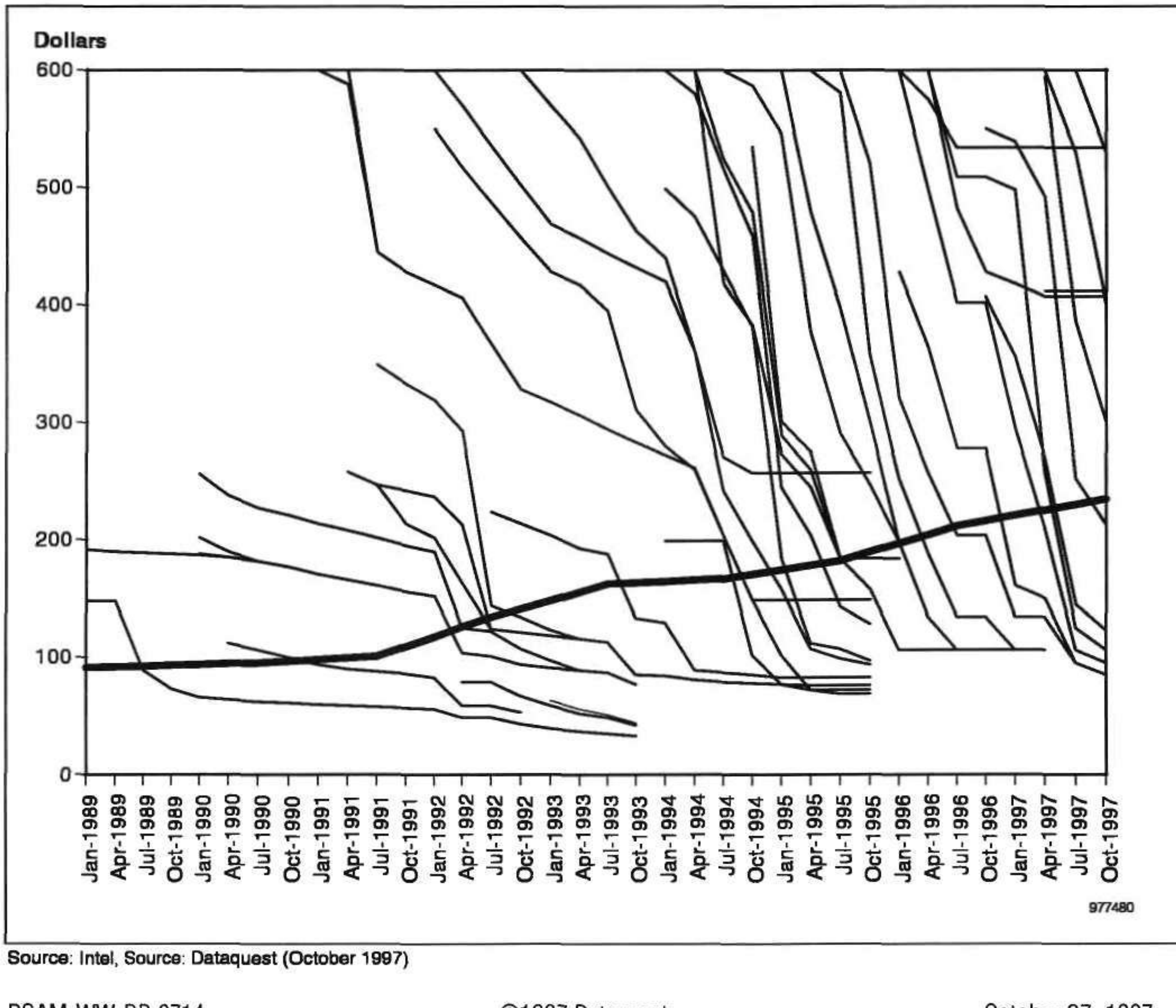
Figure 3
Historic Snapshot of Pricing for Intel x86 Microprocessors, 1989-1997 (Dollars)



Source: Intel, Source: Dataquest (October 1997)

Intel then holds off on additional launches until the congestion clears, as it has this fall. A more interesting exception occurred in late spring, when the overwhelming success of the MMX launch caused the market for non-MMX processors to wither. The four lower steps at that point all contained the older non-MMX processors, and under normal conditions, it would have taken a year for these lower bands to cycle out of the market. To keep the products in the proper relative positions, while filling the chasm that had opened at the low end, Intel accelerated the escalator and made all its Pentium products move down two steps in a single quarter. Rather than disrupt the Pentium II line, the company opportunistically inserted a new high-end 233-MHz Pentium with MMX Technology into the gap that it created by shifting the other MMX Pentium products down more rapidly than originally planned. Many stories in the media at that time viewed Intel's moves as a preemptive strike against a developing situation with the AMD K6. Given the limited quantities of product AMD was able to build then, or at any point in 1997, such an explanation seems highly unlikely.

Figure 4
Historic Snapshot of Pricing for Intel x86 Microprocessors, 1989-1997 (Dollars)



Source: Intel, Source: Dataquest (October 1997)

Why Would Intel Behave in This Manner?

Few observers familiar with Intel's corporate culture would believe that altruism alone causes the company to lower prices in such an aggressive manner. In the semiconductor industry, size matters. Bigger factories produce wafers at lower unit costs than small factories. Smaller geometries produce faster chips and more of them per wafer. To retain its market position, the company must continually reinvest in new equipment, and it must then find homes for its ever-increasing MPU output.

Because it has no competitor from which it can seize meaningful market share, Intel's strategy focuses on increasing the overall market. It depends on rapid increases in processor performance to drive this growth. Faster, more versatile processors can take on a wider variety of tasks and thus attract users for whom computers had previously served no useful purpose. Witness the growth of computer gaming and entertainment applications. Faster processors also tempt those who already own computers in good operational condition to replace those machines, just to speed up their everyday tasks. These two vectors—selling computers to those who do not already own computers, and selling computers to those who already do, form the basis for Intel's marketing strategy. Increased performance at more-or-less constant prices plays a key part in both campaigns.

Dataquest dates the onset of Intel's aggressive market growth strategy to the start of 1992, when Intel dramatically lowered prices for its 386 devices in an effort to obsolete the large base of 286-based AT-style machines in the field. At that point, the ASP for x86 microprocessors stood at $109. One year later, the ASP had grown to $140, and the company staged additional 486 processors at the high end of the price bands. After one more year, ASP had grown to $164, and the current system was fully operational. (The prices charted in Figures 3 and 4 illustrate these moves as clearly as trails in a cloud chamber reveal the presence of subatomic particles.) Intel's actions have resulted in strong PC market growth, which Dataquest estimates will continue in the range of 16 percent to 18 percent into the indefinite future.

Table 1
Intel's 32-Bit x86 Shipments, Revenue, and ASPs, 1989-1996

	1989	1990	1991	1992	1993	1994	1995	1996
Shipments (K)	14,749	19,320	29,250	32,600	40,750	50,790	57,422	68,470
Revenue ($K)	1,362,450	1,842,250	2,955,125	4,361,250	6,619,250	8,488,250	10,478,260	14,497,000
ASP ($)	92	95	101	134	162	167	182	212

Source: Dataquest (October 1997)

Is It Time to Add Another Story to Intel's House?

Until recently, Intel's world fit neatly inside a two-story building with a single escalator, which provided more than enough room to comfortably accommodate its growing family. But the company and the market have grown, and the challenge of designing and selling a single product that can span the entire market has increased. Fortunately, the larger market provides opportunities for the company to differentiate its products to service different market segments with differing price sensitivities.

The first signs of this differentiation have begun to appear in the processors Intel targets toward workstation and server markets. Unlike the high-volume desktop market, workstation and server buyers often willingly pay extremely high prices for marginal performance gains. Intel recently introduced a new version of its mature 200-MHz Pentium Pro product with twice the level-two cache of the former model (1MB total), at a price more than two and a half times higher than the earlier 512KB version ($2,675 versus $1,035). The larger cache provides a performance boost in multiprocessor servers, and, even at these prices, the resulting overall system still provides a competitive level of price/performance.

These $2,000 chips will probably not descend to $100 levels over the next few years. Rather, they will decrease in stages to a $500 price point and then disappear. By the end of 1998, the current server-targeted Pentium Pro will be replaced by a similarly priced Pentium II, with bigger, faster caches optimized for workstation and server applications. These in turn will give way to the 64-bit Merced processor a year or two later.

The full extent of the escalator for workstation and server markets has yet to be shown. The number of steps it contains and the rate at which it descends have yet to be determined, but Dataquest anticipates that it will contain fewer steps and move more slowly than its desktop counterpart.

What Does This Mean for Intel's Competitors?

For those who would compete with Intel, the company's fully staged pipeline of future products poses an awesome competitive barrier. Unless the competitor can match Intel's offerings, which roughly compares with walking up a downward-moving escalator, it will eventually be forced out of the market. (Just consider the point where the escalator's steps re-enter its housing at the bottom of the run, and imagine what would happen if the ridges on those steps were as sharp as knives. This fate awaits the competitor that tires.)

Intel achieves some of its performance gains via manufacturing technology improvements and others via architectural improvements. Changes to the manufacturing process (that is, going to smaller geometries) can double a product's performance in the space of a year, but then the benefits fall off rapidly. Major architectural changes (that is, adding new pipelines, more cache, or new instructions) can increase performance by 50 percent to 100 percent but take three to four years to implement.

This means that to compete successfully with Intel on a long-term basis, a company must have at least two processor development teams working on products with staggered introduction dates. Intel has *three*. With its dominant position, Intel controls the rate at which the escalator descends.

Should Intel experience a development program mishap, it can slow the escalator with only a minor impact to its current quarterly economic performance. Competitors have no such option; a misstep on their part may force them to the bottom of the escalator.

Viewed from this perspective, AMD's 1995 acquisition of Nexgen makes especially good sense. Not only did it acquire an almost mature design for a sixth-generation processor (since introduced as the K6), but it also got a second development center, which doubles its design bandwidth and gives it the opportunity to compete with Intel on a long-term basis. If National Semiconductor plans to keep its newly acquired Cyrix division in the computational MPU business, it would do well to add a second MPU development team, possibly out of the remains of the Israeli group that formerly developed National's proprietary MPUs.

The insatiable appetite for computational performance at relatively constant prices fuels the personal computer industry's growth and fills Intel's coffers. Other MPU vendors dream of turning their factories into gold mines, but to date only Intel has combined the development capacity to enhance processor performance on a quarterly basis with the manufacturing muscle and discipline to move these enhanced products from the lab to the consumer in high volumes and on a somewhat predictable schedule. The opportunity still exists for others to share in the profit potential of this marketplace, but they must demonstrate the strength to walk up Intel's escalator if they are to succeed.

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October 13, 1997
Consumer Multimedia Semiconductors and Applications Worldwide
Market Analysis
Geoffrey Ballew

Go to Document

PC Multimedia Chip Vendors Climb a Rocky Slope

Pricing volatility limits PC semiconductor market growth despite growing shipments of PCs. This Perspective provides Dataquest's PC and PC semiconductor forecasts with discussion of the trends and dynamics for major segments of the PC semiconductor market.

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PC Market Displays Sustained Momentum

The PC market should top 19 percent unit growth for 1997. While still a teenager, the PC market is mellowing somewhat as it heads toward the end of its second decade. Growth during the next four years will decline to 15.5 percent.

The ongoing growth of PC shipments stems from a strong replace-and-upgrade cycle, combined with new sales to growing businesses or PC-less consumers. Market growth hiccuped in 1996 with unit growth of only 17. 7 percent after the robust growth of the first half of the decade. This year appears stronger because of new microprocessor offerings from Intel Corporation, specifically Pentium with MMX technology and Pentium II. Intel's Accelerated Graphics Port (AGP) creates opportunity because it provides a higher bandwidth attach point for graphics chips. Microsoft Corporation's Memphis and Windows NT 5.0 would have been nice additions on the operating system side this year, but both have been pushed into 1998 for OEM releases. Table 1 and Figure 1 present Dataquest's PC and PC semiconductor consumption forecasts.

Table 1
PC Semiconductor Application Markets, 1995 to 2001

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
PC Shipments (M Units)	60.2	70.9	84.3	98.4	113.6	131.2	151.6	16.4
Annual Growth (%)	-	17.7	19.0	16.7	15.5	15.5	15.5	-
ASP (K)	2.05	2.13	2.10	2.21	2.22	2.20	2.20	0.6
Revenue ($B)	123.6	150.7	177.3	217.4	252.7	289.1	333.0	17.2
Handheld PCs (M Units)	0.244	0.573	0.803	1.144	1.723	2.396	3.830	46.2
ASP (K)	0.975	0.531	0.421	0.406	0.395	0.391	0.388	-6.1
Revenue ($B)	0.238	0.304	0.338	0.464	0.681	0.937	1.487	37.4
Additional Motherboard (M Units)	5.5	10.2	10.9	11.4	13.1	15.0	17.2	11.0
Annual Growth (%)	-	84.3	7.1	3.8	14.8	14.9	15.0	-
Total PCs/Additional Motherboards (M Units)	66.0	81.6	96.0	110.9	128.4	148.6	172.7	16.2
Semiconductor Content ($)	685.2	548.8	497.1	539.2	647.4	787.5	697.4	4.9
PC Semiconductor Market ($B)	45.2	44.8	47.7	59.8	83.1	117.0	120.4	21.9
Annual Growth (%)	-	-0.8	6.5	25.3	39.0	40.8	2.9	-
Source: Dataquest (September 1997)								

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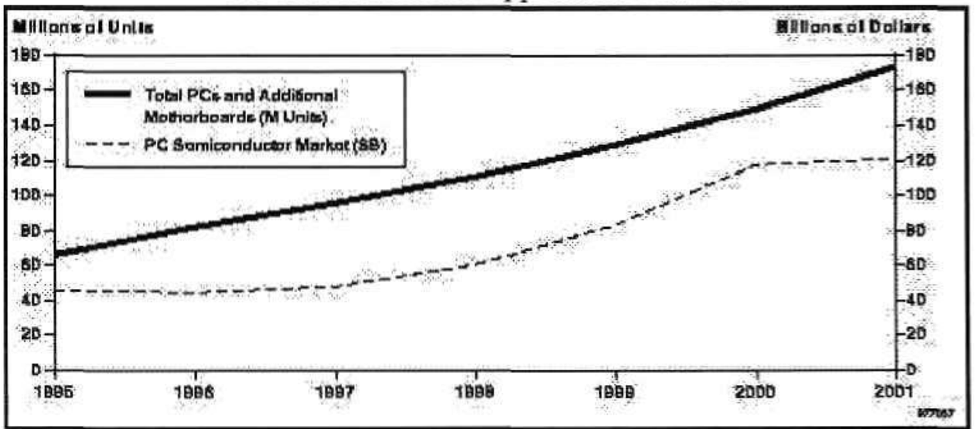
Figure 1
PC Semiconductor Application Markets



Source: Dataquest (September 1997)

PC Pricing

Growth of the PC market is closely tied to the growth of features and performance but may also depend on reaching a broader consumer market. PC average selling prices (ASPs) have changed little during the past few years. The prices for specific models decline rapidly, but there is always a new PC offered at the old price point. For example, a $2000 PC may sell for $1, 700 three months later, but only because a slightly better model has taken over that $2000 price slot.

Microprocessor pricing has some similar dynamics. Intel's ASP has increased slowly despite the fact that the company lowers prices four times a year. Intel sells yesterday's $350 processor for $300 but convinces the consumer to buy a faster, more expensive processor that sells for $355, slightly more than the previous product.

Attempts to Reach a Broader Market

The problem with these PC marketing and pricing dynamics is that by the time a PC trickles down into the sub-$1,000 price band, it is outdated. If everyone who wants a PC could afford to spend $2,000, this issue would be moot. The reality is that many potential PC buyers are priced out of the market.
PC OEMs tackling this untapped market have introduced new models designed to sell at prices around $1,000. The sub-$1,000 PC category also is referred to as "segment zero."

One example is the Presario 2200 series by Compaq Computer Corporation. These models feature the MediaGX processor from Cyrix Corporation rather than the latest and greatest from Intel. PC OEMs and software giants such as Microsoft are trying to broaden the appeal of PCs to the average consumer. Part of this strategy is to introduce compelling and less expensive models, but it also involves making PCs look and act more like consumer electronics. Issues involve everything from industrial design, ease of use, length of time it takes to "boot-up," and even audio and video quality.

The issue of audio and video quality is gaining much more attention. Taken to the extreme, this issue leads to "living room PCs," such as the Gateway Destination system with a big-screen, TV-sized monitor and the Compaq PC Theatre product. Audio and video quality is an issue in mainstream PCs, and the emphasis has grown to using traditional consumer devices as the standard (for example, TV-quality video playback). DVD is the ultimate bridge product between the consumer and computing markets and spurs the trend of comparing PC multimedia quality to that of consumer electronics products.

Attempts to broaden the appeal of PCs to more consumers may not be successful, but previous attempts have been half-hearted. This is the first year that new products have been designed and marketed without the stigma of being yesteryear's PC at a really low price. Note that the PC ASPs in the Dataquest forecast in Table 1 do not change over time. Segment zero sales resulting from the new low-cost PC initiatives could result in upside sales volume in the PC market. Greater sales of low-cost PCs would bring down the ASP but should result in higher units and total revenue.

Semiconductor Market Opportunities

The PC semiconductor market is caught between falling DRAM prices and cutthroat competition on the multimedia peripheral side. Growth of 6.5 percent for the year follows almost a 1 percent decline in 1996. Table 2 and Figure 2 provide the same top-line PC semiconductor revenue forecast shown in Table 1 and add detail for the major market segments. The growth trends speak volumes about the market dynamics for each of the market segments.

Table 2
PC Semiconductor Forecast by Market Segment, 1995 to 2001 (Millions of Dollars)

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Total Memory	25,007.4	18,230.3	15,684.9	18,912.6	29,332.4	49,080.5	42,912.9	18.7
Multimedia	2,322.6	3,680.4	5,014.7	7,207.5	8,330.8	9,238.7	10,403.4	23.1
MPU	10,949.7	14,160.3	16,773.4	20,939.0	29,105.3	36,982.4	43,168.2	25.0
Others	6,916.0	8,740.9	10,266.1	12,735.7	16,345.4	21,728.4	23,937.7	22.3
Total Revenue	**45,195.8**	**44,811.8**	**47,739.1**	**59,794.9**	**83,113.9**	**117,030.0**	**120,422.1**	**21.9**

Source: Dataquest September 1997)

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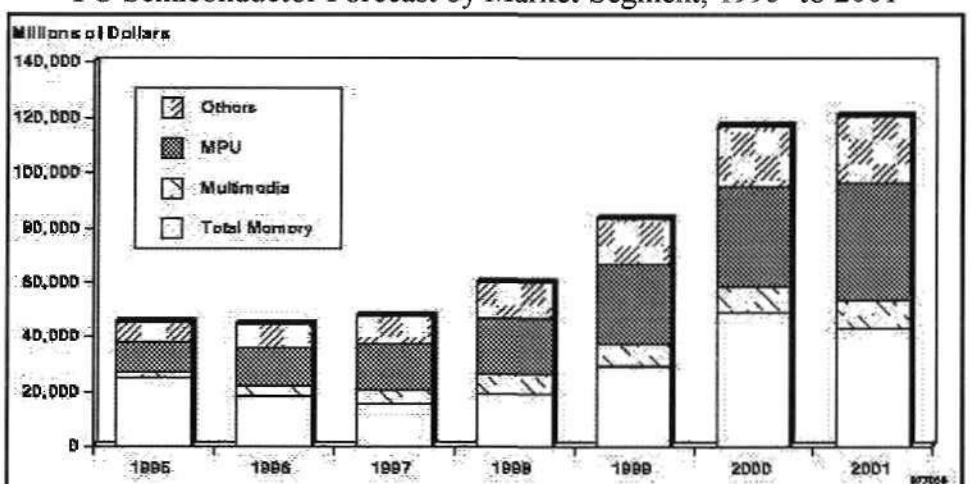
Figure 2
PC Semiconductor Forecast by Market Segment, 1995 to 2001



Source: Dataquest (September 1997)

Microprocessors

Intel's dominance of the microprocessor market is shown clearly by the steady growth of microprocessor revenue. Pricing volatility is taken out of the equation for the most part, so revenue growth mirrors PC unit shipment growth. Of course, this segment grows a bit faster than PC unit shipments because of Intel's ability to increase its ASP every year. The rapid pace of clock scaling and product introduction has given Intel the ability to lower prices like clockwork while still getting buyers to spend a little more each year.

Multimedia Chip Market

The multimedia segment of the PC semiconductor market is growing at the same time that price volatility erodes profit margins. This segment benefits from an increasing attach rate for PC audio chips and internal modems. Price erosion in the multimedia chip market is severe. Single-chip audio products that were selling for $10 at the end of last year now fetch less than $5. Also, competition on the graphics side has moved up the feature list to include the 3-D category. Last year, only a few vendors had 3-D products priced for mainstream applications. This year, virtually every major vendor has 3-D products for sale. Rapid technology shifts in the multimedia chip market create opportunities for vendors to gain or lose significant market share.

3-D Graphics

The shift to 3-D graphics from 2-D+video products creates volatility because so many new vendors are targeting the PC graphics market and using 3-D technology as their entree. Demand for 3-D features on the corporate desktop is a critical issue and affects who wins and loses in the market share game. Products such as S3 Incorporated's ViRGE DX/GX, Trident Microsystems Inc.'s 3D Image 975, Cirrus Logic's Laguna3D, and ATI Technologies Inc.'s RAGE II appeal to OEMs who want to add 3-D features to their designs but do not want to pay extra for better 3-D.

These products will continue to be successful as long as 3-D remains a check-off item. When actual 3-D performance is more of an issue, OEMs are more likely to pay a little more for the next tier of 3-D performance. That higher tier includes integrated 2-D/3-D products such as ATI's Rage Pro, NVIDIA's Riva 128, 3Dlabs Inc.'s Permedia2, Intel's upcoming chip named Auburn. Some 3-D-only accelerators, such as 3Dfx Interactive Inc.'s Voodoo Rush and NEC Electronics Inc.'s PowerVR PCX2, target the consumer gaming segment but require a 2-D+video chip for those functions rather than having them integrated into a single-chip product.

The huge number of multimedia chip suppliers is too great for the PC market to support, so Dataquest expects further consolidation in the areas of PC graphics and audio. Spring 1998 design-wins will separate winners from losers for those new vendors in the PC graphics arena. Good technology and products are plentiful, so technology is not a good metric for market success. Volume suppliers need access to fab capacity and leading-edge process technology. 3-D graphics acceleration and on-chip memories will drive the gate counts on these chips through the roof at the same time that suppliers need to maintain aggressive price points. Strategic partnerships or fab equity are critical for chip suppliers to succeed in million-plus unit volumes.

PC Audio

PC audio faces several technology shifts, but the two most significant issues are the transition from Industry Standard Architecture (ISA) to Peripheral Component Interconnect (PCI) and the AC-97 style implementation. Demand for higher performance and sophisticated features, such as AC-3 decoding and positional 3-D audio, drives the need for audio to move to the PCI bus. Compatibility with legacy software and the Sound Blaster standard as well as cost issues have prevented this change from occurring. Chip vendors have addressed both issues, and many products coming to market offer advanced features at attractive prices.

Some of these products, such as Cirrus Logic Inc.'s 4610 and Oak Technology Inc.'s TelAudia3D, are essentially programmable Digital Signal Processors (DSPs) tailored for PC audio functions. All of the key PC audio chip vendors have announced PCI-based products or will announce them soon. Other examples include ESS Technology Inc.'s Maestro family and products from Aureal Semiconductor Inc. (formerly MediaVision), VLSI Technology Inc., Creative Labs Inc., and S3.

PC audio products are less gate-intensive than graphics products and, with the growth of AC-97 style codecs, will be less dependent on mixed-signal quality as high-quality codecs become commodity products. Price and features will continue to separate the leaders from the followers in PC audio.

Analog Modems

Today's headlines on the analog modem front focus on 56-Kbps operation. Two technology camps vie for both mind share and market share, led by Rockwell International Corporation and 3Com Corporation (U.S. Robotics Inc.). Rockwell has Lucent Technologies, Motorola Incorporated, Analog Devices Inc., and others on its side. 3Com's list of supporters includes chip-makers Texas Instruments Inc., Cirrus Logic, ESS, and IBM Microelectronics.

Technology trademarks are K56flex for the Rockwell-led group and x2 for the 3Com-led team. The two technologies do not interoperate, so modem buyers run the risk of purchasing the "wrong" technology until the International Telecommunications Union (ITU) standard is finalized. Dataquest expects the ITU will ratify a new standard in the first half of 1998. Modem chipsets from virtually all suppliers promise to be upgradable to the new standard, so modem buyers have little long-term risk of incompatibility.
PC OEMs have endorsed 56K modems wholeheartedly but are divided between the K56flex and x2 technologies. Compaq, the IBM PC Company, and Hewlett-Packard Company are shipping K56flex modems in their systems, while Dell Computer Corporation, Gateway 2000 Inc., and Packard Bell Inc. chose x2 modems.

Dataquest Perspective

The market for PC semiconductors will grow dramatically from 1997 through 2000 following meager expectations for growth in 1997. Growth in 2001 will be anemic, driven by steep declines in memory prices because of another cycle of oversupply.

Profits and market share for semiconductor vendors will be more elusive than market growth for the next couple of years. Memory and multimedia chip suppliers face abundant competition, and price erosion is a direct consequence of that competition.

On the memory side, commodity market dynamics rule the roost. Supply will outpace demand until 2000, so margins will stay thin until supply becomes tighter. The multimedia chip market should firm a bit for the fall and winter, but spring 1998 will bring renewed volatility as the flurry of design activity for fall 1998 products determines who has the resources to stick around. Consolidation during the next 12 to 18 months in the multimedia chip market should lead to less volatility in 1999. Multimedia chip suppliers are encouraged to build solid foundry relationships and--to the extent that they can--sell solutions rather than chips. Suppliers who address the software availability and compatibility issues for their customers

Perspective

Personal Computer Semiconductors and Applications Worldwide

Market Analysis

PC Semiconductor Quarterly Outlook: The Bow Is Drawn, but Will the Arrow Find Its Mark?

Abstract: *Second quarter financial results for PC-related vendors show an uneventful quarter, with some positive indicators for the second half of the year, assuming PC sales remain strong. This Perspective includes a list of the most notable events to complement the discussion of aggregate financial results.*
By Geoff Ballew

Cautious Optimism for the Second Half

Second quarter financial results from chip vendors and PC OEMs inspire cautious optimism for a stronger second half. Many PC chip companies warned investors during the quarter that earnings might not meet expectations and the final results bear out the veracity of those sentiments. Suffice it to say that second quarter results achieved a happy medium with some positive signs to offset limited revenue growth. Low inventories bode well for second-half sales. Table 1 contains some financial data for several key vendors in the PC and PC semiconductor markets. Looking at this data by the three market segments—microprocessors, peripherals, and systems—provides an interesting, if not unexpected, story.

Group Dynamics

Intel Corporation dominates the microprocessor group, so strong year-over-year growth with a single-digit decline in sequential revenue surprises no one. Nonmicroprocessor revenue from SGS-Thomson (ST) colors this group's results substantially, as well. ST's results acted as contra-indicators to the overall group revenue trends.

Dataquest

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Table 1
PC Semiconductor and PC System Vendor Performance for Calendar Q2 1997

Group	Company	Ticker Symbol	Fiscal Year Ending	Q2/96 Revenue ($)	Q1/97 Revenue ($)	Q2/97 Revenue ($)	Q2 to Q1 Revenue Growth (%)	Q2 to Q2 Revenue Growth (%)	Q2/96 Gross Margin (%)	Q1/97 Gross Margin (%)	Q2/97 Gross Margin (%)	Q2 1996 Days of Inventory	Q1/97 Days of Inventory	Q2/97 Days of Inventory
Microprocessors	Advanced Micro Devices	AMD	Dec-97	455,077	551,999	594,561	8	31	17	37	37	42	38	39
Microprocessors	Intel	INTC	Dec-97	4,621,000	6,488,000	5,960,000	-8	29	53	64	61	62	54	55
Microprocessors	Cyrix	CYRX	Dec-97	25,068	75,616	39,517	-48	58	2	44	38	83	57	145
Microprocessors	SGS-Thomson	STM	Dec-97	1,049,700	940,500	963,900	2	-8	44	38	38	85	80	84
	Overall Microprocessors	-	-	6,150,845	8,056,115	7,557,978	-6	23	49	59	56	64	57	59
Peripherals	Cirrus Logic	CRUS	Mar-97	214,896	212,900	201,623	-5	-6	38	23	39	91	70	72
Peripherals	ATI Technologies	ATY	Aug-97	115,100	151,460	135,050	-11	17	27	30	34	31	53	48
Peripherals	ESS Technology	ESST	Dec-97	48,450	81,468	45,142	-45	-7	55	49	40	97	74	97
Peripherals	LSI Logic	LSI	Dec-97	325,359	308,388	332,004	8	2	46	47	49	63	44	50
Peripherals	National Semiconductor	NSM	May-97	612,400	680,500	599,200	-12	-2	35	38	44	74	51	49
Peripherals	S3	SIII	Dec-97	103,825	138,166	108,892	-21	5	38	41	35	73	60	60
Peripherals	Texas Instruments	TXN	Dec-97	2,845,000	2,263,000	2,559,000	13	-10	28	35	38	50	39	42
Peripherals	VLSI Technology	VLSI	Dec-97	182,526	177,684	182,472	3	0	39	43	45	51	51	48
Peripherals	3COM	COMS	May-97	727,201	786,778	829,892	5	14	52	54	52	63	64	52
	Overall Peripherals	-	-	5,174,759	4,800,344	4,993,275	4	-4	34	39	42	57	48	47
Systems	Compaq	CPQ	Dec-97	4,001,000	4,805,000	5,012,000	4	25	23	25	25	45	31	38
Systems	Gateway 2000	GATE	Dec-97	1,137,262	1,420,000	1,392,658	-2	22	19	19	19	19	25	37
Systems	IBM	IBM	Dec-97	18,183,000	17,308,000	18,872,000	9	4	40	38	39	55	49	46
Systems	Apple Computer	APPL	Sep-97	2,179,000	1,601,000	1,737,000	8	-20	18	19	20	34	35	35
	Overall Systems	-	-	25,500,262	25,134,000	27,013,658	7	6	34	33	34	49	42	43

Source: Company reports and Dataquest (August 1997)

The peripheral group performed better than expected given the volatility in the multimedia chip markets. Taking a closer look at individual companies' results makes this easy to understand. Larger vendors such as National Semiconductor, Texas Instruments, and 3COM overwhelm this category, even though a lower percentage of their revenue stems from PC semiconductor markets. 3COM's growth indicates strength in the communications chip market. Strong sales of modem chipsets and other DSP-based products helped TI's growth as well.

ATI Technologies Inc., Cirrus Logic, ESS Technology, and S3 Inc. each faced declines over the previous quarter because of volatility in the PC graphics and PC audio markets. Note the declines in gross margin that ESS and S3 posted. Cirrus' gross margin almost doubled to 39 percent, but it still did not beat the average margin for the peripherals group. ATI posted a gain in gross margin, benefiting from its transition to Customer Owned Tooling (COT) as well as introductions of leading-edge products.

The best news comes from the systems group. This group posted revenue growth on a sequential as well as year-to-year basis. That growth did not break the single-digit range, but it is growth, nonetheless. Chip vendors should be pleased to see that inventories at the PC OEMs remain relatively low. In fact, inventories declined sharply on a year-to-year basis as measured by days of inventory. Dataquest remains optimistic about strong PC sales for the second half of this year. System sales will necessarily create new chip orders because of the low inventories.

The lower inventories at PC OEMs on a year-to-year basis reflect the trend among those vendors to follow what Dataquest calls a "velocity model" for systems manufacturing. The next section of this document briefly discusses the velocity model. Dataquest believes that many system OEMs are changing their business practices with an eye for the cost of inventory ownership. These OEMs are working to minimize inventory costs relative to their sales volumes in an effort to improve their profitability without requiring higher gross margins.

The Velocity Model

The velocity model focuses on increasing the product of gross margin multiplied by inventory turns rather than gross margin multiplied by sales. The time factor of this equation is the critical element. An investment that yields a 1.5 percent return doesn't sound attractive compared to one that yields 10 percent. But if the 1.5 percent yield is *per month* and the 10 percent is *per year*, the 1.5 percent yield becomes more interesting! If a vendor can make 15 percent gross margin on inventory it has held for one week, that can be preferable to 25 percent gross margin on inventory it has held for two weeks. Dell Computer Corporation is the clearest example of this model among the leading PC OEMs. Other leading vendors have incorporated the velocity model into their business practices with emphasis on build-to-order (BTO) and channel configuration programs.

Notable Events and News

This summer brought a host of ground-breaking headlines. A selected list of high-impact announcements and events includes the following:

- Intel offered in July to buy Chips and Technologies for $17.50 per share, for a total of roughly $420 million. The FTC responded in mid-August with a request for more information and thereby extended the period of time it has to review the transaction. Intel extended the tender offer to October 17.
- Microsoft made a $150 million investment in Apple Computer. Mac faithfuls at MacWorld booed upon hearing the news and seeing Bill Gates' visage on the display at the Boston show in early August. In one fell swoop, Gates delivered severe blows to both Netscape and Sun. Apple will package Internet Explorer rather than the Netscape Web browser with its systems and will also support Microsoft's flavor of Java rather than the 100 percent pure Java touted by Sun. Microsoft agreed to continue developing software for the Macintosh, assuring that leading productivity applications would be available for the ailing platform.
- National Semiconductor offered to buy Cyrix, adding sixth-generation microprocessor technology to its PC product list. This follows the purchase of Pico Power from Cirrus Logic earlier this year for core logic products and expertise. National plans to incorporate Cyrix-developed technology into x86-based single-chip systems that can drive so-called "information appliances" priced at less than $500.
- Intel introduced the 440LX core logic chipset and three new motherboards that use it. The 440LX brings accelerated graphics port (AGP) and SDRAM capabilities to Pentium II PCs. Intel now supports SDRAM across its entire line of chipsets and processors.
- Intel's VxD will enable AGP features on AGP systems until Windows 98 and Windows NT 5.0 ship. Microsoft expects to release those two operating systems to OEMs in the first half of 1998. Earlier operating systems do not support the AGP architecture.
- 56 Kbps modem shipments climb as acceptance grows. Rockwell and TI combined had shipped more than 17 million 56 Kbps-capable modem chipsets by the end of July. Support for 56 Kbps operation spreads as these chipsets wend their way to end users and remote access servers. Interoperability issues remain stalemated as the ITU members work toward a worldwide standard. Dataquest expects a new ITU standard to emerge in the first half of 1998.
- The leading PC OEMs continue to gain strength as top-tier vendors seized a bigger share of the total market for the second quarter. Apple remains the notable exception to the growth trend.
- Apple's search for a CEO continues following Gil Amelio's departure and Steve Jobs' refusal to accept the position.

Dataquest Perspective

The seasonally slow second quarter met mid-quarter expectations without any unusual surprises (either good or bad). Revenue grew year over year and inventories remain under control at historically low levels. The bow is drawn—now the archer simply needs to hit the mark. What is necessary to hit that bull's-eye? Strong PC sales through the Christmas buying season will bring growth for PC semiconductor markets. If system sales are strong, then chip orders and revenue growth will follow.

Do not expect growth to exceed single-digits, though, unless PC sales outpace the Dataquest forecast of 19 percent unit growth for the year. Volatility in the PC multimedia chip markets appears to be easing a bit following the design cycle for Q4 products; but it should rear its ugly head again next spring as the PCI audio and 3-D graphics battles heat up once again.

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September 17, 1997

Dear Client:

The enclosed copy of "PC Semiconductors and the Three M's: Multimedia, Microprocessors, and Memory," product code PSAM-WW-DP-9712, once again replaces the copy previously mailed to you. Because of a production error, the title for Figure 5 once again appeared on a different page than the figure itself. To ensure that this problem has not been repeated with this mailing, we have printed this version from hard copy rather than an electronic file. Please discard all copies of this document that you previously have received and replace them with the copy enclosed. We apologize for this inconvenience and have made modifications to our document templates to ensure that this will not happen in the future.

Sincerely,

Randolph F. Frey

Randolph F. Frey
Director, Document Production

Perspective

Personal Computer Semiconductors and Applications Worldwide

Event Summary

PC Semiconductors and the Three M's: Multimedia, Microprocessors, and Memory

Abstract: *This document contains text of the June 24, 1997, telebriefing presented by the Personal Computer Semiconductors and Applications Worldwide program. The PC semiconductor market continues to grow, fueled by PC shipments, faster CPUs, and memory-hungry multimedia applications. Market revenue will top $125 billion in the year 2001, up from $44 billion in 1996.*

By Geoff Ballew and Nathan Brookwood

Overview

Dataquest's PC forecast is the foundation of the PC semiconductor forecast. This telebriefing covers the overall trends of semiconductor consumption in PCs, highlighting overall growth rates as well as the breakouts for microprocessor and memory revenues. The two other forecasts that have just been published by this program, the graphics controller forecast and the PC audio chip forecast, and the markets for microprocessors and PC core logic will also be discussed.

Figure 1 shows that the Dataquest forecast is characterized by consistent growth through the five-year horizon. The growth in unit shipments is the key driver of the following semiconductor forecast. Mobile computer shipments will grow faster than deskbound shipments, but Dataquest sees no major upsets to the existing balance. From a regional point of view, Japan and Asia/Pacific will grow faster than the Americas, but the Americas region still shows by far the largest consumption. The European region faces certain economic challenges that will limit PC growth there.

Dataquest

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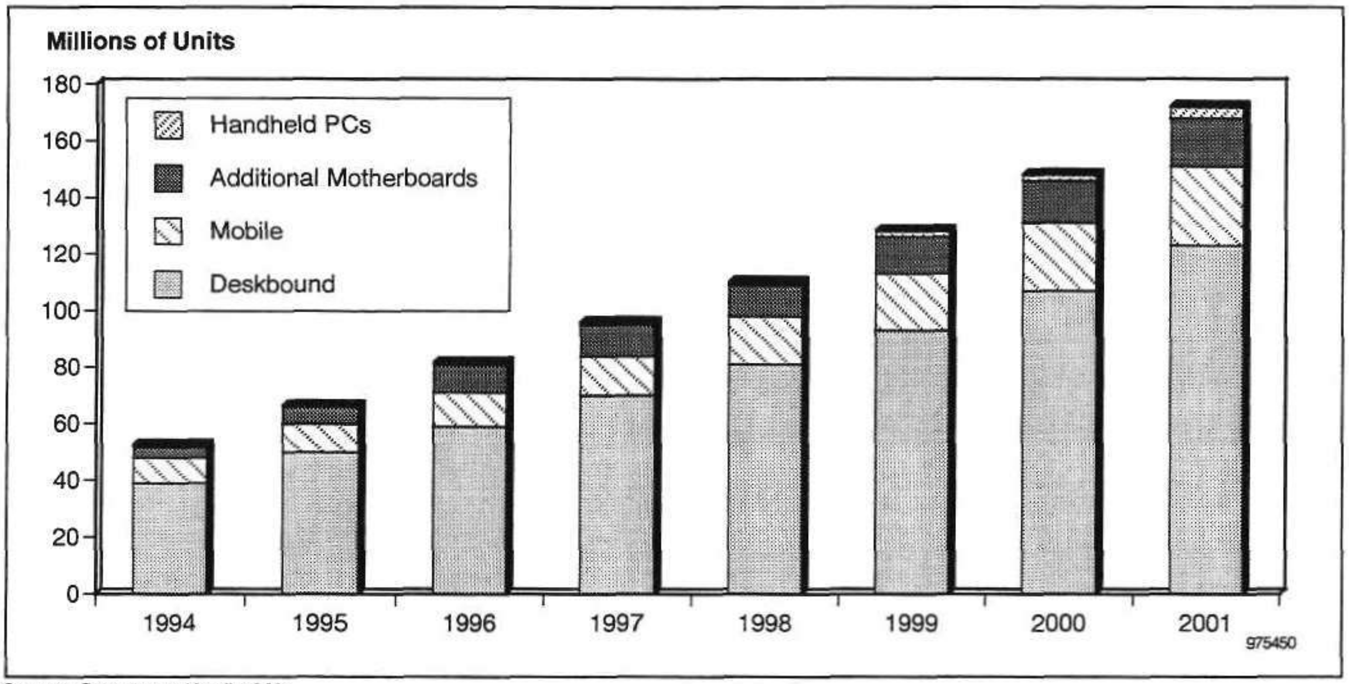
Figure 1
PC Unit Shipment Forecast, 1994 to 2001



Source: Dataquest (April 1997)

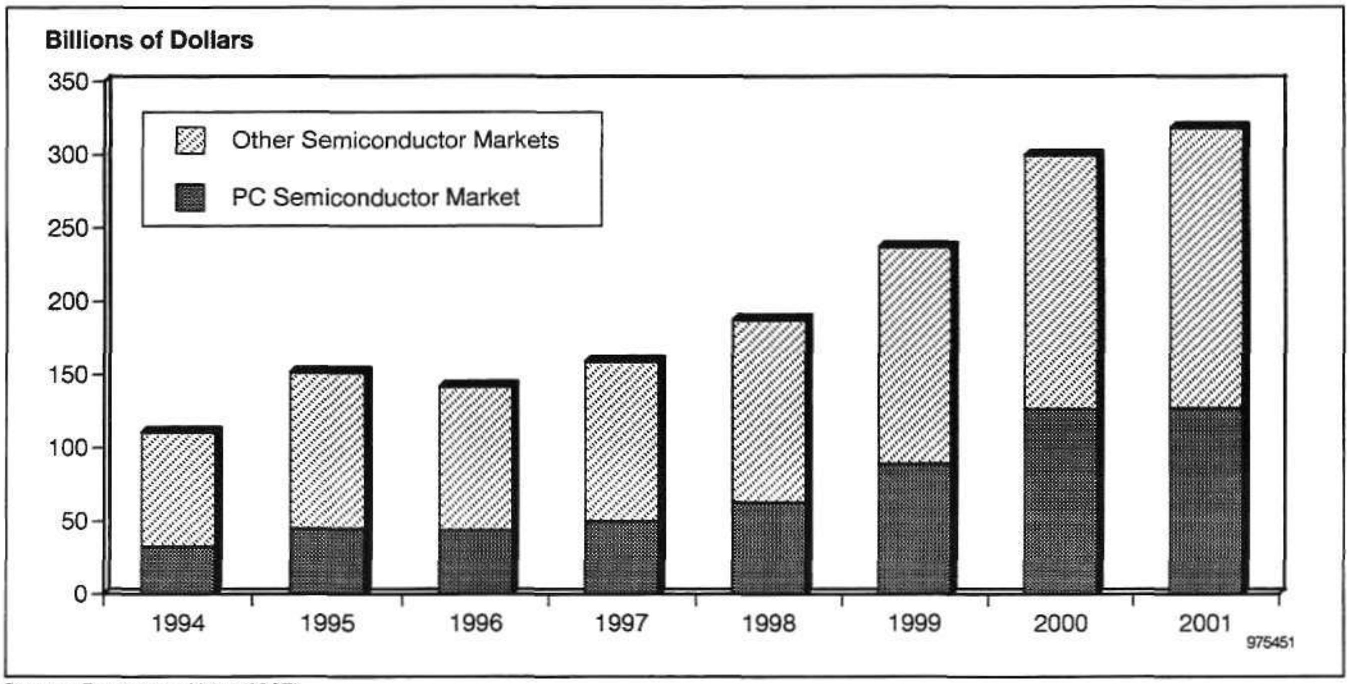
Figure 2 and Table 1 show the overall PC semiconductor revenue forecast and compare it with the total semiconductor revenue forecast. PCs continue to be a major driver of semiconductor market growth. The road is not without some bumps, however. PC semiconductor revenue fell almost 3 percent from 1995 to 1996 because of the combined affect of high inventory and volatile pricing and a volatile pricing environment for memory. The outlook for 1997 is growth in the low double digits, specifically 13.8 percent. This growth for 1997 comes in the midst of a price-competitive market for many key PC semiconductor products, including graphics chips, audio chips, communication ICs, and memory. The growth rate will pick up sharply in 1998 and top 40 percent per year in both 1999 and 2000. The rate is expected to be essentially flat after the year 2000 because of another cycle of oversupply, but that oversupply will not be as severe a supply situation as in 1996. PC semiconductor revenue is forecast to grow faster than the overall semiconductor market. Several major trends are responsible for this, including the following five key points.

- PC shipments are forecast to grow at a compound annual growth rate of 16.2 percent from 1996 to 2001. So as PC shipments are growing, spending on semiconductors is also growing.
- Spending on semiconductors per PC will increase at about a 6 percent compound annual growth rate (CAGR). This increase in semiconductor revenue per PC is based on higher attach rates for some multimedia and communications ICs, as well as microprocessor and memory pricing dynamics.

- The DRAM cycle continues as Dataquest sees the supply/demand imbalance changing to create a balanced market late this year and through 1998, leading to a supply shortage in 1999 to 2000.
- Microprocessor average selling prices (ASPs) continue to increase based on Intel's pricing model and that company's dominance in unit shipments.
- PC multimedia chip markets will benefit from higher attach rates for audio and communications chips as well as changes in the PC graphics market.

The highly competitive PC multimedia chip market will see some consolidation as many current vendors fail or simply exit the market over the next 12 to 18 months. This consolidation will lead to a more stable pricing environment for 1998 to 2000.

Figure 2
PC Semiconductor Revenue, 1994 to 2001



Source: Dataquest (June 1997)

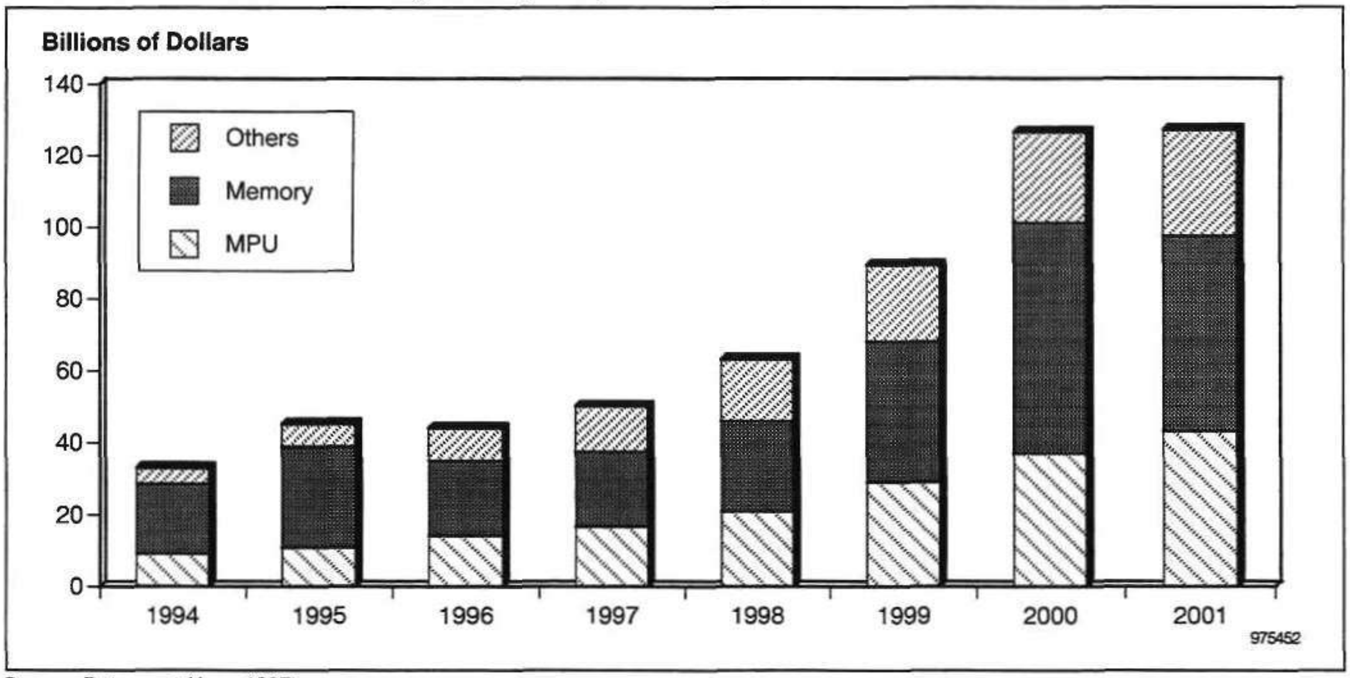
Table 1
PC Semiconductor Revenue, 1994 to 2001 (Billions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
PC Semiconductor Market*	33.0	45.2	44.0	50.1	63.1	89.3	126.4	127.1	23.6
Year-to-Year Growth (%)	-	36.9	-2.7	13.8	26.0	41.5	41.6	0.5	-
Other Semiconductor Markets	77.5	106.1	97.7	108.7	124.0	147.4	173.0	191.2	14.4
Total Semiconductor Market	**110.5**	**151.3**	**141.7**	**158.8**	**187.1**	**236.7**	**299.4**	**318.3**	**17.6**

*Includes semiconductor content of all PC categories: deskbound, mobile, handheld, and additional motherboards
Source: Dataquest (June 1997)

Figure 3 and Table 2 show some additional detail of this forecast. Table 2 includes the PC semiconductor revenue line from the previous table but adds breakouts for microprocessors and memory, showing the dramatic effect of supply and demand balance on memory pricing. Everyone is familiar with the effect that DRAM pricing has had on semiconductor revenue over the past 18 months. Memory revenue for PC applications declined from 1995 to 1996, while megabytes per system increased more than 50 percent. Dataquest expects another 50 percent increase in megabytes per system for 1997 over 1996, but we expect revenue to be essentially flat. Short supply of synchronous DRAM (SDRAM) later this year could affect overall price-per-megabyte and provide some upside to the $20.7 billion forecast. DRAM pricing will drive tremendous revenue growth, well over 50 percent, for this segment in 1998 and 1999. Dataquest expects megabytes per system to continue increasing through those years despite tighter pricing for main memory products.

Figure 3
PC Semiconductor Consumption by Major Category, 1994 to 2001



Source: Dataquest (June 1997)

Table 2
PC Semiconductor Consumption by Major Category, 1994 to 2001 (Billions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Microprocessor	9.3	11.0	14.2	16.8	20.9	29.1	37.0	43.2	25.0
Memory	19.4	28.1	20.9	20.7	25.1	39.1	64.2	54.5	21.1
Others	4.3	6.1	8.9	12.6	17.0	21.1	25.2	29.4	26.9
Total	**33.0**	**45.2**	**44.0**	**50.1**	**63.1**	**89.3**	**126.4**	**127.1**	**23.6**

Source: Dataquest (June 1997)

In the microprocessor market, which will be discussed in a later section, rising ASPs coupled with rising unit shipments provide a regular pattern of revenue growth.

Other areas of semiconductor content growth include all of the multimedia ICs, including communications, power regulation, DC-to-DC conversion, and input/output phases, such as Universal Serial Bus (USB) and IEEE 1394. Multimedia IC revenue growth in the short term is driven by higher attach rates for audio, modem, and network controllers. Longer-term growth is tied to expected price stability coupled with a host of technology transitions. Some of the key technology transitions are:

- For microprocessors, the movement from Pentium- to Pentium II-class processors
- For PC graphics, the change from 2-D plus video controllers to 3-D graphics acceleration
- For PC audio, the movement to PCI from ISA as well as the rise of AC-97-style implementations, the growth of wave table, and the prospects for wave guide audio
- For modems, the transition to 56-Kbps operation, which will greatly extend the life of the analog modem market
- For main memory, the movement from extended data out (EDO) DRAM to SDRAM
- For graphics memory, the move is also from EDO but to SGRAM instead of SDRAM. There is significant growth opportunity for embedded memory or integrated memory products in the graphics market, particularly on the mobile side.
- For networking, the transition from 10-Mbps Ethernet to the 10/100 combinations, as well as single-chip full 100-Mbps products

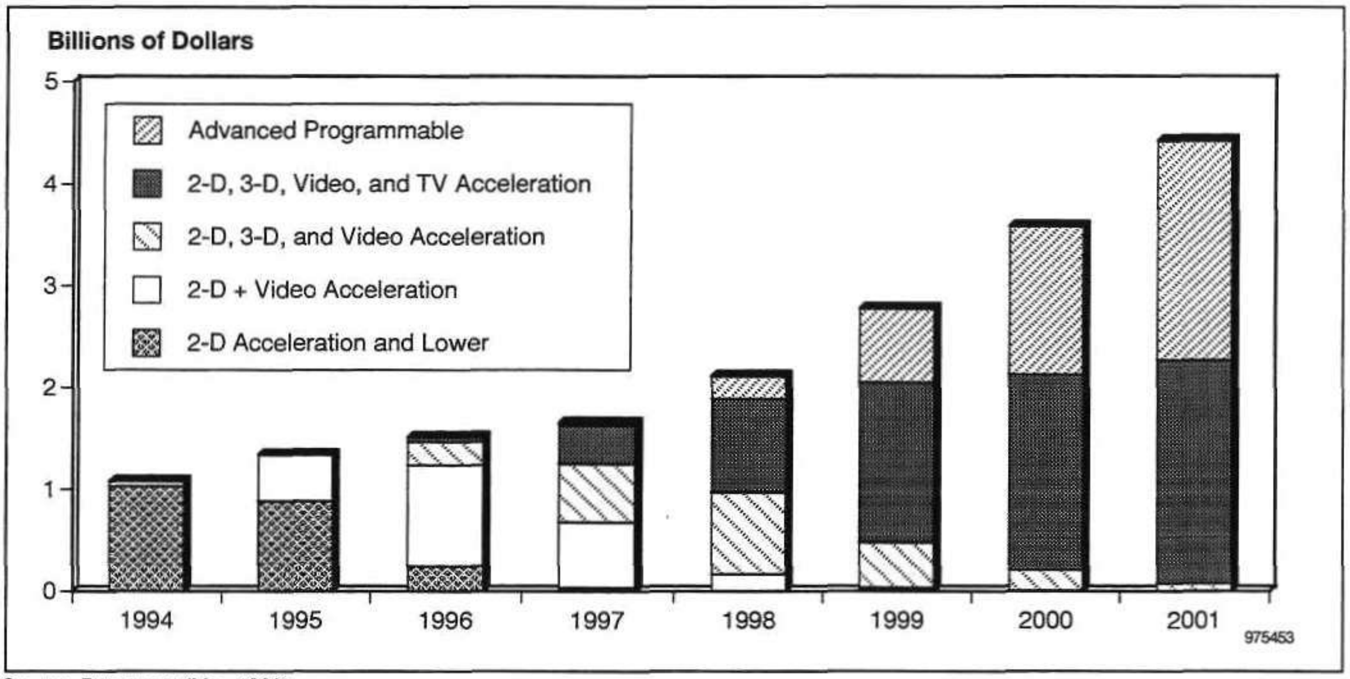
PC Graphics Controllers

Figure 4 and Table 3 show the PC graphics controller forecast. The PC graphics controller market finished 1996 at over $1.5 billion, up 13.5 percent, despite significant price pressure on 2-D-plus-video products.

3-D products from S3 Inc. and ATI Technologies Inc. contributed significantly to the revenue growth because they offset some of the price erosion in the 2-D-plus-video segment. Both of those vendors realized higher margins on their 3-D products because of limited competition in that segment last year.

That situation has changed, however, and 1997 is positioned as another year of declining ASPs because the competition has moved to the 3-D segment. All major desktop graphic vendors have 3-D products today. And everyone is fighting for those sockets. Competition is getting fiercer as the last rounds of Christmas design-wins are being finalized. Dataquest believes that most decisions about motherboard graphics chips are made by the middle of May, and decisions about board-level graphics products are being finalized now. At this time next year, following the 1998 design-win cycle, we expect some vendors to leave the market either voluntarily or through competitive failure.

Figure 4
PC Graphics Controller Forecast, 1994 to 2001



Source: Dataquest (May 1997)

Table 3
PC Graphics Controller Forecast, 1994 to 2001 (Billions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Total	1.1	1.3	1.5	1.7	2.1	2.8	3.6	4.4	23.8
Year-to-Year Growth	-	24.0	13.5	9.0	27.2	31.6	28.7	23.6	-

Source: Dataquest (May 1997)

Two vendors in recent weeks have officially bowed out. S-MOS Systems Inc. and Brooktree Corporation, which have not been active, strong players recently, featured the PIX 3-D accelerator and the MediaStream combined graphics and video products, respectively. Dataquest expects to see similar announcements from other vendors because this market is simply too crowded. It cannot sustain all of the vendors targeting 3-D graphics for PCs.

Following this period of intense competition, Dataquest believes that pricing will firm, and a transition to more advanced graphic chips will cause ASPs to rise. On the mobile graphics side, integrated memory will cause ASPs to rise rather quickly. The forecast shows a rapid penetration of integrated memory into the mobile market, with 80 percent of unit shipments by 2001 featuring integrated frame buffers. This does show up as revenue growth in the graphics market, because the graphics vendor will get high ASPs from that added value. Of course, this will limit the growth of discrete memory ICs for mobile PC graphics as some of that memory is integrated.

A portion of the ASP growth will come at the cost of discrete memory revenue. Deskbound and mobile graphics chips will all get 3-D features in that time, as well as TV display features, particularly flicker filters and TV output. The long-term outlook for the graphics controller market also includes some products that Dataquest has labeled "advanced programmable chips" for this forecast. These advanced programmable chips will look quite similar to what are called media processors today. These chips will most likely have a programmable core and handle concurrent functions in a manner similar to today's media processors.

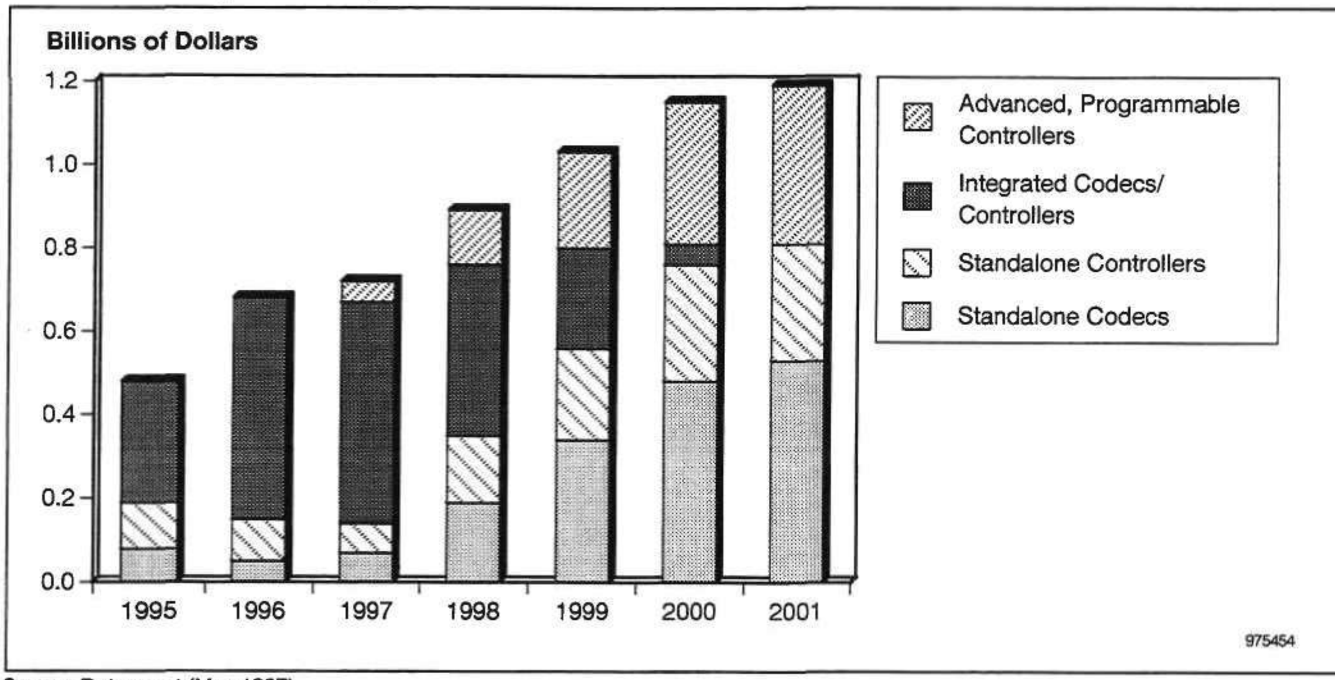
This is both good news and bad news for current media processor vendors—good news because they are ahead of their time, but bad news because the established graphics vendors are likely to control this market and retain ownership of those sockets during this transition. The transition is not likely to be night and day, but will be slower—evolutionary rather than revolutionary. At this point, the current graphics vendors are strong, particularly the four market share leaders. The most notable media processor design-wins today are the recent announcements from Gateway 2000 and Micron Technology Inc. Micron announced that it would be using Chromatic Research Inc.'s Mpact chip for DVD add-in card functions. This is good news for the media processor market because it both validates the model and actually gets units out in real user situations. However, the current media processor offerings do not appear to be competing directly with standard graphics chips. This will change over the next couple of years as graphics chips grow into a broader role.

PC Audio Chips

Figure 5 and Table 4 show the PC audio chip forecast. The PC audio chip market has several things in common with the graphics market. Slow growth for 1996 is not one of them, but slow revenue growth for 1997 is.

The PC audio chip market benefited in 1996 from higher attach rates as well as Sound Blaster audio becoming essentially a standard feature for most mobile PCs. The revenue growth rate for 1996 is very high because the 1996 numbers do include some additional chip value from add-in card shipments that use the same chip-level products as those that vendors Aztech Systems Ltd. and Creative Technology Ltd. sold on the merchant market. We decided to include those unit shipments because the chips used on those boards are identical to the ones sold to other customers and therefore fall into Dataquest's merchant chip definition. Revenue growth for 1997 is forecast to be only 6.4 percent. Price competition has hit the audio chip market quite hard, starting with a slowdown at the end of the fourth quarter and steep price erosion through the first half of this year for single-chip products.

Figure 5
PC Audio Chip Forecast, 1995 to 2001



Source: Dataquest (May 1997)

Table 4
PC Audio Chip Forecast, 1995 to 2001 (Billions of Dollars)

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Total	0.5	0.7	0.7	0.9	1.0	1.2	1.2	11.8
Year-to-Year Growth (%)	-	39.6	6.4	24.2	16.0	11.0	2.9	-

Source: Dataquest (May 1997)

Growth should bounce back to 24 percent in 1998 on the strength of continued increases in attach rates as well as a transition from ISA-based single-chip subsystems to more advanced PCI-based AC-97-type implementations. The new PCI-based products are more focused on audio quality and new features such as positional 3-D sound, wave table synthesis, and even wave guide synthesis. Essentially, until recently, the audio chip market was directed by vendors' efforts to reduce cost and increase integration. This was the race toward the single chip. ESS Technology Inc. led this race and basically built its audio business on it. The market is expected to make a transition now, with less emphasis on lowest price and highest integration and more emphasis on audio quality. Particularly with AC-97 implementation, consumer quality levels of audio are quite possible in PCs. Those quality levels are unlikely with an integrated single-chip product. Several of these products should be considered advanced programmable chips.

The forecast does include a growing market for programmable audio chips. Although similar to the media processor products, these programmable audio chips are really targeting only audio and modem functions. The math-intensive tasks of AC-3 decoding and positional 3-D audio require powerful chips, and several vendors are making their products based on programmable digital signal processor (DSP) cores. Positional 3-D technology is used for virtualizing multispeaker audio, such as AC-3 or ProLogic, using only two speakers for playback. Of course, this does not sound as good as having more speakers, but it is critical for the teeming masses who will not hook more than two speakers to their PCs. Specific PC/TV combination products are likely to be exceptions, as these products are designed for the living room entertainment center rather than the desktop. It seems much more likely that consumers would hook all six speakers of an AC-3 system to their living room PCs than to their PCs in the den.

Following 1998, growth in the PC audio chip market will decelerate as attach rates approach 100 percent. Some of those audio implementations will simply be an AC-97 codec and will use software running on the host microprocessor for the synthesis and control functions. Dataquest believes that, of PCs with audio features, approximately one out of two in the year 2001 will have only a codec rather than both a codec and a separate hardware controller. By the same token, the hardware controllers that are added will be an opportunity for chip vendors to add significant value with higher-end features, such as AC-3, positional 3-D, and other audio enhancements.

Microprocessors

Figure 6 shows the compute microprocessor unit shipment forecast to the year 2001. This is based on Dataquest's PC forecast, workstation forecast, mainframe forecast, and server forecasts of all different flavors and shapes. We get the feedback from our systems groups and that drives a lot of this forecast. In 1996, the compute microprocessor market was 83 million units, with a lot of that, obviously, in PCs. The market will grow to 173 million units in the year 2001. It is difficult to see the gradations between the x86 and everything else because the x86 more or less drowns out everything else, so Figure 6 strips the x86 out of the compute microprocessor market. Figure 7 shows that the rest of the market will grow from 5 million units in 1995 to about 10 million units in 2001.

Figure 8 strips out the PowerPC and leaves just the RISC processors that are used in workstations and servers and the microprocessors that are used in mainframes, two growing markets. That is the good news; the bad news is they are growing from about 1.5 million to 2.5 million units. Of course, margins are better in those markets. However, the volume certainly is not great. Figure 9 translates those units into revenue.

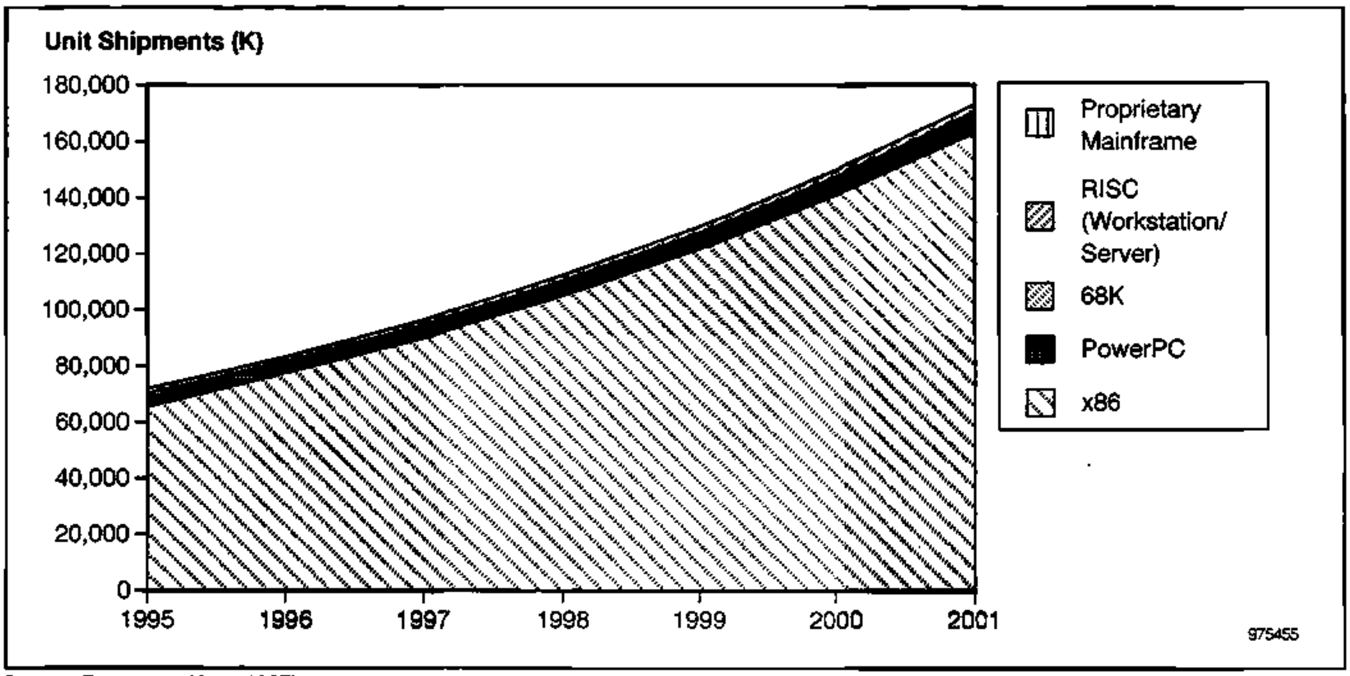
Figure 9 shows that the compute x86 market, which was about $15 billion in 1996 will be growing to $30 billion in the year 2000 and $43 billion in the year 2002. This is why there is so much activity in the x86 clone market.

Figure 9 makes it clear that—as Willy Sutton answered when asked why he robbed banks—that is where the money is. Companies that want to make money making microprocessors must be in the x86 segment. In terms of unit shipments, the compute x86 market will grow from about 77 million units in 1996 to about 140 million units in the year 2000.

This is largely driven by increasing PC unit demand. Clearly the fact that the x86 is moving into the server environment also helps, but that is a very minor factor, especially in terms of units. It is slightly more of a factor in terms of revenue because of some of the strategies Intel is now using to raise the average price of microprocessors in servers. Dataquest has been arguing for the last six months and will continue to argue that the x86 clones—from Advanced Micro Devices Inc., Cyrix Corporation, Centaur Technology Inc., Integrated Device Technology Inc., and others that will appear over the next year or two—will be able to take approximately 25 percent of the units in this market. Figure 10 shows compute x86 shipments.

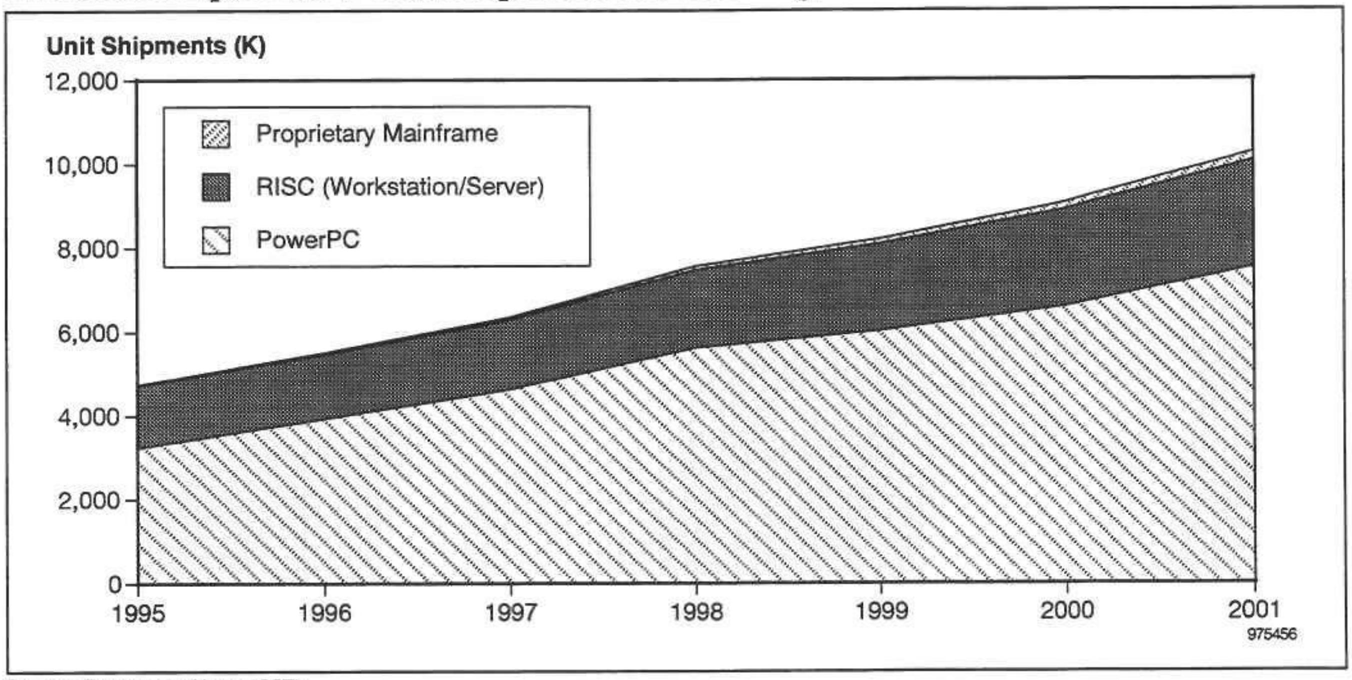
By the year 2000, x86 clones will gain 25 percent share (see Figure 11), which means that they will have approximately 41 million units by the year 2000. That pales compared to what Intel will be doing, but it is still a healthy business. And one of the things that makes it healthy is that the average selling price of x86s continues to increase (see Figure 12). It was slightly over $200 in 1996 and will grow to approximately $225 by 2002.

Figure 6
Compute MPU Unit Shipments to Double by 2001



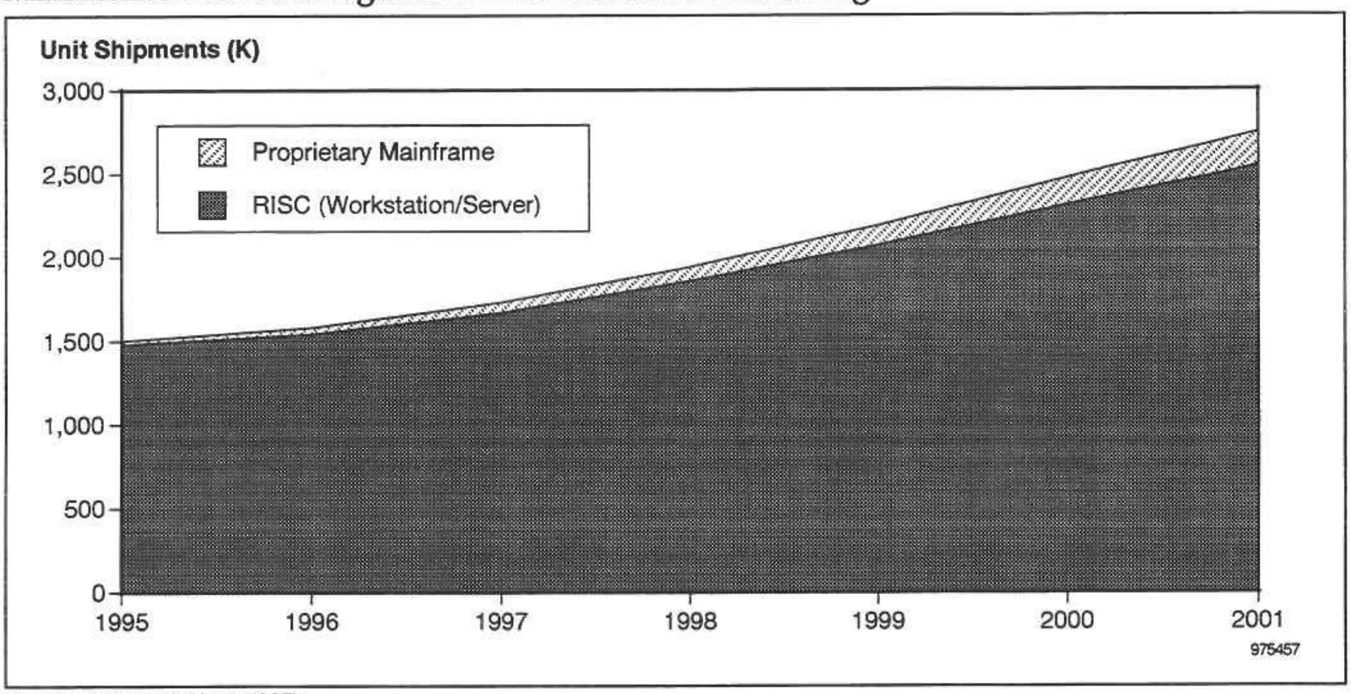
Source: Dataquest (June 1997)

Figure 7
Non-x86 Compute MPU Unit Shipments Are Growing, Too



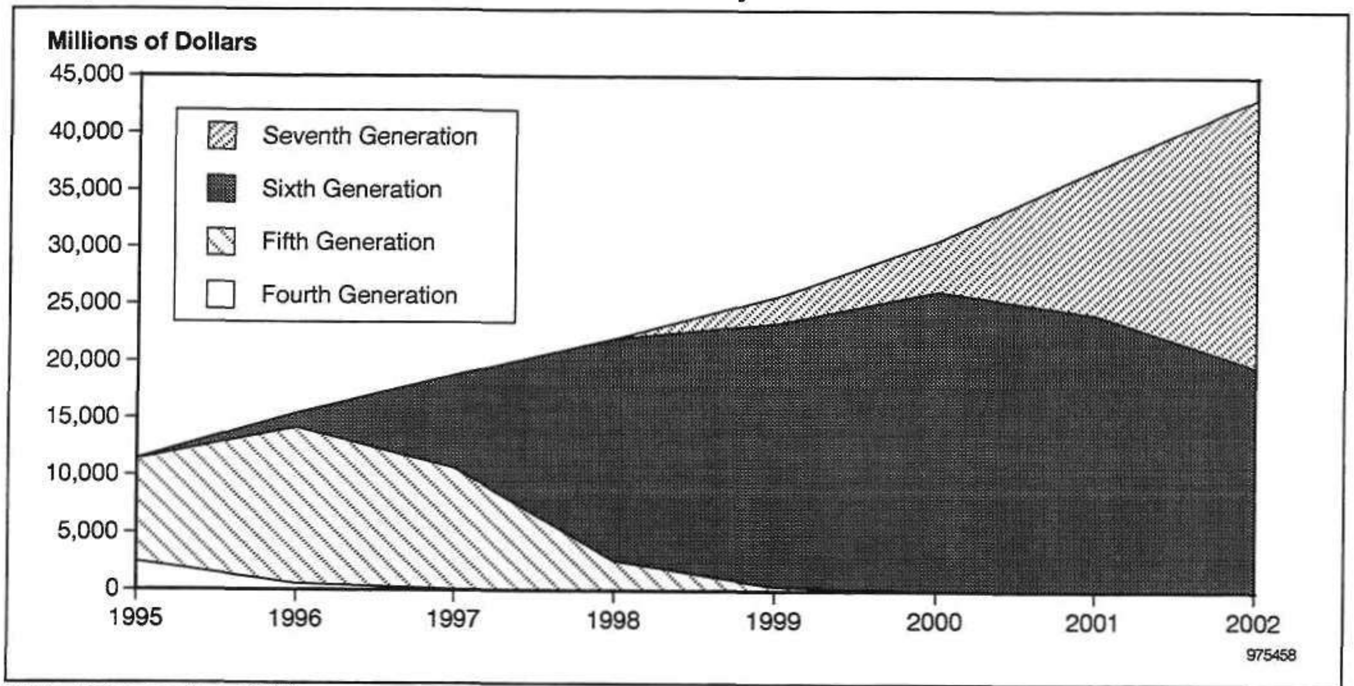
Source: Dataquest (June 1997)

Figure 8
Mainframe and Midrange MPU Units Are Also Increasing



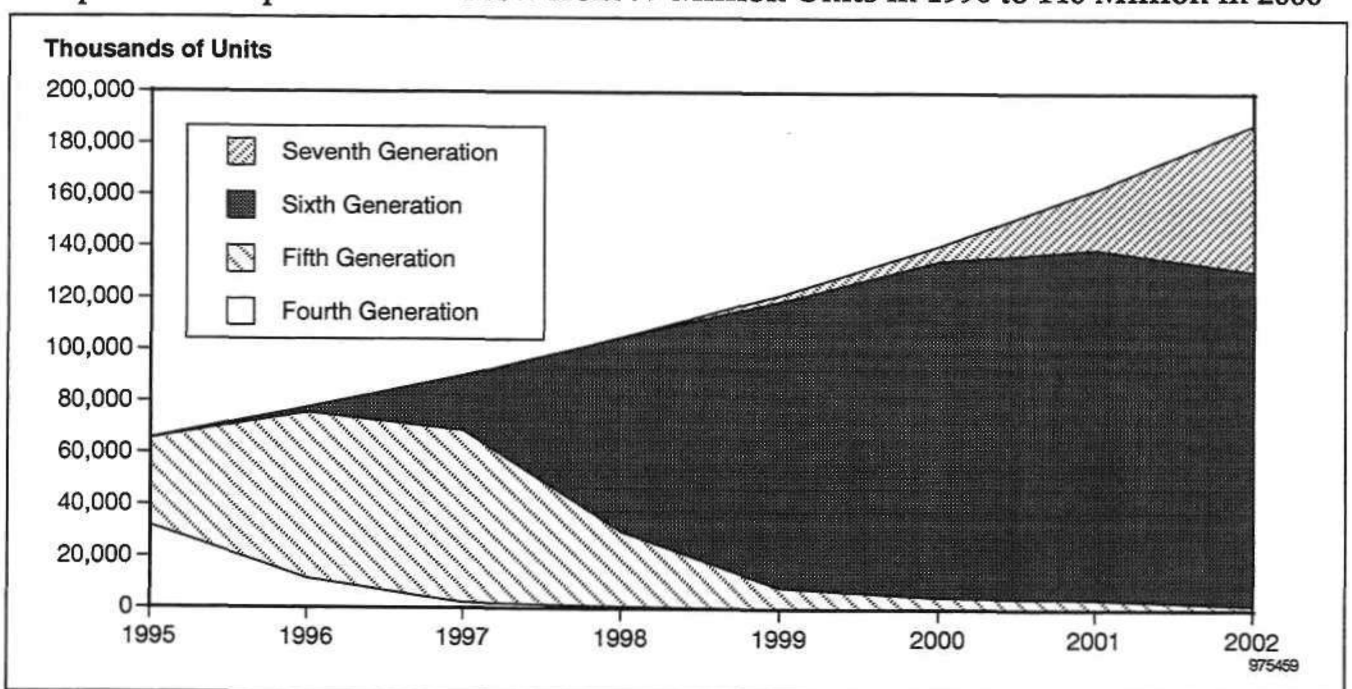
Source: Dataquest (June 1997)

Figure 9
Compute x86 Revenue to Double to $30 Billion by 2000



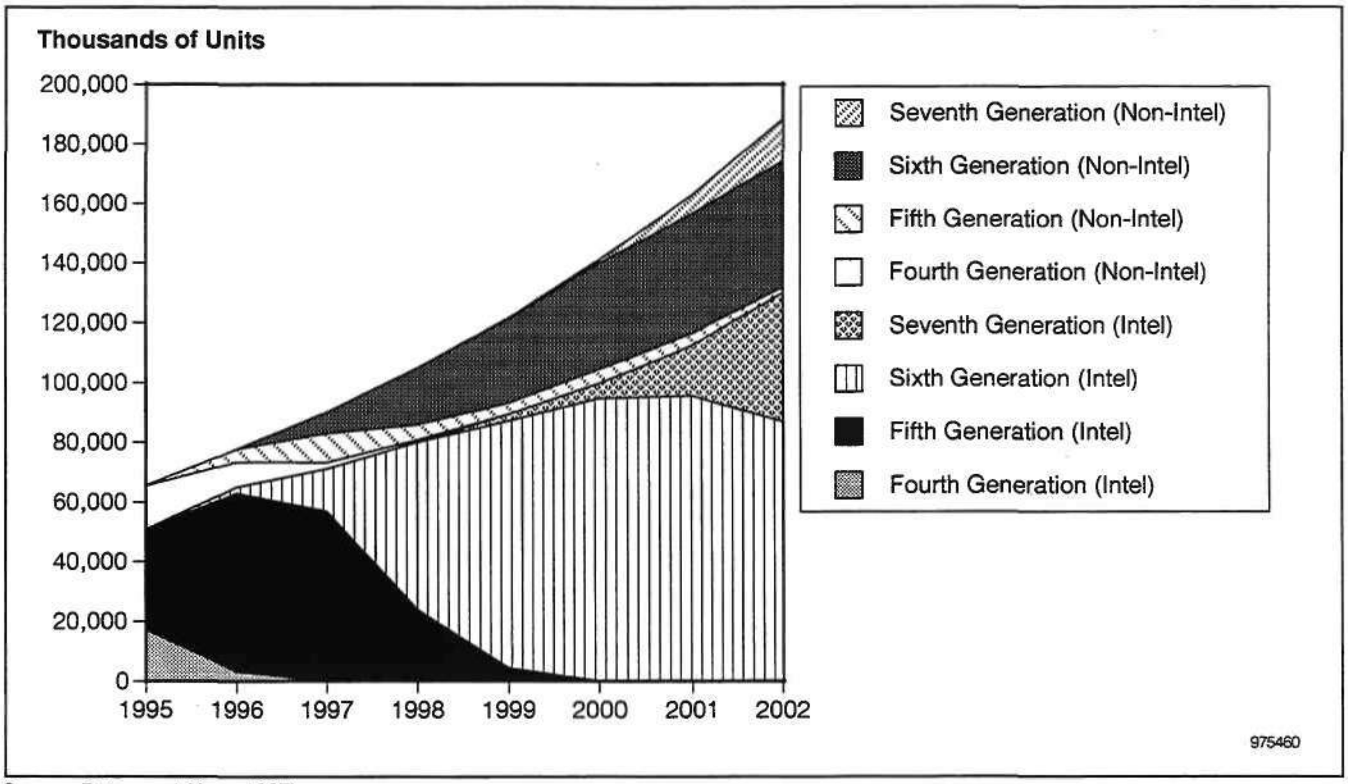
Source: Dataquest (June 1997)

Figure 10
Compute x86 Shipments Will Grow from 77 Million Units in 1996 to 140 Million in 2000



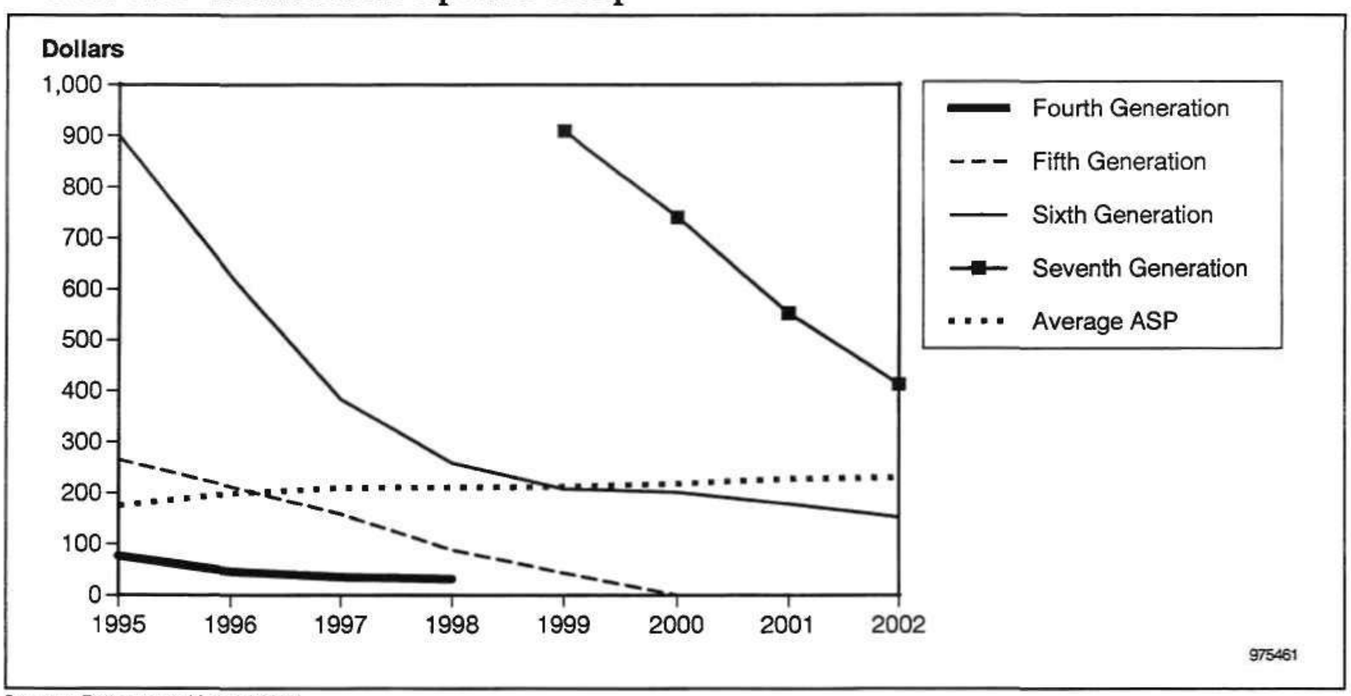
Source: Dataquest (June 1997)

Figure 11
x86 Clones Gain 25 Percent Share by Year 2000



Source: Dataquest (June 1997)

Figure 12
The x86 ASP Continues Its Upward Creep



Source: Dataquest (June 1997)

Driving the upward creep is increased added value in the microprocessor, for example, taking on the sound functions, taking on more of the core logic functions, as in the Cyrix MediaGX, and so on, as well as increasing performance. The amazing thing is that even though the prices continue to come down on individual products, the average goes up overall as consumers shift from one of those curves to the next. Companies like Intel are very skillful at managing the mix and trying to induce people to move from the dying fourth-generation curve to the Pentium and then to the sixth generation and the seventh generation. As long as vendors can provide more power and as long as software developers can provide applications to use that power in ways that are compelling, this story continues. If either of those struts should fall out—that is, if Intel cannot figure out how to make the processor go faster, or if Microsoft and the application companies cannot figure out how to make it go slower—then the industry will be in a lot of trouble.

Even though the clones will have a decided presence, they will not be able to challenge Intel on pricing parity, at least not in the near term (see Figure 13). Cyrix gave Dataquest a nice data point on that last year. The company tried it, and it was a dismal failure as an experiment; Cyrix obviously learned a lesson. This year, when it introduced its M2 or 6x86MX product, it came in aggressively below Intel and AMD and even IBM, which seems to show that the company is really pushing hard on value.

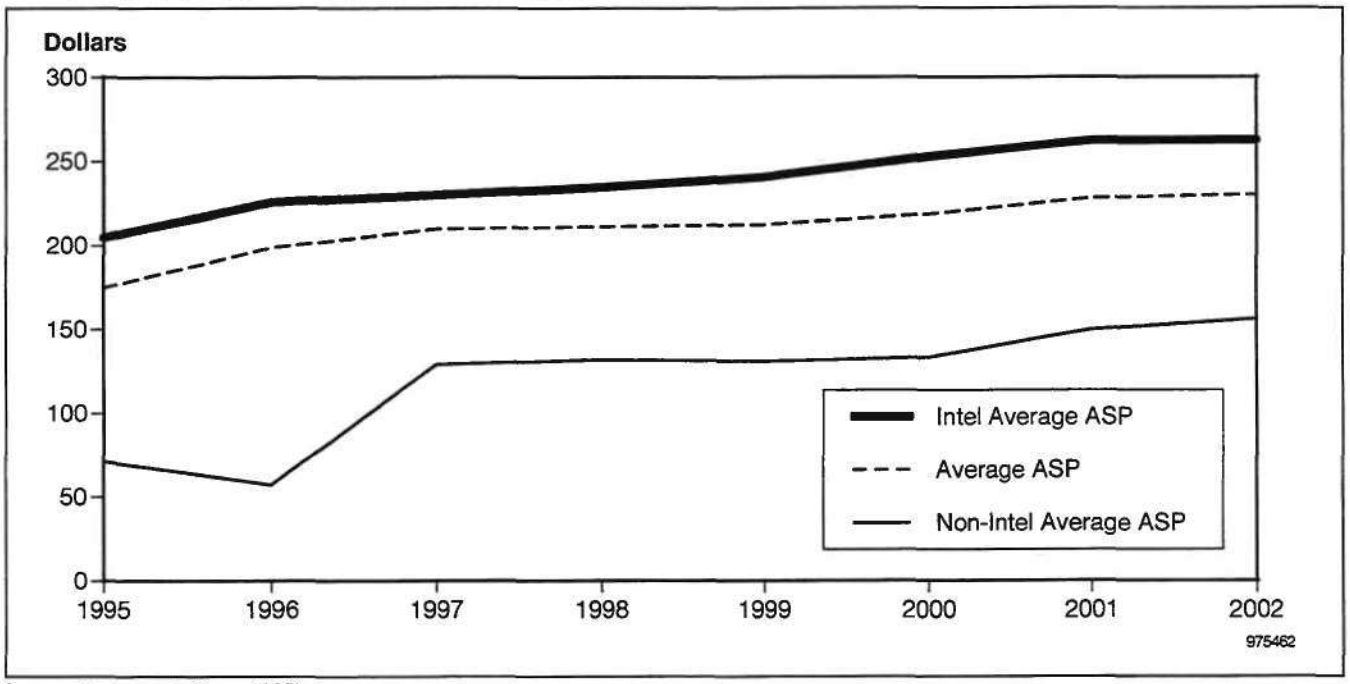
Overall, Dataquest would expect to see the clones selling at a 25 percent-to-30 percent discount to Intel over the longer haul. That might narrow a bit if they gain additional respectability and the "Intel Inside" campaign proves to be weaker than expected. Companies like Digital Equipment Corporation that are pricing products that have Intel at one point and AMD with identical performance at another point are going to provide a really useful piece of data. And Dataquest thanks them for running that experiment.

The quarterly transition from current Pentium-generation to sixth-generation products is well under way (see Figure 14). Dataquest expects that, by the fourth quarter of this year, the mix of sixth-generation parts and fifth-generation parts will be approximately 50/50.

Intel's mix, as shown in this figure, does not mean that Intel will be shipping half Pentium II and half Pentium products, but that the Pentium II is categorized by Dataquest as a sixth-generation part, as is the Pentium Pro. But Dataquest also rolls the M2 or 6x86MX and AMD's K6 into the sixth-generation part, and that clearly swells that ratio by quite a bit because both of those vendors are committed to moving out of their Pentium-class products and into the K6 and M2 completely by the end of the year.

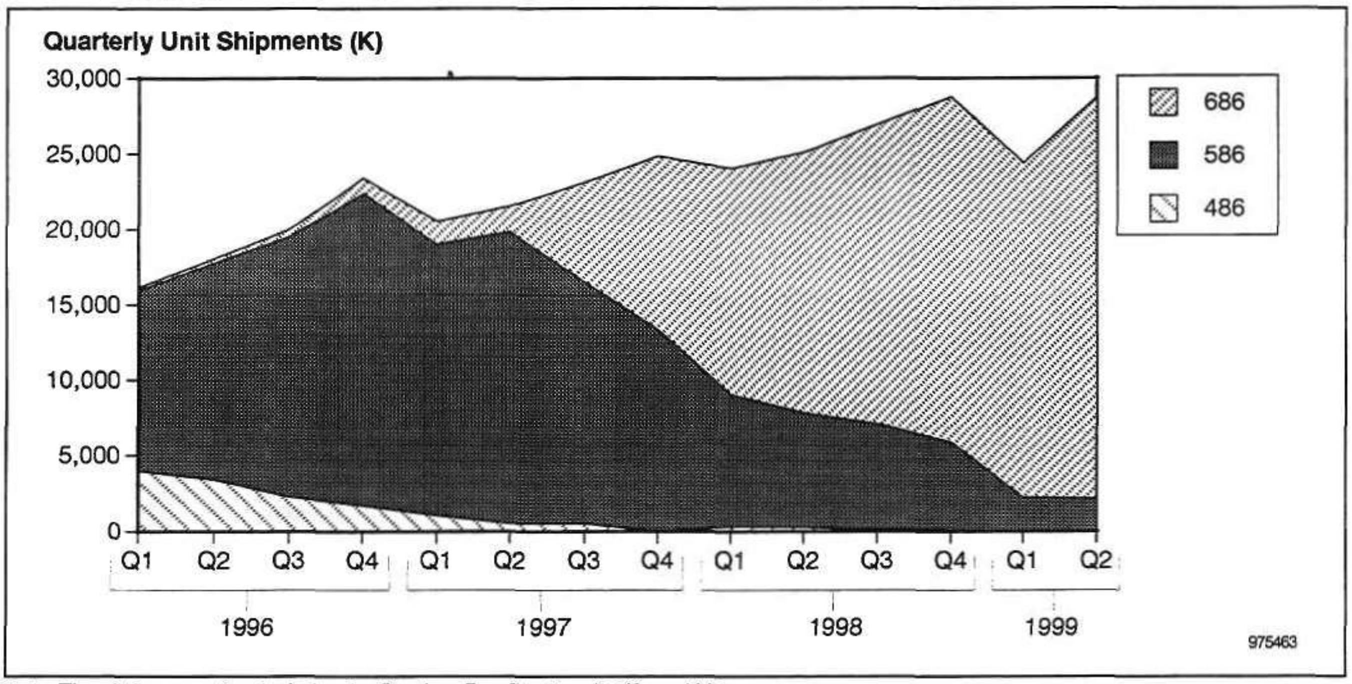
Shifting gears from looking ahead five years to looking back one year, the compute microprocessor market, according to the figures that Dataquest has been tallying over the last few months, exceeded $16.5 billion in 1996.

Figure 13
"Intel Inside" Continues to Command a Premium Price



Source: Dataquest (June 1997)

Figure 14
Sixth-Generation x86 Will Reach 50 Percent of Units by Fourth Quarter 1997



Note: The sixth generation includes the Pentium Pro, Pentium II, K6, and M2.
Source: Dataquest (June 1997)

Intel accounted for about $14 billion of the $16.5 billion of the overall (see Figure 15), so everybody else was fighting for about $2 billion in this market.

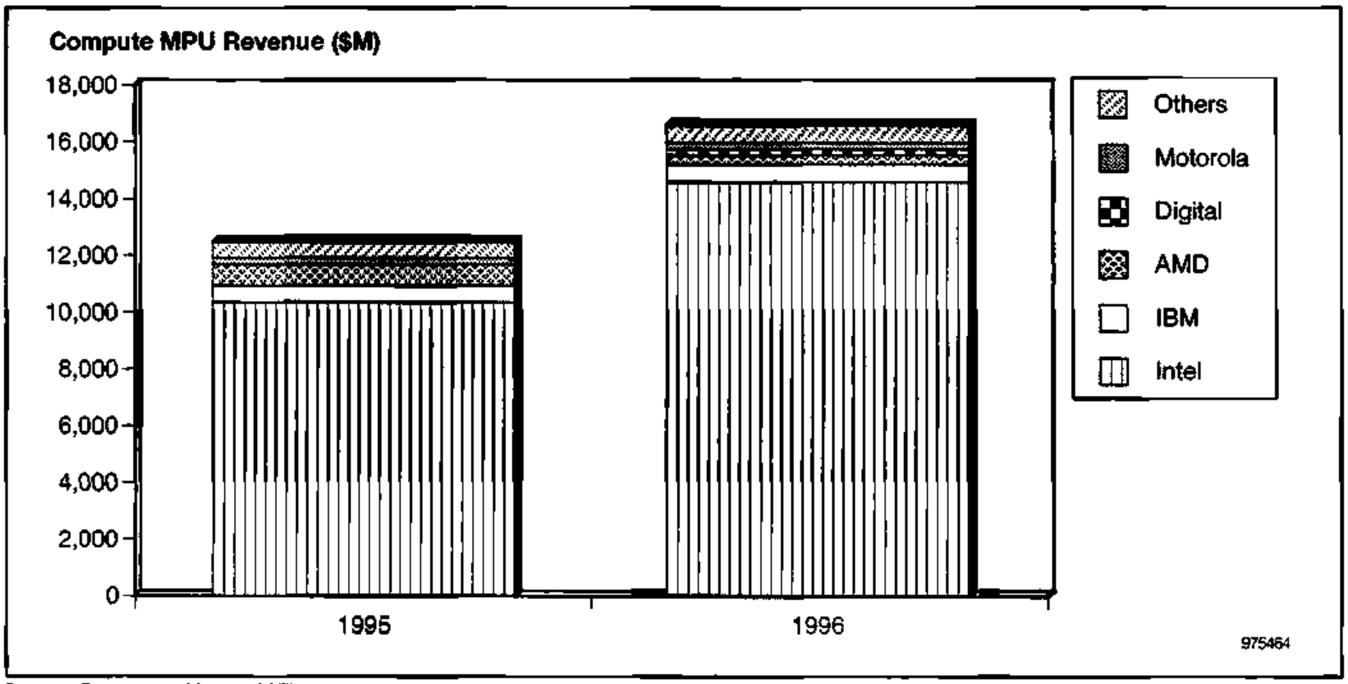
And Intel, of course, gained market share. Dataquest estimates that, of all microprocessors used in computational applications, including the PowerPC, the Alpha, and obviously the x86s and so on, Intel captured 88 percent of the market as measured in dollars.

This year we expect that Intel that will lose some market share—just a little bit, but when a company has 88 percent market share already (see Figure 16), it's hard to go up from there. In the 32-bit CISC market, which eliminates the PowerPC and all the rest of that, Intel's revenue share was about $15 billion.

In Figure 17, again, Intel dominates. AMD and IBM are also key players in this market, IBM with the Cyrix part and also Cyrix with the Cyrix part. SGS-Thomson is beginning to play in this market. This market, of course, is a bit more narrowly defined than the broader computational microprocessor market, but Intel had 96 percent of it last year (see Figure 18). That is, out of every dollar spent on this class of product, Intel captured $0.96 and the rest of the vendors argued over $0.04.

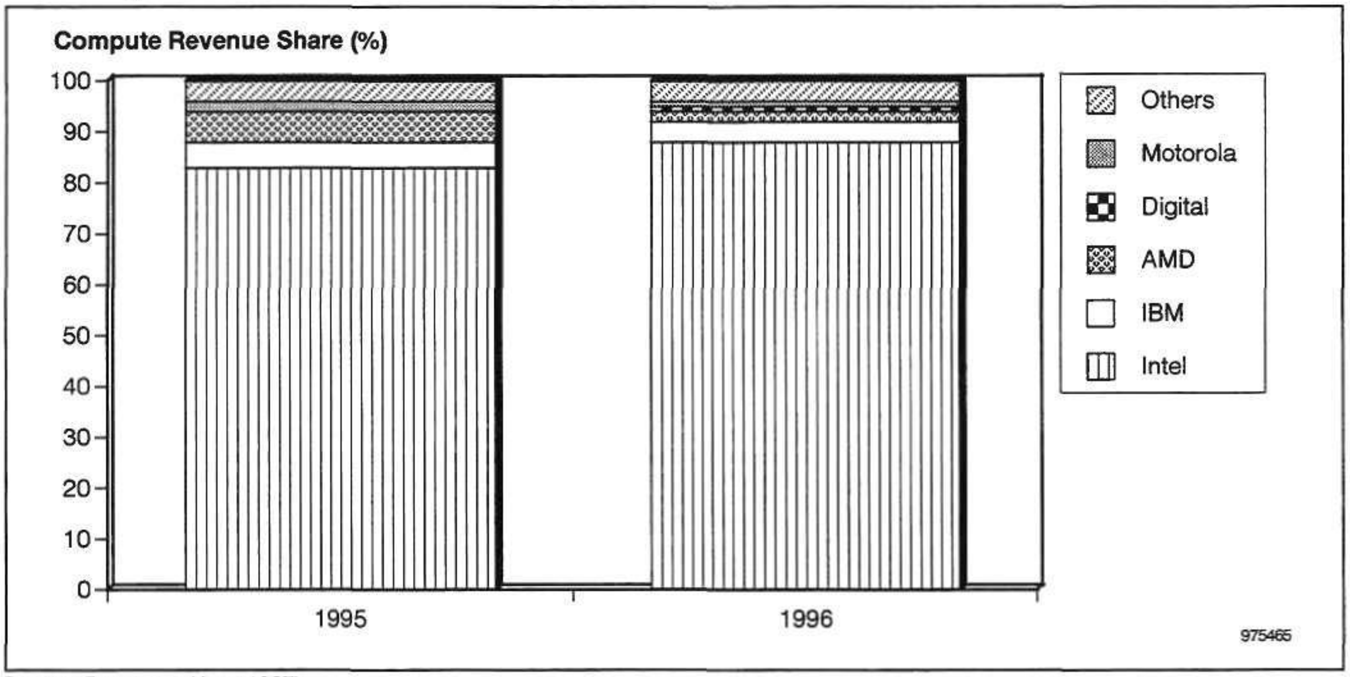
Figure 19 puts the competition in this market into perspective and again emphasizes why the alternative vendors are making such a major effort to get into this market. There is a ton of money to be made by those who can play. Looking at Intel's share of the CISC compute market based on units rather than revenue shows that Intel captured only 84 percent of all the units, and that obviously speaks to the fact that Intel has a higher average selling price than its competitors in this market.

Figure 15
The Compute MPU Market Exceeded $16.5 Billion in 1996



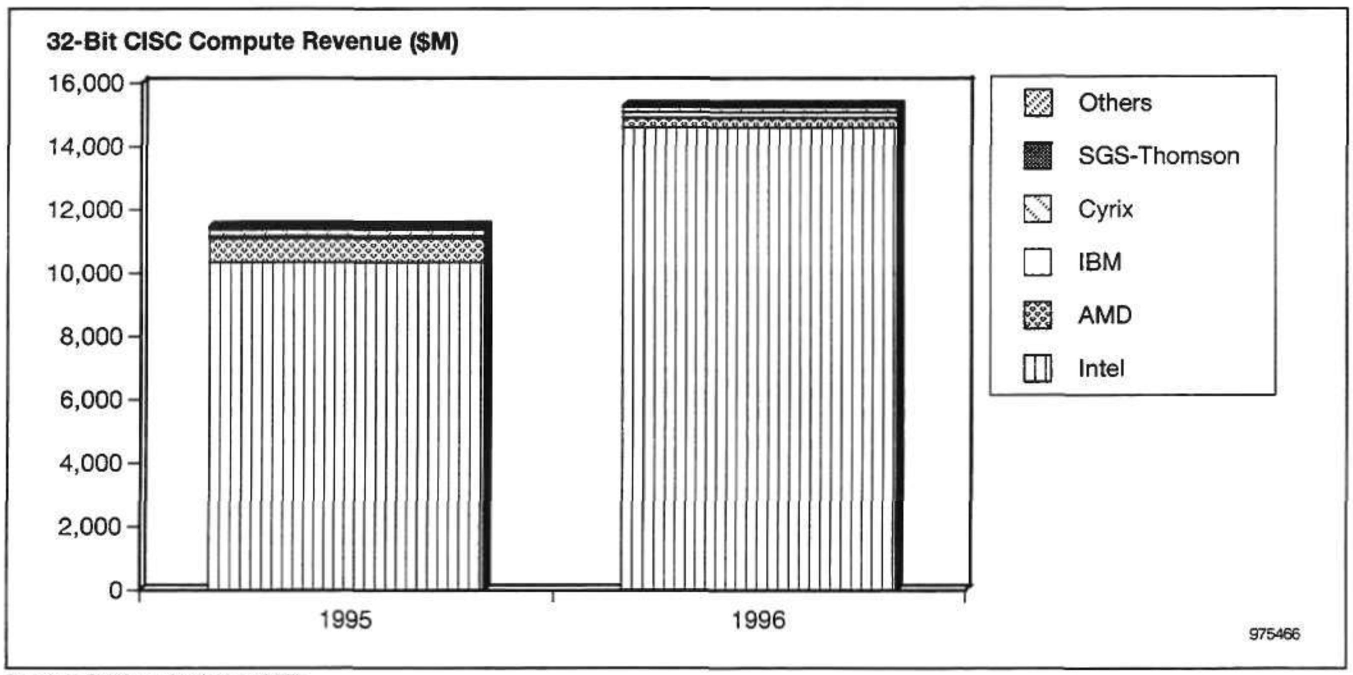
Source: Dataquest (June 1997)

Figure 16
Intel Captured 88 Percent of the Compute MPU Market in 1996



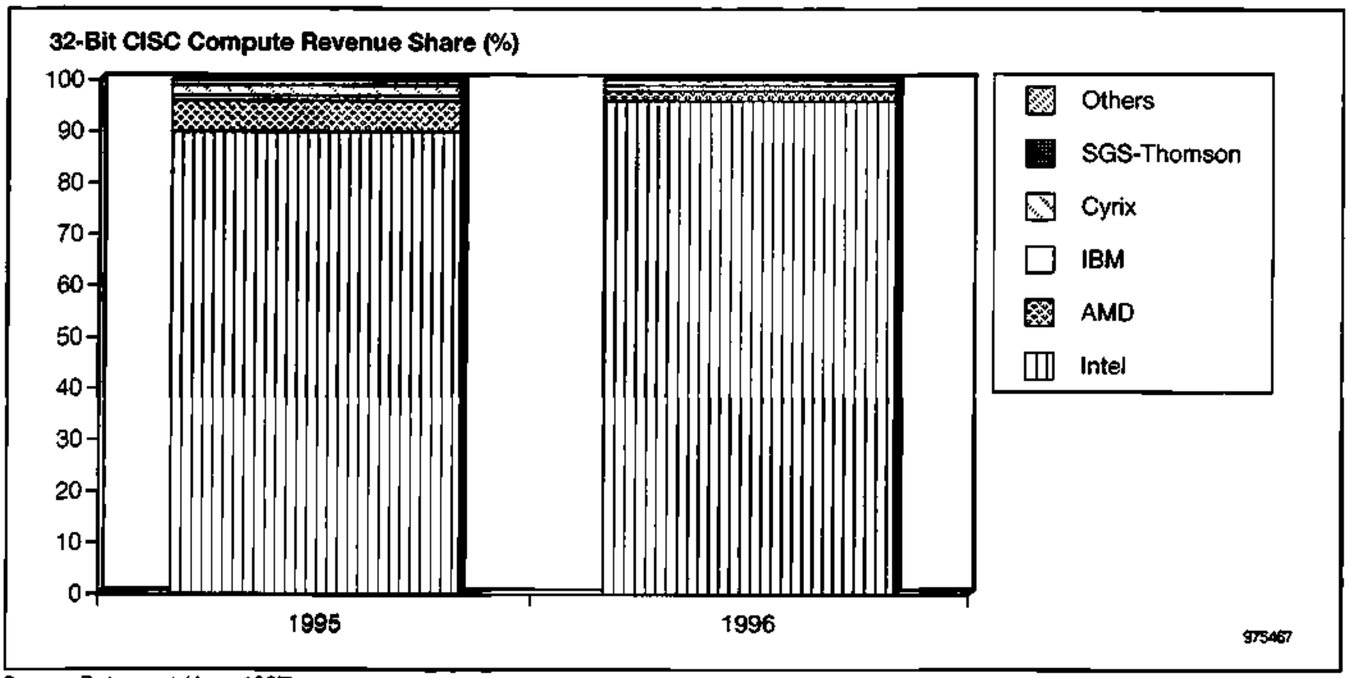
Source: Dataquest (June 1997)

Figure 17
32-Bit CISC Market Exceeded $15 Billion in 1996



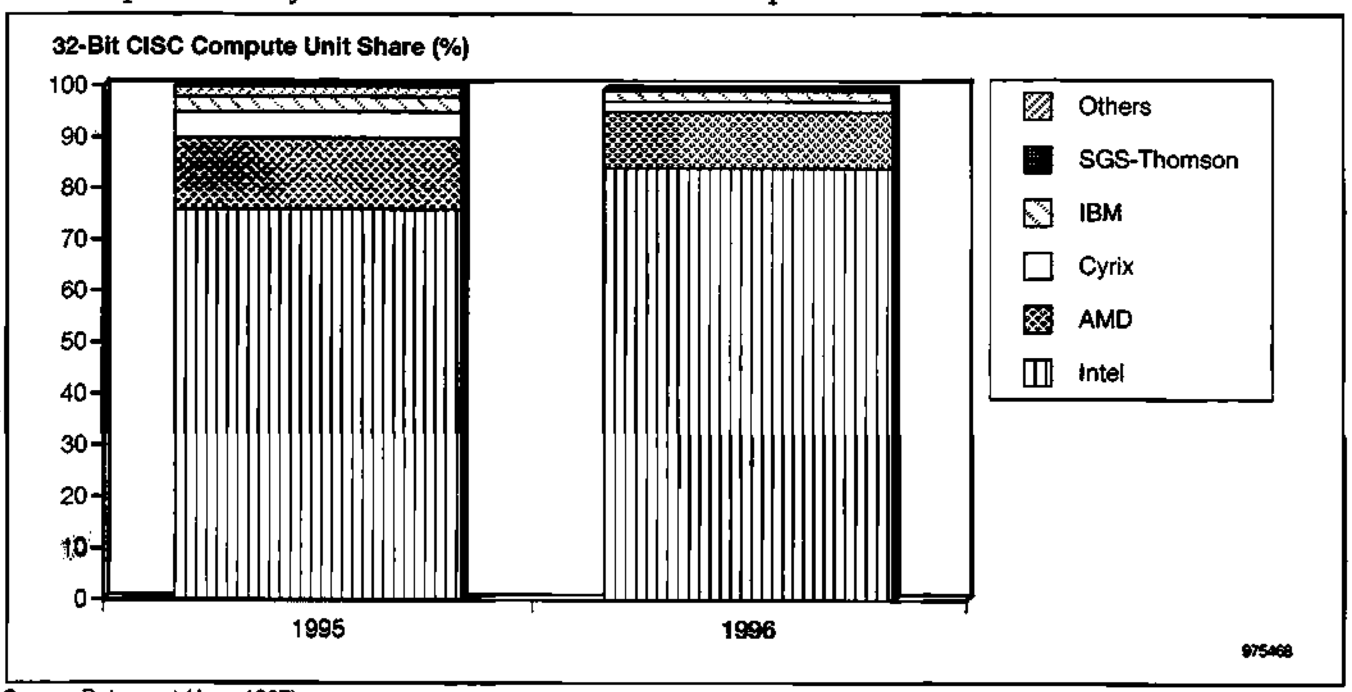
Source: Dataquest (June 1997)

Figure 18
Intel Captured 96 Percent of the 32-Bit CISC Compute Market in 1996



Source: Dataquest (June 1997)

Figure 19
Intel Captured Only 84 Percent of 32-Bit CISC Compute Units



Source: Dataquest (June 1997)

Figure 20 shifts the focus to the RISC market. The 32-bit RISC compute market, which includes the 64-bit RISC market, remains fragmented.

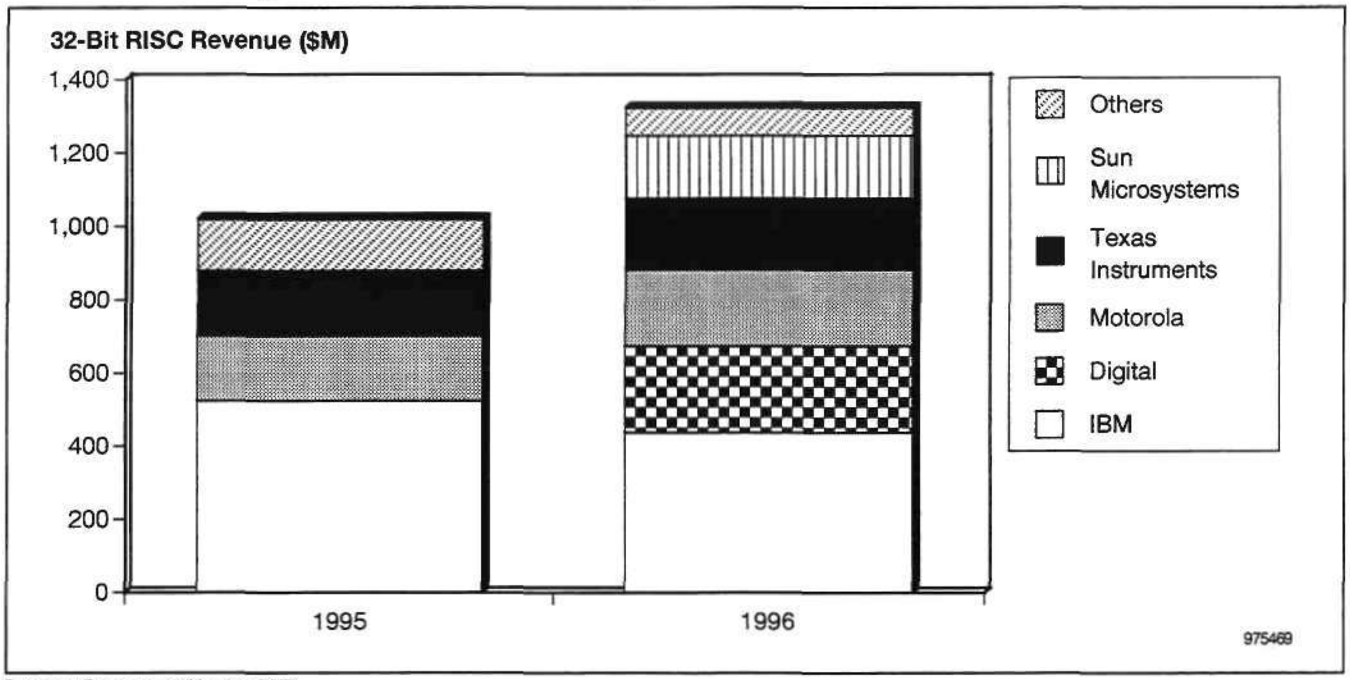
Some of the data in Figure 20 results not from anything specific happening in the market but from the way Dataquest has been tallying numbers. We are changing from counting Sun Microsystems Inc.'s sales of SPARC microprocessors as part of Texas Instruments Inc. and Fujitsu Ltd. revenue to counting it as part of Sun's Microelectronics Unit.

In terms of 32-bit RISC, IBM continues to lead the market (see Figure 21) with about 30 percent of revenue last year, down from about 40 percent the year before, all driven by the PowerPC. And the future of the PowerPC, especially in computational markets, remains somewhat in doubt. Dataquest is waiting to see how Apple Computer Inc. resolves all of its issues before we can really go forward with confidence in that forecast.

Core Logic

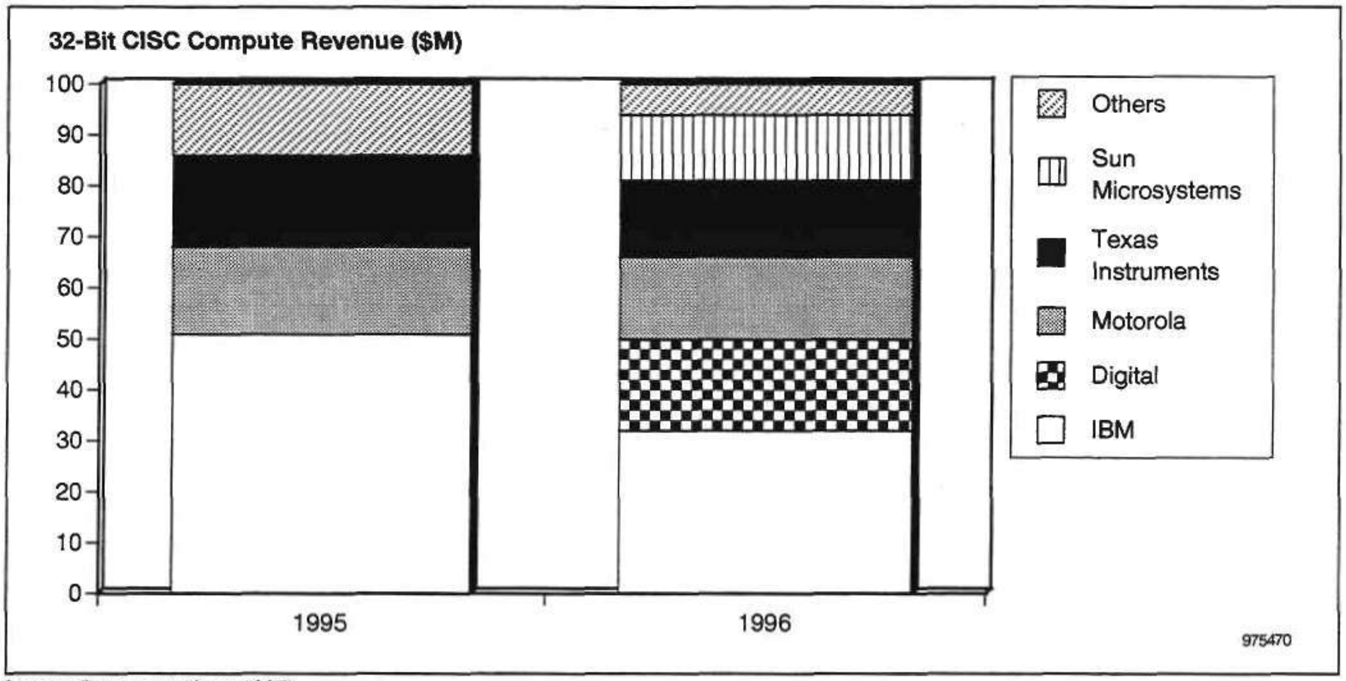
There's a popular myth that Intel now owns the core logic market. That myth is a slight exaggeration. As Figure 22 shows, Intel captured approximately $1 billion of the $1.5 billion core logic market, leaving $0.5 billion for everybody else. And some of the vendors in that market actually grew last year, rather than shrinking or disappearing. In particular, VIA Technologies Inc. and Acer Laboratories grew. OPTi Inc. shrank; United Microelectronics Corporation sold its business to ITE. Both companies saw shrinkage, and VLSI Technology Inc. got out of the market completely, as did Symphony Laboratories (although Symphony was not in the market in a very big way). OPTi tried desperately to grow its laptop or mobile business and in fact added 1.5 million units. Unfortunately, it lost 5.5 million units on the desktop, and that affected its market share.

Figure 20
32-Bit RISC Compute Market Remains Fragmented



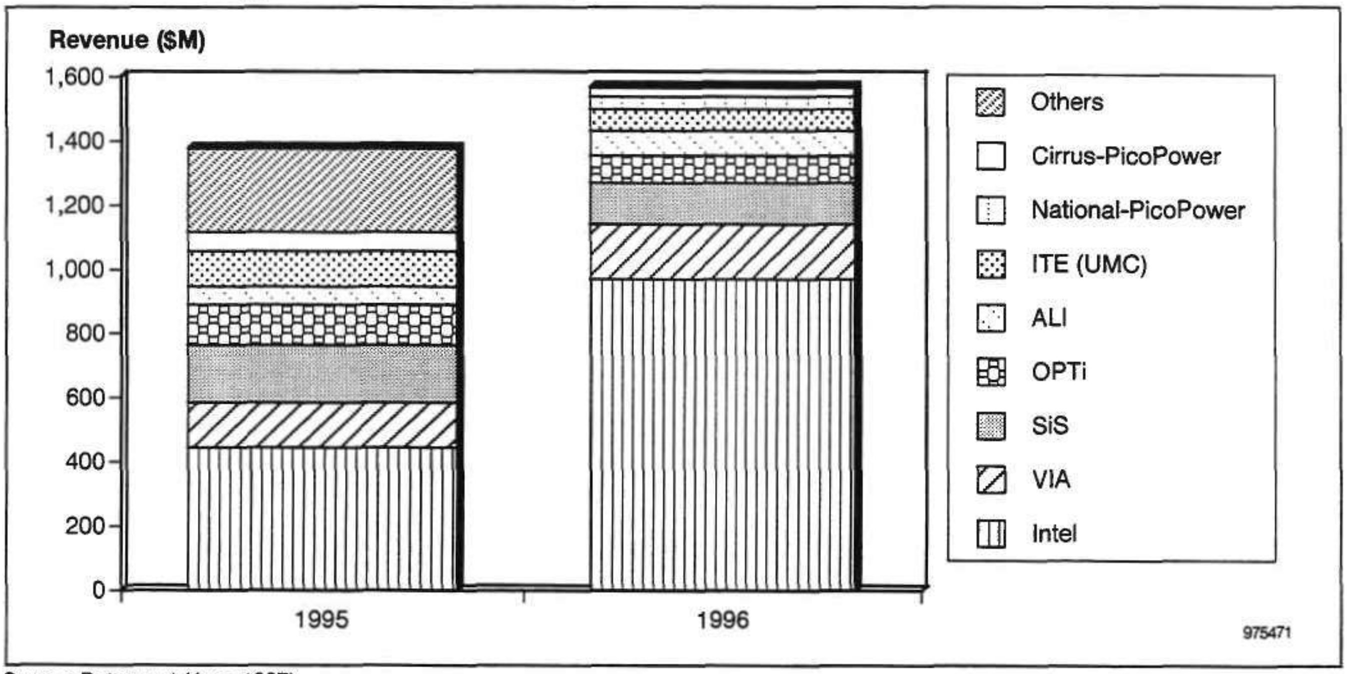
Source: Dataquest (June 1997)

Figure 21
IBM Continues to Lead in 32-Bit Compute RISC



Source: Dataquest (June 1997)

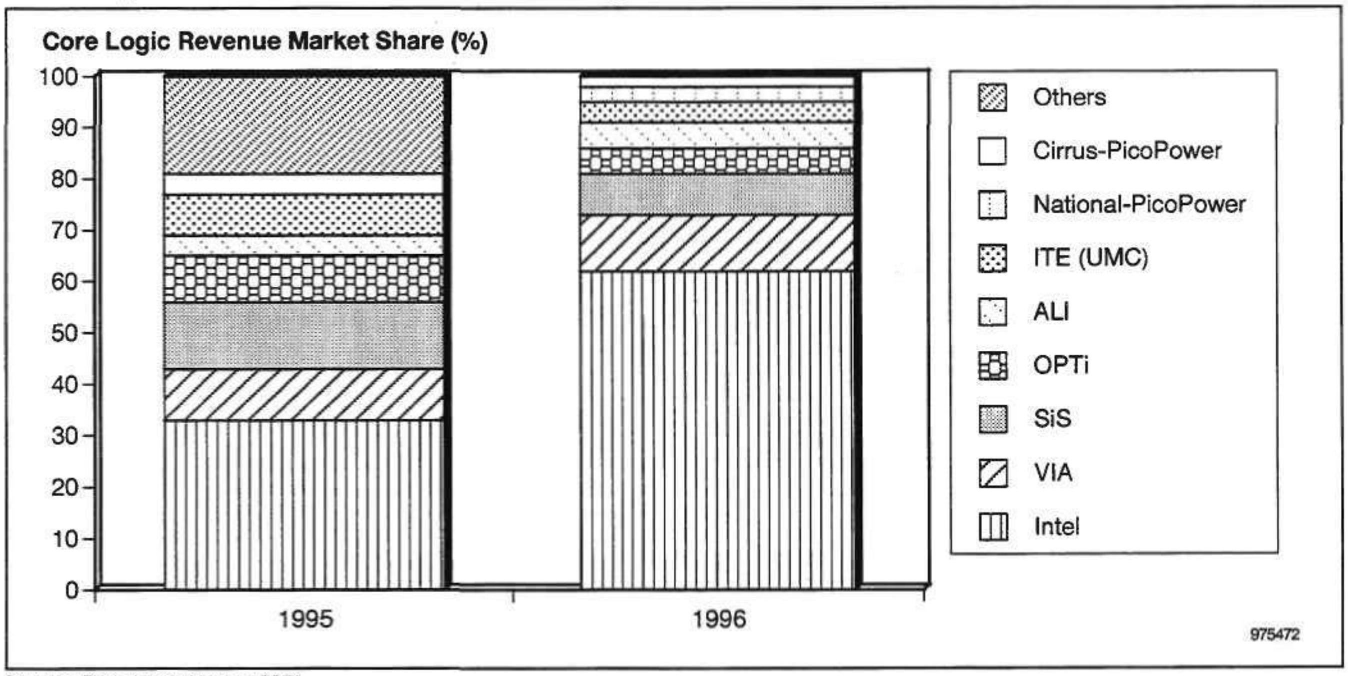
Figure 22
The x86 Core Logic Market Exceeded $1.5 Billion in 1996



Source: Dataquest (June 1997)

In terms of dollar market share, Intel accounted for about 62 percent of core logic revenue, up from about 40 percent (see Figure 23). That is respectable growth for Intel, but it by no means dominates the core logic market in the way that it dominates the x86 market. Intel's share of x86 shipments and revenue were 88 percent and 96 percent, respectively. However, Intel captured only 52 percent of the core logic units (see Figure 24). That is because Intel has a higher ASP in this market than the other players, primarily because a lot of its products go out on motherboards and it provides the reference designs. And it did have a perceived performance advantage for most of the year.

Figure 23
Intel Captured 62 Percent of x86 Core Logic Revenue in 1996



Source: Dataquest (June 1997)

Questions and Answers

Question (Q): What is Dataquest's estimate for the 1997 PC shipment growth rate? And was there recently an announcement from Intel saying that it is going to decrease its ASPs for all of its MPUs—its advanced technology as well as its older MPU technology? Intel is going to decrease its ASPs in July and then again in November; is this reflected in your forecast?

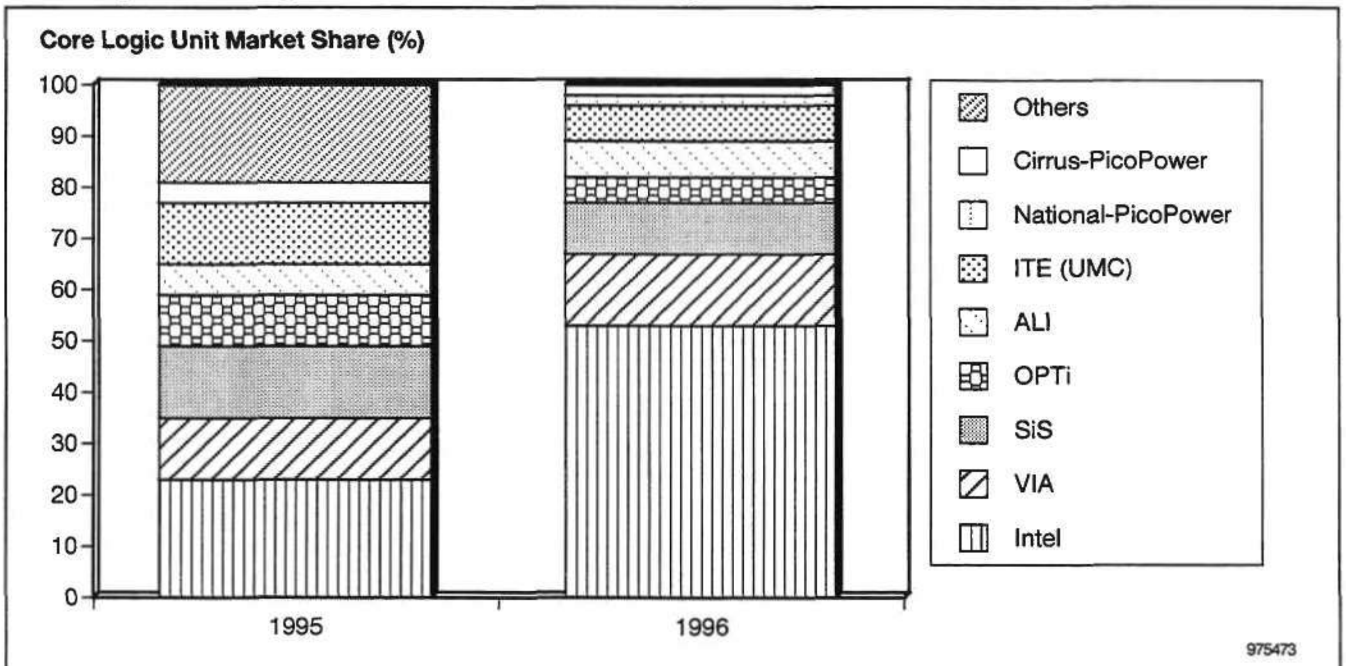
Geoff Ballew (GB): The 1997 unit growth rate for PC shipments over 1996 is right at about 19 percent, and mobiles are a little bit stronger than desktops.

Nathan Brookwood (NB): The second question is a very interesting one and comes up quite frequently. Intel's lowering its selling prices for its microprocessors will have virtually no effect on Intel's revenues. And that is a very counterintuitive kind of concept. But basically what Intel is doing is delivering more performance at each price point. And so the 200-MHz processor will cost $400 instead of $600. But there's another, faster part that costs $600, and people who are interested in paying $2,000 for a PC will be glad to spend $600 for the faster chip. Similarly, every other product in

Intel's list drops down a rung or two. As a matter of fact, what made the August prices a little bit steeper than usual was that instead of just notching everything down one rung, Intel notched them down two, because the two bottom rungs in its pricing ladder, the non-MMX products, were just not selling. As a result, Intel's mix of $100 processors, $200 processors, $300 processors, and up will stay about the same. But people will get more performance, and one could argue that the fact that performance is increasing faster might serve as a spike to PC unit demand and increase Intel's revenue. We'll see how that plays out. But it should not have an impact on either Intel's unit volumes or on its overall revenue, just on what is being sold at each price point. (A Dataquest Perspective that will appear later this summer goes into the mechanics of this, which I think is not well understood outside the industry.)

Q: For PC semiconductor consumption, the data given earlier described MPU memory and "others." In the "others" category, the year 2001 total is $29.42 billion. The detail provided for graphics and audio chips leaves about another $25 billion. What are the major categories in "others" and their approximate sizes in 2001?

Figure 24
Intel Captured Only 52 Percent of x86 Core Logic Units in 1996



Source: Dataquest (June 1997)

GB: All categories are growing, but Dataquest sees a significant increase in communications, audio, and power regulation. Also, we have built in some growth rate for some unknown future, maybe I/O technology, because IEEE 1394 seems to be gaining a lot of steam. All of these combined will add to that "others" semiconductor line. The graphics attach rate is already at parity with PC shipments, but communications, particularly modem and network, is not yet there. We see growth in those areas.

Q: I'm interested in Dataquest's assessment of the thin client or the Net PC arena and its impact on the CPU market.

NB: Clearly, if the network computer were to find major acceptance, that might have some impact, because the network computer is microprocessor-architecture independent. And, of course, IBM is selling versions that have PowerPC chips. Sun is selling versions that have SPARCs and will eventually have Java chips and so forth. We do not see the NC becoming a major market. Dataquest did publish a Perspective that detailed a number of reasons why we thought the network computer would not have a major impact ("Can Network Computers Topple the Wintel Paradigm?" MCRO-WW-DP-9704 and PSAM-WW-DP-9702, February 1997). In terms of the network PC and the Intel-Microsoft initiative, the major emphasis from Dataquest's perspective is not so much on low cost as it is on manageability. The key issue in a Net PC is that an MIS department can manage all of those machines from a central site. It does not have to send technicians out to install new software, upgrades, and so forth, which is becoming a major component of the expense of having a personal computer. Gartner Group, Dataquest's parent company, identified that traditional PCs can very expensive to own. They are cheap to buy but expensive to own for large corporations, somewhere in the neighborhood of $12,000 a year. The network computer companies, that is, Oracle Corporation and Sun, are running around saying that their products will be cheaper to own because they won't involve all of those administrative expenses. Intel and Microsoft clearly now have co-opted that argument by making major strides in reducing the cost of owning a PC. That is what the Net PC initiative is really all about. It is easier to identify with boxes, and so everybody was showing boxes without floppies at the PC Expo recently, but that's really a sideshow in this campaign.

Q: Please comment on Cyrix's position in the market versus AMD's and Intel's.

NB: Cyrix clearly had some good news and some bad news. The good news was that that low-end personal computers, that is, the sub-$1,000 boxes, are an important growth segment. Cyrix is better positioned in that segment with its MediaGX processor than anybody else because it actually has some technology that it can use to lower the price, as opposed to just taking a margin hit. And the fact that Compaq Computer Corporation lined up with Cyrix certainly does not hurt. Also, Dataquest is hearing all sorts of positive noise from Cyrix and Compaq about the reception of the Presario 2100 series. In terms of the higher-end product—the M2 versus the K6—Cyrix is just really starting. It was very quiet in the spring regarding the M2. We're impressed with the performance claims being made for it and also with its very aggressive pricing. What remains to be seen is whether Cyrix can line up a major OEM customer to consume some volume. Obviously, IBM is moving some in terms of its Aptiva lines in Europe and Canada. Cyrix last year struggled to find a major customer for the M1. If it can get a good design-win with M2, it will just be in great shape as the year unrolls. If not, it will have to continue selling through distribution. This provides a nice revenue stream, but it does not provide the glamour and the glory that comes from having Compaq or Hewlett-Packard, for example, selling machines with Cyrix chips inside.

Q: Please list the four leading graphics vendors.

GB: They are S3 Incorporated, ATI Technologies Inc., Trident Microsystems Inc., and Cirrus Logic Inc. Cirrus was the second-largest vendor last year and the only one of the top three that is actually losing market share. The other three are rapidly gaining strength in the marketplace.

Q: In the reported price cuts that Intel is going to make in late July, a couple are listed at below $100. It has been a while since Intel has had a microprocessor listed at below $100. It seems to have given up that area. Does Dataquest read anything into that—maybe that the low end of the market is in fact growing faster, and it is a segment that Intel wants to address now?

NB: That's a good point. The parts listed at below $100 are not Pentium with MMX. It may be that Intel has found that its marketing department did a good job of convincing everybody that they wanted MMX, although it is still a little puzzling what real value MMX offers the buyer other than a bigger cache. But consumers do not want non-MMX processors. They have said that very clearly, and Intel and AMD and Cyrix are all doing their best now to flush their lines of non-MMX processors. Whether Intel will keep that processor at the $80 price point is, of course, a very interesting question. It has sold parts at a similar price before as a special deal, but it has never posted a price like that before, as the questioner observed. This may be a short-term issue relating to the transition from non-MMX to MMX, or it may indicate a longer-term direction.

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September 1, 1997
Semiconductor Application Markets Worldwide
Event Summary
Geoffrey Ballew

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PC Semiconductors and the Three M's: Multimedia, Microprocessors, and Memory

This document contains text of the June 24, 1997, telebriefing presented by the Personal Computer Semiconductors and Applications Worldwide program. The PC semiconductor market continues to grow, fueled by PC shipments, faster CPUs, and memory-hungry multimedia applications. Market revenue will top $125 billion in the year 2001, up from $44 billion in 1996.

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graphics as some of that memory is integrated.

A portion of the ASP growth will come at the cost of discrete memory revenue. Deskbound and mobile graphics chips will all get 3-D features in that time, as well as TV display features, particularly flicker filters and TV output. The long-term outlook for the graphics controller market also includes some products that Dataquest has labeled "advanced programmable chips" for this forecast. These advanced programmable chips will look quite similar to what are called media processors today. These chips will most likely have a programmable core and handle concurrent functions in a manner similar to today's media processors.

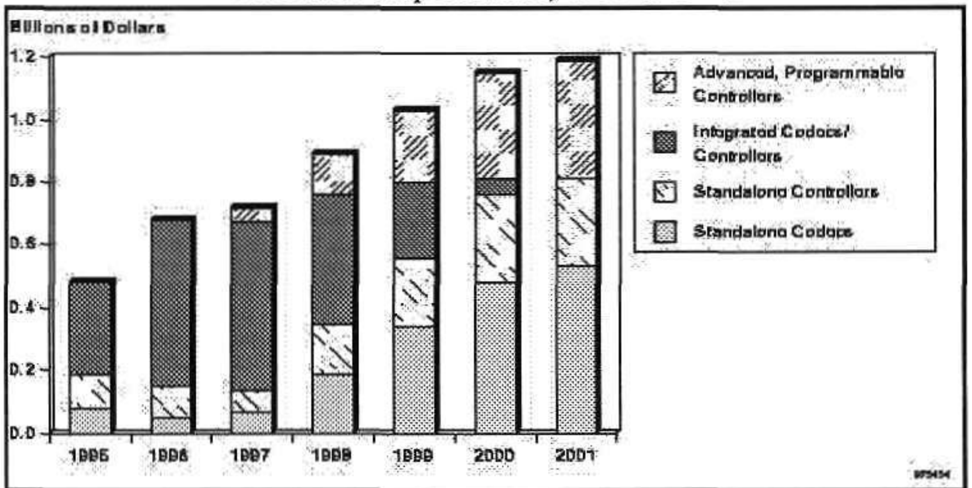
This is both good news and bad news for current media processor vendors--good news because they are ahead of their time, but bad news because the established graphics vendors are likely to control this market and retain ownership of those sockets during this transition. The transition is not likely to be night and day, but will be slower--evolutionary rather than revolutionary. At this point, the current graphics vendors are strong, particularly the four market share leaders. The most notable media processor design-wins today are the recent announcements from Gateway 2000 and Micron Technology Inc. Micron announced that it would be using Chromatic Research Inc. 's Mpact chip for DVD add-in card functions. This is good news for the media processor market because it both validates the model and actually gets units out in real user situations. However, the current media processor offerings do not appear to be competing directly with standard graphics chips. This will change over the next couple of years as graphics chips grow into a broader role.

PC Audio Chips

Figure 5 and Table 4 show the PC audio chip forecast. The PC audio chip market has several things in common with the graphics market. Slow growth for 1996 is not one of them, but slow revenue growth for 1997 is.

The PC audio chip market benefited in 1996 from higher attach rates as well as Sound Blaster audio becoming essentially a standard feature for most mobile PCs. The revenue growth rate for 1996 is very high because the 1996 numbers do include some additional chip value from add-in card shipments that use the same chip-level products as those that vendors Aztech Systems Ltd. and Creative Technology Ltd. sold on the merchant market. We decided to include those unit shipments because the chips used on those boards are identical to the ones sold to other customers and therefore fall into Dataquest's merchant chip definition. Revenue growth for 1997 is forecast to be only 6.4 percent. Price competition has hit the audio chip market quite hard, starting with a slowdown at the end of the fourth quarter and steep price erosion through the first half of this year for single-chip products.

Figure 5
PC Audio Chip Forecast, 1995 to 2001



Source: Dataquest (May 1997)

Table 4
PC Audio Chip Forecast, 1995 to 2001 (Billions of Dollars)

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Total	0.5	0.7	0.7	0.9	1.0	1.2	1.2	11.8
Year-to-Year Growth (%)	-	39.6	6.4	24.2	16.0	11.0	2.9	-
Source: Dataquest (May 1997)								

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Growth should bounce back to 24 percent in 1998 on the strength of continued increases in attach rates as well as a transition from ISA-based single-chip subsystems to more advanced PCI-based AC-97-type implementations. The new PCI-based products are more focused on audio quality and new features such as positional 3-D sound, wave table synthesis, and even wave guide synthesis. Essentially, until recently, the audio chip market was directed by vendors' efforts to reduce cost and increase integration. This was the race toward the single chip. ESS Technology Inc. led this race and basically built its audio business on it. The market is expected to make a transition now, with less emphasis on lowest price and highest integration and more emphasis on audio quality. Particularly with AC-97 implementation, consumer quality levels of audio are quite possible in PCs. Those quality levels are unlikely with an integrated single-chip product. Several of these products should be considered advanced programmable chips.

The forecast does include a growing market for programmable audio chips. Although similar to the media processor products, these programmable audio chips are really targeting only audio and modem functions. The math-intensive tasks of AC-3 decoding and positional 3-D audio require powerful chips, and several vendors are making their products based on programmable digital signal processor (DSP) cores. Positional 3-D technology is used for virtualizing multispeaker audio, such as AC-3 or ProLogic, using only two speakers for playback. Of course, this does not sound as good as having more speakers, but it is critical for the teeming masses who will not hook more than two speakers to their PCs. Specific PC/TV combination products are likely to be exceptions, as these products are designed for the living room entertainment center rather than the desktop. It seems much more likely that consumers would hook all six speakers of an AC-3 system to their living room PCs than to their PCs in the den.

Following 1998, growth in the PC audio chip market will decelerate as attach rates approach 100 percent. Some of those audio implementations will simply be an AC-97 codec and will use software running on the host microprocessor for the synthesis and control functions. Dataquest believes that, of PCs with audio features, approximately one out of two in the year 2001 will have only a codec rather than both a codec and a separate hardware controller. By the same token, the hardware controllers that are added will be an opportunity for chip vendors to add significant value with higher-end features, such as AC-3, positional 3-D, and other audio enhancements. 50%

Microprocessors

Figure 6 shows the compute microprocessor unit shipment forecast to the year 2001. This is based on Dataquest's PC forecast, workstation forecast, mainframe forecast, and server forecasts of all different flavors and shapes. We get the feedback from our systems groups and that drives a lot of this forecast. In 1996, the compute microprocessor market was 83 million units, with a lot of that, obviously, in PCs. The market will grow to 173 million units in the year 2001. It is difficult to see the gradations between the x86 and everything else because the x86 more or less drowns out everything else, so Figure 6 strips the x86 out of the compute microprocessor market. Figure 7 shows that the rest of the market will grow from 5 million units in 1995 to about 10 million units in 2001.

Figure 8 strips out the PowerPC and leaves just the RISC processors that are used in workstations and servers and the microprocessors that are used in mainframes, two growing markets. That is the good news; the bad news is they are growing from about 1.5 million to 2.5 million units. Of course, margins are better in those markets. However, the volume certainly is not great. Figure 9 translates those units into revenue.

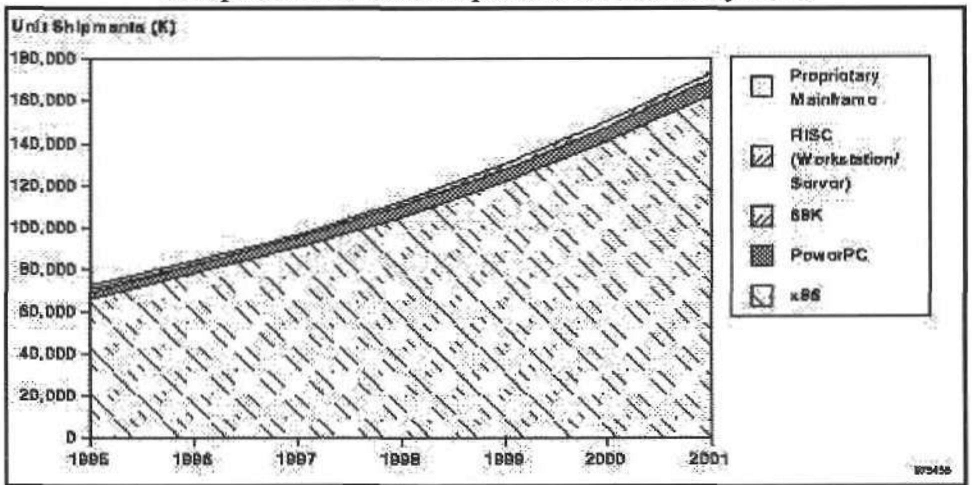
Figure 9 shows that the compute x86 market, which was about $15 billion in 1996 will be growing to $30 billion in the year 2000 and $43 billion in the year 2002. This is why there is so much activity in the x86 clone market.

Figure 9 makes it clear that--as Willy Sutton answered when asked why he robbed banks--that is where the money is. Companies that want to make money making microprocessors must be in the x86 segment. In terms of unit shipments, the compute x86 market will grow from about 77 million units in 1996 to about 140 million units in the year 2000.

This is largely driven by increasing PC unit demand. Clearly the fact that the x86 is moving into the server environment also helps, but that is a very minor factor, especially in terms of units. It is slightly more of a factor in terms of revenue because of some of the strategies Intel is now using to raise the average price of microprocessors in servers. Dataquest has been arguing for the last six months and will continue to argue that the x86 clones--from Advanced Micro Devices Inc., Cyrix Corporation, Centaur Technology Inc., Integrated Device Technology Inc., and others that will appear over the next year or two--will be able to take approximately 25 percent of the units in this market. Figure 10 shows compute x86 shipments.

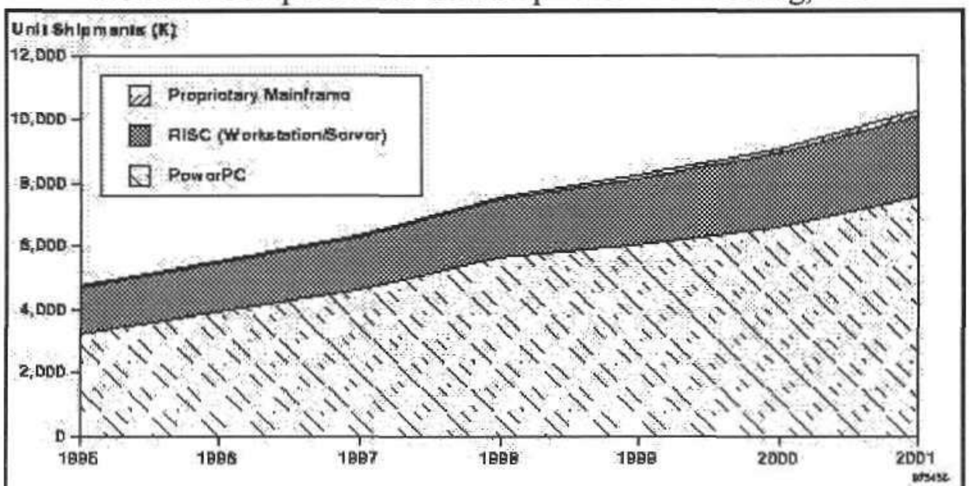
By the year 2000, x86 clones will gain 25 percent share (see Figure 11), which means that they will have approximately 41 million units by the year 2000. That pales compared to what Intel will be doing, but it is still a healthy business. And one of the things that makes it healthy is that the average selling price of x86s continues to increase (see Figure 12). It was slightly over $200 in 1996 and will grow to approximately $225 by 2002.

Figure 6
Compute MPU Unit Shipments to Double by 2001



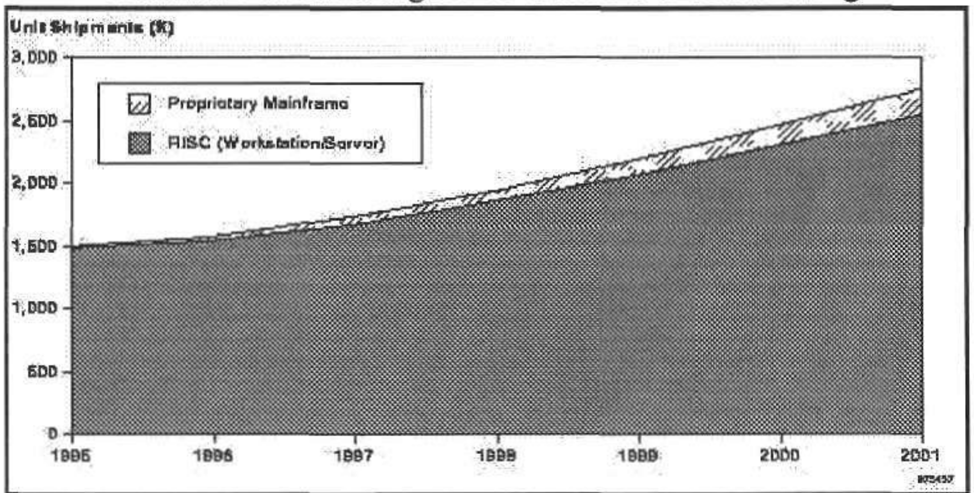
Source: Dataquest (June 1997)

Figure 7
Non-x86 Compute MPU Unit Shipments Are Growing, Too



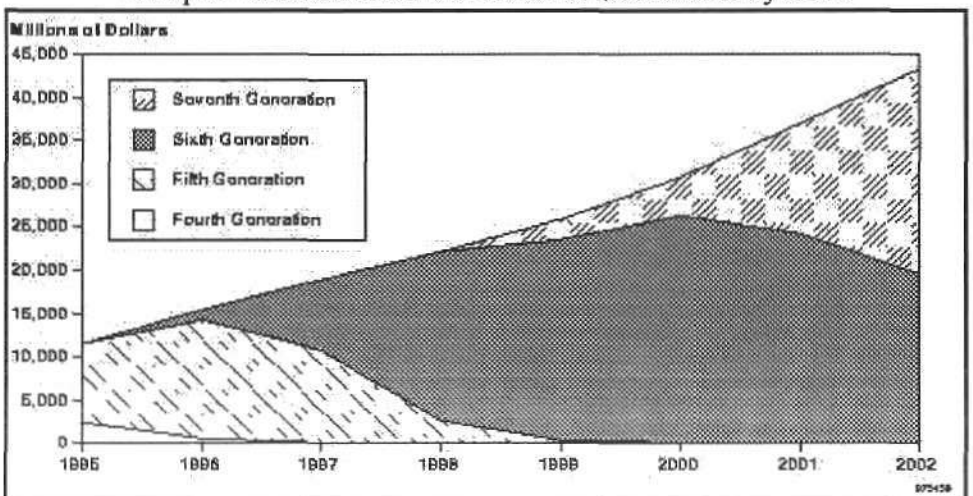
Source: Dataquest (June 1997)

Figure 8
Mainframe and Midrange MPU Units Are Also Increasing



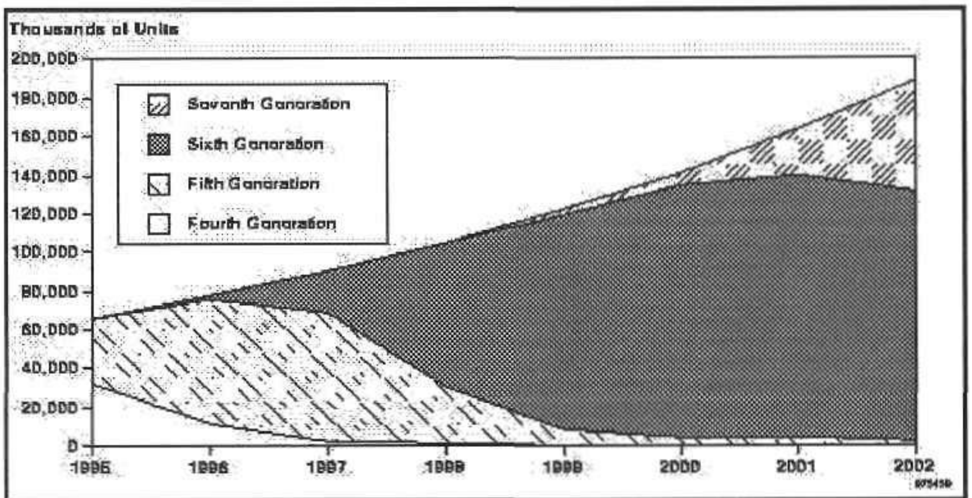
Source: Dataquest (June 1997)

Figure 9
Compute x86 Revenue to Double to $30 Billion by 2000



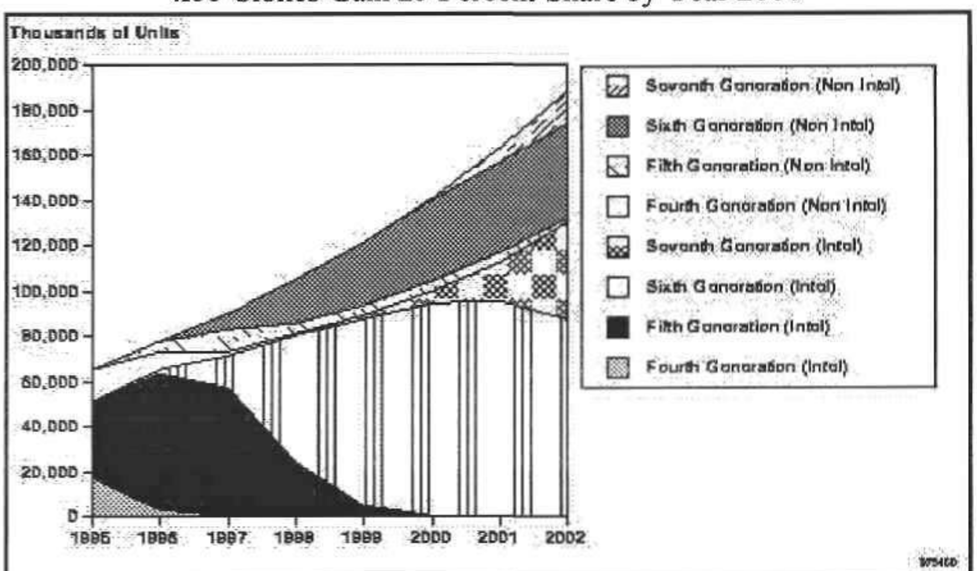
Source: Dataquest (June 1997)

Figure 10
Compute x86 Shipments Will Grow from 77 Million Units in 1996 to 140 Million in 2000



Source: Dataquest (June 1997)

Figure 11
x86 Clones Gain 25 Percent Share by Year 2000



Source: Dataquest (June 1997)

Perspective

Personal Computer Semiconductors and Applications Worldwide

Market Analysis

Personal Computer Chip Market Quarterly Outlook: The Calm Before the Storm?

Abstract: *This Perspective examines the health of the personal computer market for semiconductor products. As industry players exit a mostly predictable second quarter, the occasional burst of a Wall Street earnings disappointment shatters the quiet air and places the industry on alert for further signs of the market's direction.*
By Nathan Brookwood

The Gathering Clouds

Semiconductor vendors serving the personal computer market turned in respectable performances during the first quarter of 1997, but a series of warnings of impending disappointments has marred the exuberance the industry felt at the start of the quarter. Most notable was Intel Corporation's late May announcement of an anticipated revenue shortfall of 5 percent to 10 percent, revising its former estimate of no growth in revenue to one of declining sales for the quarter. Intel attributed this change in business to a soft European market, although Compaq Computer Corporation quickly noted that its sales remained strong in that region. Additional problems emerged at Cabletron Systems Inc., Seagate Technology Inc., and ESS Technology Inc. As the quarter draws to a close, vendors remain optimistic about the prospects for the second half of the year, but clearly they are on the lookout for additional warning signs.

The problems that began to appear late in the second quarter were little in evidence as the period began. As Table 1 illustrates, most vendors displayed robust growth from the year-earlier period, and some even

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managed to post gains over the seasonally stronger fourth quarter. Most vendors managed to increase margins, although competition drove them lower in the graphics arena. Inventories were little changed from the prior quarter.

Microprocessor vendors had a busy quarter, as Advanced Micro Devices Inc., Intel, and Cyrix Corporation all rolled out products targeted at high-volume, sixth-generation markets. All three added MMX technology to their x86 offerings, and by the end of the quarter, they all agreed that they would respect the sanctity of Intel's MMX trademark. AMD and Cyrix both returned to profitability following their extremely weak performances in 1996. Intel's gross margin increased to 64 percent, and the company once again indicated that such high margins could not be sustained on a long-term basis.

The display controller market was far less sanguine, as vendors struggled to gain market share in the rapidly growing 3-D segment. S3 Incorporated, after turning in a solid performance in which it increased market share and reported first-quarter sales up 26 percent from the prior year—all the while maintaining 40 percent (and higher) margins—announced that it expected to see its own margins drop by 10 points because of the increased competition in this market. Cirrus Logic Inc., the former leader, continued to struggle on the road to recovery, as sales decreased and margins eroded from the fourth quarter.

After talking about 56Kb technology for most of 1996, vendors began shipments of modems based on both the x2 standard supported by U.S. Robotics Inc. and the 56Kflex standard offered by Rockwell International Corporation and Lucent Technologies. To address concerns about the lack of interoperability between these two standards, several vendors guaranteed free upgrades to whatever standard the International Telecommunications Union (ITU) finally adopts early in 1998.

Microprocessors: The Sixth Generation Is On Its Way

The Processor Formerly Known as K6

AMD led the quarter off with the announcement of its sixth-generation microprocessor, the AMD-K6 MMX Processor, (formerly known as K6). This marks the first time in recent history that AMD has brought an x86 product to market while it was still competitive with the high end of Intel's offering (where the real dollars are earned).

It is also the first time that Intel has had to face a rival that has both a competitive product and the capacity to produce it in meaningful volumes. Unlike the situation last year, where a customer might save $10 or $20 by using a slow and inexpensive AMD K5 in lieu of a slow and inexpensive Pentium, the savings here might really sway some users' purchasing decisions.

Although no major OEM customers for the K6 were visible on announcement day, a few months later Digital Equipment Corporation launched new K6-based versions of its Venturis PC line, aimed at value-oriented commercial users. Digital claims that its customers can save $200 on average by using the K6 instead of a Pentium processor. As the year plays out, this may prove to be the acid test of the effectiveness of Intel's long-running "Intel Inside" campaign.

Table 1
Personal Computer Semiconductor and System Vendor Performance, Q1/1997

	Quarterly Revenue ($K)			Quarterly Revenue Growth (%)		Quarterly Gross Margin (%)			Days Inventory		
	Q1/97	Q4/96	Q1/96	Q1/Q4	Q1/Q1	Q1/97	Q4/96	Q1/96	Q1/97	Q4/96	Q1/96
Microprocessors											
Advanced Micro Devices	551,999	496,800	544,212	11	1	37	29	32	38	39	41
Cyrix	75,616	72,058	51,606	5	47	44	21	49	57	39	66
Intel	6,488,000	6,440,004	4,644,000	1	40	64	63	48	54	62	57
Motorola	6,642,000	7,685,002	6,955,000	-14	-5	34	32	32	71	50	59
SGS Thomson	940,500	1,033,802	1,019,100	-9	-8	38	40	43	80	76	0
Peripherals											
3COM	786,778	820,002	606,002	-4	30	54	55	53	64	57	68
Analog Devices	292,063	304,647	280,769	-4	4	49	50	49	129	129	100
ATI	151,460	164,068	115,877	-8	31	30	29	26	53	32	49
Cirrus Logic	212,900	253,309	233,073	-16	-9	23	38	4	70	74	54
ESS Technology	81,468	76,679	41,188	6	98	49	51	57	74	79	105
LSI Logic	308,388	301,788	311,352	2	-1	47	45	43	4	49	64
National Semiconductor	680,500	661,500	600,300	3	13	38	35	39	51	55	80
Rockwell International	1,899,000	2,608,003	3,464,000	-27	-45	30	25	25	123	83	70
S3	138,166	132,063	110,072	5	26	41	41	40	60	62	65
Texas Instruments	2,263,000	2,459,002	3,076,000	-8	-26	35	15	29	39	30	47
VLSI Technology	177,684	183,573	167,712	-3	6	43	42	37	51	47	55
Systems											
Apple	1,601,000	2,129,000	2,185,000	-25	-27	19	14	-19	35	25	51
Compaq	4,805,000	5,422,003	4,205,000	-11	14	25	24	21	31	25	52
Dell	2,588,000	2,412,000	1,638,000	7	58	22	22	19	12	12	17
Gateway 2000	1,420,000	1,552,831	1,142,202	-9	24	19	20	19	25	20	20
IBM	17,308,000	23,140,004	16,559,000	-25	5	38	29	41	49	50	64

Source: Company reports and Dataquest (March 1997)

The Processor Formerly Known as Klamath

One month after AMD's introduction, Intel launched Pentium II (formerly known as Klamath). Although Intel officially launched its sixth-generation x86 processors with Pentium Pro in November 1995, the earlier products proved difficult to manufacture in high volume. The new design in its distinctive black cartridge can be made by the tens of millions, and soon will be. Given the initial prices Intel has set for these devices, they will likely appear in desktop configurations selling for $2,500 or more, an area previously addressed by the 200-MHz Pentium Pro and the 200-MHz Pentium with MMX technology. Dataquest anticipates that as production volumes ramp, Intel will reduce chip prices, resulting in system prices of $2,000 by the fourth quarter and $1,700 by this time next year.

Just prior to the May 2 announcement, an Intel gadfly attempted to disrupt the proceedings by announcing the discovery of a bug in the way the new chips handled certain esoteric math functions. Intel demonstrated that it had taken to heart the $475 million lesson it got following its maladroit handling of the last floating point bug, and this time the company dealt with the problem in such a smooth fashion that it was soon relegated to the ranks of the erratum list, where it had belonged all along.

The Processor Formerly Known as M2

One month after Intel's Pentium II introduction, Cyrix and IBM came forth with their new 6x86-MX processor (formerly known as M2). Last year, Cyrix tried to gain pricing parity with Intel—and failed miserably. This year, Cyrix has taken the opposite approach and has priced its chips at a 50 percent discount to Intel's. IBM took a more conservative approach and priced its version (technically identical to the one Cyrix sells) at a 25 percent discount to Intel, and more or less in line with AMD's K6 pricing. These new chips will certainly complicate the lives of system vendors, who up to now could satisfy all their processor requirements by dialing 1-800-INTELx86. The chips should also complicate Dataquest's MPU data collection task, since it will now be necessary to deal with several entries in the MPU vendor category.

Intel surprised the world in late May with the announcement that it anticipated a revenue shortfall of 5 to 10 percent for second quarter, after having said in April that it expected sales to be flat compared to the $6.4 billion recorded during the first quarter. Intel attributed the shortfall to weakness in Europe, where it generates about 30 percent of its revenue. It also hinted that customers had developed such a liking for the new MMX versions of its processors that they no longer wanted the non-MMX versions, complicating Intel's overall mix and suggesting there might be some "product transition" difficulties falling out of the move to MMX-flavored devices. Intel's announcement caused yellow flags to be displayed around the world, as vendors, buyers, and investors all tried to sort out transitional, seasonal, and competitive factors affecting Intel's business and possibly the entire PC industry.

Digital Moves the MPU Battle from the Market to the Courtroom

On May 13, Intel's lawyers woke up to the sound of the process server dropping a pile of papers from Digital at their door. Digital has claimed that Intel's Pentium-class products infringe 10 Digital patents dealing with microprocessor design. Two weeks later Intel countered, claiming Digital refused to return Intel's proprietary design information regarding forthcoming Pentium II processors. Intel also hinted that it might not accept additional purchase orders from Digital after the contract between them runs out at the end of September.

Dataquest expects that the likely outcome of this matter will involve a broad, cross-licensing agreement between Digital and Intel, possibly with royalties flowing between the two companies. The direction in which the money would flow remains to be determined.

In Other Microprocessor News...

The quarter saw some other intriguing MPU developments, including:

- AMD surprised Wall Street by announcing its first profit in four quarters. AMD earned $12.9 million, or $0.09 a share, in the first quarter of the year.
- NEC Corporation launched a new RISC processor for the Windows CE market. The VR4102 device offers higher performance and peripheral enhancements, including a "soft modem" to which the vendor must add only a codec and DAA for complete modem functionality.
- Digital announced a 600-MHz version of its Alpha 21164 microprocessor for workstations and servers. The new chip, with a peak execution rate of 2.4 billion instructions per second, delivers an estimated 18.0 SPECint95 and 27.0 SPECfp95.
- Start-up Exponential Technology Inc. announced it would discontinue its efforts on the 533-MHz PowerPC it had been developing and close its San Jose, California development facility. Exponential becomes the latest in a long series of companies that have lost the bet they could outrun CMOS technology. Someday, CMOS technology will hit a brick wall, and some small start-up eagerly pursuing an alternative technology will have its day in the sun. But it will not happen in 1997, and it is unlikely to happen in this century.
- SGS-Thomson Microelectronics B.V. acquired a majority stake in Metaflow Technologies, a San Diego-based privately held company that designs high-performance microprocessors. The acquisition follows nearly two years of activity between the two companies. Metaflow is widely believed to be developing an x86 microprocessor, and the relationship between this and SGS-Thomson's Cyrix-related activities remains unclear.

Computer Graphics: Looking Better All the Time

Overall, the computer graphics business seems to have grown brighter during the last quarter, with key developments such as:

- S3 announced an exclusive and semi-exclusive deal that allows it to apply certain Faroudja video technology to bring high-quality video to the personal computer. Faroudja Laboratories, a household name in high-quality video processing, has been largely unknown within the computer field until now. The agreement includes Faroudja's Line Doubling technology, Detail Enhancer and Cross Color Suppression, Motion Tracking and Compensation, and a Digital Compression Filter that eliminates MPEG artifacts such as "blockiness" and unwanted sharp edges in both digital versatile disc (DVD) and DSS applications. These enhancements combine to make video look better when displayed on a computer screen. S3 intends to incorporate this technology into its high-end products first, and then move it downmarket over the next several years.

- Cirrus Logic reported fourth-quarter net sales of $212.9 million, compared to $233.1 million a year earlier, along with a net loss of $51.9 million. For fiscal year 1997, net sales of $917.2 million compared poorly to $1.15 billion for fiscal 1996. It was a year Cirrus would rather forget.
- Trident Microsystems Inc. began sampling its Cyber9388 graphics chip for notebook PCs. The chip includes 16Mb of on-chip memory and is essentially a complete graphics subsystem on a single chip. Until now, NeoMagic Corporation had been the only vendor to produce an integrated product. NeoMagic's sales skyrocketed to more than 1 million units in 1996. Trident's chip, as well as others soon to be released by S3 and Chips & Technologies Inc., will change the competitive landscape for mobile graphics chips. Dataquest expects that by the year 2001, as much as 80 percent of mobile PC graphics chips will have integrated memory.
- NeoMagic responded with the introduction and volume shipment of the MagicGraph128XD, which integrates 2MB of DRAM and a multimedia accelerator on a single chip. The MagicGraph128XD provides 16 million color full-motion video playback on LCD panels or external CRTs. With a 128-bit wide memory, 64-bit acceleration, and both horizontal and vertical bilinear interpolation of video, the MagicGraph128XD is capable of delivering more than 30 frames per second of MPEG or animation playback.
- Chromatic Research announced that STB Systems and Elecede Technologies Inc. (E4) will incorporate Chromatic's Mpact media processor into PCI-based DVD add-in cards for the PC market. These add-in cards will perform a variety of audio and video processing tasks to enable playback of MPEG-2 video with AC-3 audio content. Media processors, in general, face some FUD (fear, uncertainty, and doubt) factors from OEMs, even though the technical story line looks good. This design should take Mpact processors out of the test labs and into real user environments, and reduce the FUD factor.

A Wave of New PCI Audio Products

During the quarter, Crystal Semiconductor Corp., a wholly owned subsidiary of Cirrus Logic, introduced the CS4610 high-performance PCI audio accelerator—the first in a new DSP-based family of advanced audio processors for next-generation multimedia PCs. Unlike earlier audio processors that sit on a low-speed Industry Standard Architecture (ISA) bus, the CS4610 attaches to the much-faster PCI interface. Crystal's chip takes direct aim at next-generation consumer PC applications, such as advanced 3-D gaming and DVD playback. Crystal's announcement follows similar launches from Oak Technology Inc., VLSI Technology Inc., ESS, and S3, and adds to the momentum building for this new approach to PC audio.

Coming Soon to a Modem near You

After talking about 56-Kb technology for most of 1996, vendors finally began to ship modems based on both the x2 standard supported by U.S. Robotics and the 56Kflex standard offered by Rockwell and Lucent. To address concerns about the lack of interoperability between these two standards, several vendors guaranteed free upgrades to whatever standard the International Telecommunications Union (ITU) finally adopts early in 1998.

The U.S. Robotics customer satisfaction program for its x2 high-speed modems and systems hubs includes free upgrades to the international standard expected next year. The program also gives buyers of new x2 desktop and PC card modems one month of free Internet service worth up to $25 with a provider using x2, plus a 30-day "satisfaction guaranteed" return policy. The U.S. Robotics program matches an offer made a few weeks earlier by Hayes Microcomputer Products Inc.

ESS became the latest vendor to license 56K modem technology from U.S. Robotics. ESS will incorporate x2 into its forthcoming modem chipset, the ES2820, making modems based on those chips compatible with other x2-based modems. The modem chip market is sharply divided regarding 56 Kbps technology. Rockwell garnered support from Lucent and Motorola Incorporated but is opposed by Texas Instruments Inc. Cirrus, and now ESS. These two technology camps are battling for leadership in the high end of the market for analog modem chipsets. The Rockwell technology, called K56flex, is a combination of Rockwell's K56 technology and Lucent's V.flex technology.

At stake is the glory of being the No. 1 modem chip supplier for 56K products. Rockwell has dominated the modem chip market for the past few years, but TI and Lucent are gunning for more market share. U.S. Robotics is the largest modem OEM in the world and is very strong in the retail channel in the United States. Rockwell is the modem chip leader and doesn't want to lose that title. The modem chipset market will be exciting to watch for the rest of this year.

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Perspective

Personal Computer Semiconductors and Applications Worldwide
Market Analysis

PC Market Growth Is Tied to New Directions for PCs

Abstract: *This document presents the topline numbers –units and revenue—from Dataquest's Spring 1997 PC Forecast and 1996 PC Market Statistics. A brief discussion highlights some regional trends and identifies several barriers to future PC growth that are being addressed by PC OEMs and other related technology vendors.*
By Geoff Ballew

1996 Was Another Strong Year of Growth

When the dust settled after the fourth quarter buying season and the final sales were tallied, PC unit shipments had grown almost 18 percent for the year. Revenue growth was higher—reaching almost 22 percent—as buyers bought a little bit higher on the price scale compared to 1995.

Regional dynamics are important to note. Unit growth in the United States was markedly slower than in the previous year as the consumer market cooled following the ramp in home PC buying from 1992 to 1995.

Both the United States and Western Europe are dominated by replace-and-upgrade cycles rather than "new seats," so growth rates are lower than in most other regions of the world.

Shipments in Asia and Latin America buoyed the worldwide growth as penetration rates increased for both professional and private markets.

Table 1 shows the regional growth rates for PCs.

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Table 1
Regional Growth Rates for PC Unit Shipments

Region	1995-1996 Growth (%)	1996-2001 CAGR (%)
Americas	15.0	16.1
Europe*	14.7	13.4
Japan	32.3	16.7
Asia/Pacific	25.8	24.1
Total Worldwide	17.7	16.4

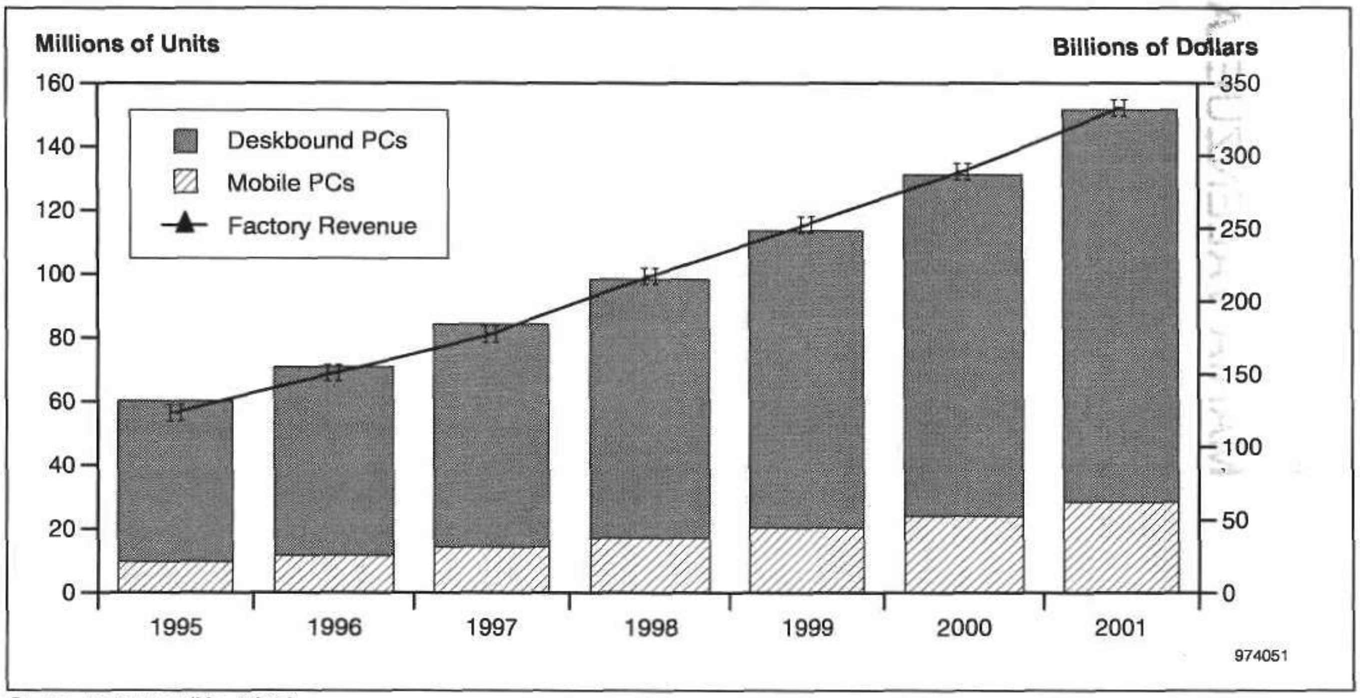
*Includes Eastern Europe, Africa, and the Middle East
Source: Dataquest (May 1997)

Long-Term Growth Tops 16 Percent

Dataquest expects the PC market to continue growing at very respectable rates, but not at the high rates seen in the previous few years. The year 1997 is the exception as unit shipments are expected to exceed 1996 by 19 percent. The five-year compound annual growth rate (CAGR) will be 16.4 percent, according to Dataquest's latest forecast. Figure 1 shows Dataquest's five-year PC forecast. Table 2 provides the data from Figure 1.

The PC market cannot be described as "business as usual" these days, because significant changes are taking place. These changes are meant to address certain barriers to growth in both the consumer and corporate markets. Foremost among those barriers are price, cost of ownership, and relevance.

Figure 1
Worldwide PC Forecast



Source: Dataquest (May 1997)

Table 2
Worldwide PC Forecast

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Mobile PCs (K Units)	9,721	11,783	14,391	17,183	20,364	24,061	28,411	19.2
Deskbound PCs (K Units)	50,450	59,067	69,887	81,194	93,232	107,156	123,190	15.8
Total PCs (K Units)	60,171	70,850	84,278	98,377	113,596	131,217	151,601	16.4
Factory Revenue ($M)	123,639	150,711	177,337	217,357	252,651	289,102	332,978	17.2

Source: Dataquest (May 1997)

Price is of greater concern for consumers rather than corporate buyers. The $1,000 PC concept has received much greater attention recently with new product lines targeted at price-sensitive consumers. The $1,000 PC segment is sometimes referred to as "segment 0" and includes lower-cost PCs with end-user prices up to $1,000. Corporate buyers like a low price too, of course, but are looking more for overall value.

The total cost of ownership (TCO) of PCs is much more of a concern for corporations, and is receiving greater attention than it has in the past. The Gartner Group published a much-quoted study showing that the annual cost of ownership of a PC in a corporate environment can be many times larger than the purchase price of the PC itself. Most discussions of TCO do not tackle issues of cost versus benefit, which is critical to justify purchasing a PC in the first place. However, TCO issues are being addressed as both software and hardware OEMs work to reduce TCO without reducing the utility or benefits of PC use.

Relevance is the third major issue that PC OEMs and other related hardware and software vendors are tackling. About one-third of households in the United States do not feel that owning a PC is important. This, in addition to price, is a barrier to achieving the high household penetration rates for PCs that many consumer electronics, such as color TVs and VCRs, have reached. Usage of the Internet, particularly the World Wide Web, is a critical element of increasing the relevance of PCs to a broader audience. However, PC OEMs are making consumer PCs more stylish, as well as more like traditional consumer electronics with easy-to-use controls for playing audio CDs and other activities. The goal of these changes is to make consumers attach greater value to PCs.

Dataquest Perspective

These issues highlight some of the barriers to higher PC market growth. The good news is that the PC industry is addressing these very issues, and therefore should maintain unit growth in the high teens. Microsoft initiatives such as OnNow and Zero Administration Windows (ZAW) are directed straight at consumer and corporate PC ownership issues, respectively. Several PC OEMs are tackling the cost and form factor issues that have kept some consumers from buying PCs. Examples include Compaq's Presario 2100 PC that sells for $995 or less, as well as stylish and innovative designs such as IBM's Aptiva S series. Aptiva S PCs feature a desktop "pizza box" style cabinet for the floppy disk drive and CD-ROM drive while stowing all of the other PC components in a traditional case that can be located under the desk. These changes add up to a simple conclusion: The PC industry today is clearly not doing "business as usual."

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Perspective

Personal Computer Semiconductors and Applications Worldwide

Product Analysis

The Intel-Microsoft NetPC and Wired for Management

Abstract: *On March 12, Intel and Microsoft jointly disclosed version 0.9 of the NetPC specification. In this Perspective, we explore some of the aspects and implications of this announcement.*

By Nathan Brookwood, Scott Miller, and Martin Reynolds

Market Impact

Intel Corporation and Microsoft Corporation jointly disclosed the specification for version 0.9 of the NetPC on March 12. In terms of the overall market, we do not expect the NetPC to cause a major shift in either volumes or price points. In other words, its effect is neutral. We see it as a transparent subset of the PC market that does not demand a separate forecast. However, it will propagate new software, system management, and maintenance technologies into the market and will initiate the exploration of smaller form factors earlier than otherwise might be expected. Therefore, it deserves close attention from system manufacturers.

NetPC also serves as a platform focus for Intel's larger Wired for Management strategy. Wired for Management aims to ensure a basic level of manageability across all PCs, incorporating software and hardware monitoring and control techniques down to the BIOS level of the machine. This baseline raises the bar for well-behaved clients and will ideally make even the most lowly PC a more palatable corporate client by virtue of strong support for central administration and control. Because of the strategic nature of this initiative for Intel and the company's position in the industry, we expect most, if not all, of Wired for Management features to be included in both NetPCs and the standard flexible PCs over time, in part through Intel's work in the area of chipsets and motherboards. In fact, PCs in 1998

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should include many of the specifics of NetPC. However, because the real advantages of the NetPC will only be realized with Windows NT 5.0, any time-to-market advantage over the standard PC will, in practice, be slight.

End Game

At a basic level, NetPC solves a few problems for Intel and Microsoft. First, network computers continue to raise questions about the necessity of fat clients and user-accessible systems. Additionally, they offer an opportunity for the IS manager to recover power and control back from the hands of the users. NetPC fills a perceived gap in the product line, enabling traditional PC companies to position these products as low-risk alternatives to those who care about the issues NCs address. Second, Plug-and-play has never worked well with ISA cards, making ISA-based systems tricky to configure and manage. Eventually, the standard PC market will exclusively migrate to PCI, but NetPC may accelerate the transition. NetPC is a tactical move, while Wired for Management is strategic. The PC as a network appliance will take some time to manifest, and we expect the mix to favor traditional PCs for some time to come.

Recommendations for System Manufacturers

The NetPC drives four simple recommendations for system vendors:

- Introduce a NetPC product
- Design a new case, not a new motherboard
- Ensure that regular PCs meet NetPC specifications
- Make sure that the NetPC is secure

No doubt, the NetPC has a lot to offer the industry through its management and software maintenance features. However, a standard PC should also be able to provide the benefits of a NetPC without restricting the flexibility of the machines for redeployment, resale, or reconfiguration. Therefore, we expect IS departments to implement NetPC standards and practices but to use regular PCs to do it.

Over time, the 1394 interface will eliminate the need for PCI slots, and we can expect to see the desktop form factor approximate that of a high-end notebook. Therefore, the distinction between a NetPC and a PC will gradually evaporate over the next five years.

In the interim, though, we recommend that manufacturers redeploy a motherboard from an existing desktop unit and redesign the casework to reflect a NetPC form factor (which may be as simple as a new bezel that eliminates the floppy drive).

Security is always a question in the PC environment, and the NetPC takes steps to closing the loopholes. To this end, a full implementation should have a persistent cover open detect switch that locks out access to the network once triggered and can only be reset through the office of the administrator. This safeguard prevents a user from gaining access to the inside of the machine and enabling a feature that permits data transfer on or off the network.

The NetPC

The NetPC is a strange hybrid driven by technology, competition, and user demand. In terms of technology, the NetPC is arguably the vanguard for a new generation of system management tools and perhaps harbingers the next step of evolution of the PC's form factor. Although system management concepts have existed for some time, the NetPC comes at a time when the hardware features are about to become standard in all PCs, and the NetPC itself brings the ability to control software levels from a central location. These management features help deliver on the promise of a small unit that can be substituted at will because the user's profile resides on the server, not the desktop.

The initial network computer brouhaha began in 1995 and focused on building a less expensive ($500) desktop unit. Once the details were worked out, and business models were adjusted to allow for necessary margins, the $500 NC began to look like a $1,000 NC, eliminating any capital cost advantage that the devices might have. About this time, the NC proponents discovered "total cost of ownership"—TCO—and found a better platform on which to stand. The NC camp argued that the PC standard had evolved into such a complex beast that it had become impossible (or at least very expensive) to administer. Their easy-to-understand solution was to start all over again and rebuild things in a more manageable and maintainable fashion.

Of course, the NC camp should have anticipated that the guardians of the protean personal computer would seek a way to respond to the quite legitimate concern over TCO while preserving their empire. The NetPC addresses the TCO issue in three ways. First, its management hardware allows the network administrator to check the state of a PC anywhere on the network, identifying trouble in the form of hardware failure or user modification without having to take a trip to visit the machine.

Second, the remote storage of software, applications, and data means that varying and unknown software revision levels become a thing of the past. This feature also allows for the trivial substitution of a new machine without affecting the user's data or programs and also for users to use any available machine for their work.

Finally, the NetPC is designed to keep the user out: Its USB and floppy disk I/O can be disabled by the system administrator, preventing the user from installing unauthorized software (Doom, for example). This simple barrier can eliminate much of the time that users spend running unauthorized software, driving them back to the water cooler to waste time in a more obvious fashion.

Several of the system management initiatives included in the NetPC specification were already in process when the NC brought additional focus to the problem. Microsoft and Intel have wisely chosen to join the battle to reduce TCO and will cite this cause as justification for changes to the PC standard that users might otherwise have resisted. ("Take this medicine—it's good for you.")

The NetPC and Total Cost of Ownership

The NetPC was designed to address the high life cycle cost of personal computers as well as head off the conceptual threat of the network computer. In conjunction with Microsoft's Zero Administration Windows (ZAW) initiative, the NetPC provides a platform with reduced software administration and management costs. It does this through a lack of floppy or CD-ROM drives, no ISA slots, and adherence to the PC '97 driver model. The lack of floppy or CD-ROM provides the equivalent of a hermetically sealed data and functional environment, thus simplifying the total infrastructure. The lack of ISA slots is intended to enable elegant plug-and-play as well as deterministic device identification—asset management requires that one know what assets are deployed. Adherence to the PC '97 driver model ensures that these devices can be managed when detected.

Additionally, many organizations do not value the expansion capability of the standard PC. Most TCO models show that it is far more expensive to extend the life of PCs on a part-by-part basis than to simply replace the entire system. For organizations that take this message to heart and that also do not need to support legacy ISA cards, a sealed case is preferable to traditional locking mechanisms. It certainly provides a much more deterministic and homogeneous environment on which to develop a life cycle management strategy. Unfortunately, many organizations will find that giving up ISA slots means a very expensive legacy application migration, and giving up expansion flexibility means implementing a new support infrastructure. Both of these are valuable exercises in the long run but will take time to implement.

Controlled and Secure

In highly secure environments, the lack of user access to a floppy or CD-ROM drive is important. While Windows 95 and Windows NT both allow drives to be disabled, there are businesses that "lock out" floppy drives mechanically. It is always better to enforce security by providing fewer options than showing users what they cannot have. For this reason, we believe the lack of removable storage on the NetPC will appeal to those organizations that already implement tight central control of PCs.

Architecture and System Cost Issues

From a system perspective, the NetPC is a PC like any other with all the same architectural components in place. However, the balance of the components and the form factor are somewhat different from that of a typical PC today. The memory and processor configurations track those of a standard PC, with the full gamut of processor options and memory sizes available. Indeed, the nature of the product suggests that the configurations tend to be at the high end to extend the useful life of the unit. The specification also eliminates the conventional I/O ports in favor of USB. Given the nature of the application, this is a reasonable approach as most corporate PCs rely exclusively on the network for printing and communication.

The Processor: CISC (x86) for Low Risk

Intel and Microsoft tout the NetPC concept as the "low-risk" approach to reducing TCO while maintaining compatibility with the installed base of PC hardware and software. We certainly concur that it is "low-RISC" in that it effectively bars potential inroads the SPARC, PowerPC, or ARM camps might make on the desktop via the CPU-neutral definition included in the Sun/Oracle NC Reference Profile. Interestingly, Digital Equipment's Alpha manages to sneak into the NetPC definition as a "Windows NT-compatible RISC-based processor." This loophole gives Digital the ability to pursue NCs with its StrongARM processor and NetPCs with its Alpha.

The NetPC definition specifies a 133-MHz Pentium (or equivalent) as its minimum acceptable MPU, and this strikes Dataquest as overkill from a user requirement (although perhaps not user demand) perspective for some applications. Network computer proponents argue that "underutilized" PCs often end up as expensive replacements for dumb terminals, and they suggest NCs can be more cost-effective in such environments. To the extent that such devices exist in meaningful quantities (and nobody has the figures to prove the case one way or the other), then P133-based systems might provide more power than some users would ever want, need, or enjoy paying for. If the NetPC is to provide an effective counter to the NC in such applications, the specification should permit a cost-optimized, low-performance model. Dataquest suspects that even if Intel does not want to sell microprocessors that fit the cost model needed to support sub-$1,000 system prices, other MPU vendors might see this as an attractive opportunity. Indeed, the recently announced Cyrix MediaGX MPU could be used as the basis for a very inexpensive NetPC, requiring USB and Ethernet interfaces to be traded for the modem card use in Compaq's consumer product using this device.

On the positive side, the specification allows for the fastest processor that Intel makes. A smart IT manager may be able to lure users to the NetPC platform with the promise of a faster box than the user would otherwise get. For the IT manager, the trade-off comes in the ease of redeployment later in the unit's life cycle.

Mass Storage

The disk drive area suffers somewhat in the NetPC, compared to that of a regular PC. In the NetPC, the hard drive is purely a cache device, holding frequently used program components locally. This approach eliminates the network thrashing associated with a diskless device, increasing the effective bandwidth of the network and ensuring that the networked systems deliver acceptable performance. Initially, we expect Microsoft to store just key files on the hard drive. Over time, the caching algorithms will mature to hold code fragments, perhaps in compressed format, to maximize the effectiveness of a low-end disk drive.

This analysis would tend to suggest that there will be a market for low-end hard disk drives to support the NetPC. Also, it may become unimportant to maintain consistency of size and type between drives as the drive itself becomes a noncritical component in the system. Therefore, the NetPC will drive a market for low-cost mass storage device to be used purely as cache; we wonder if perhaps Zip-type technology may fill this slot.

On the server side, central storage drives a requirement for large disk drive systems. Generally, server storage space costs about 10 times that of PC storage space in terms of disk capacity, a hidden cost that may surprise some IT managers.

Form Factor

In terms of the form factor, the NetPC has no in-the-box expansion capability whatsoever: no slots, no bays, and no user access. The presence of a USB connector allows for a broad range of peripherals to be attached (if permitted), covering devices that would previously have been ISA cards. The ascendance of 1394 over the next few years will provide a similar replacement for PCI peripherals. Therefore, the NetPC can be delivered in a small form factor case with a relatively low-cost power supply. The small form factor makes these units essentially interchangeable and portable, eliminating many of the barriers to replacing and redeploying standard PCs.

In the long term, most PCs may well be built into a form factor defined initially by the NetPC. This transition will be the end result of the proliferation of 1394 high-speed expansion devices and a shift toward LCD displays.

Potential Cost Savings

Now comes the catch. Although this device has significant restrictions in terms of I/O and mass storage, it is fundamentally a PC. Therefore, its cost is very close to that of a regular PC (within $30 to $60), with some small savings for the absence of the floppy drive, a smaller hard drive, and a somewhat less expensive case. Furthermore, a regular PC can be operated in a NetPC configuration. Currently, therefore, the NetPC looks "defeatured" to most, and we believe organizations will expect to pay less for the lack of traditional features. However, the lower price point is an impossible challenge given the small cost savings. In other words, the NetPC will garner many fewer sales than considerations.

Software

On the software front, we have many questions. It would appear that the NetPC ships without an operating system, downloading everything from the network with a simple boot loader such as that formerly used for diskless PCs. In this case, we wonder as to where Microsoft will collect its royalty;

system manufacturers will no doubt balk at paying a royalty for software that they do not use!

Also, NetPCs will be similar on the surface but will come with many configurations. The configuration data has to reside somewhere, and loading it into the machine would imply some level of persistent local storage. The alternative is to struggle through some form of configuration process at every boot, a difficult and unattractive option.

The introduction of the NetPC will also drive some focus onto Microsoft's file sizes. We all know about the inflation of applications, but once installed, they do not grow. The problem now is that file sizes are growing. It is trivial to generate a document that is a large fraction of a megabyte, and tens of megabytes are possible with just a few moment's work (for example, a picture downloaded from the Internet). These huge files are somewhat manageable on a local hard drive, but the aggregate of a hundred users on one server may result in continual, unpopular, and expensive disk drive purges.

Therefore, we expect to see some back pressure on Microsoft to tighten up file sizes.

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Perspective

Personal Computer Semiconductors and Applications Worldwide

Market Analysis

S3 Dominated the PC Graphics Market in 1996

Abstract: *S3 is the undisputed king of the PC graphics controller market with another year of tremendous growth in 1996. Other major players increased their market share, too, with the notable exception of Cirrus Logic. Overall, the PC graphics controller market slowed to single-digit revenue growth. Stiff competition for 2-D graphics chips and a slow transition to 3-D products resulted in lower ASPs. This document provides the market share and market size statistics for the overall PC graphics controller market as well as breakouts for the deskbound and mobile segments.*

By Geoff Ballew

Market Share Results

The names of the top five PC graphics controller vendors did not change in 1996, but their rank order did. S3 Incorporated and ATI Technologies Inc. both moved up one notch in the rankings. These two companies are executing like well-oiled machines with respect to new product introductions, and their results reflect this. Cirrus Logic Inc. and Chips & Technologies Inc. each moved down one notch, leaving Trident Microsystems Inc. in its familiar No. 3 spot. S3 and ATI were the only major vendors shipping controllers with 3-D acceleration in 1996. The higher average selling prices (ASPs) associated with 3-D chips helped buffer those two vendors from the price erosion for the 2-D chips. The 3-D controllers from both companies were not the fastest 3-D products, but they were pin-compatible with those vendors' most popular 2-D products. That pin-compatibility made the transition to 3-D less risky for many OEMs. Cirrus Logic was late with its mainstream 3-D product, Laguna3D, and missed the 1996 market. Table 1 shows the overall graphics controller market share statistics. Tables 2 and 3 show the market share statistics for the deskbound graphics controller and mobile graphics controller markets, respectively.

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Table 1
Overall PC Graphics Controller Market Share

	1995 Units (K)	1996 Units (K)	Change (%)	1995 Revenue ($M)	1996 Revenue ($M)	Change (%)	1995 Rank	1996 Rank	Market Share (%)
S3	15,500	29,038	87.3	288.0	462.8	60.7	2	1	32.3
Cirrus Logic	26,900	17,250	-35.9	488.1	259.0	-46.9	1	2	18.1
Trident Microsystems	10,791	12,750	18.2	132.8	180.0	35.5	3	3	12.6
ATI Technologies	5,000	8,000	60.0	100.0	144.0	44.0	5	4	10.1
Chips & Technologies	6,425	6,430	0.1	115.9	134.5	16.0	4	5	9.4
Matrox	850	1,950	129.4	24.6	50.1	103.8	8	6	3.5
NeoMagic	5	1,070	213.0	0.2	37.5	186.5	NR	7	2.6
Tseng	3,000	1,500	-50.0	39.0	25.0	-35.9	6	8	1.7
Avance	1,417	1,800	27.0	18.4	23.4	27.2	9	9	1.6
Ark Logic	1,300	1,800	38.5	15.6	21.6	38.5	10	10	1.5
Others	6,480	5,810	-10.3	116.6	94.2	-19.7	-	-	6.6
Total	77,668	87,398	-	1,339.2	1,432.2	-	-	-	100.0
Year-to-Year Growth (%)		12.5			6.9				

NR = Not ranked
Source: Dataquest (March 1997)

Table 2
Deskbound PC Graphics Controller Market Share

	1995 Units (K)	1996 Units (K)	Change (%)	1995 Revenue ($M)	1996 Revenue ($M)	Change (%)	1995 Rank	1996 Rank	Market Share (%)
S3	15,500	28,910	87	288.0	460.0	60	2	1	40.2
Cirrus Logic	25,000	14,750	-41	446.3	206.5	-54	1	2	18.0
ATI Technologies	5,000	8,000	60	100.0	144.0	44	4	3	12.6
Trident Microsystems	10,381	10,580	2	124.6	136.6	10	3	4	11.9
Matrox	850	1,950	129	24.6	50.1	104	6	5	4.4
Tseng	3,000	1,500	-50	39.0	25.0	-36	5	6	2.2
Avance	1,417	1,800	27	18.4	23.4	27	7	7	2.0
Ark Logic	1,300	1,800	38	15.6	21.6	38	8	8	1.9
Alliance Semiconductor	0	1,000	NA	0	14.5	NA	NR	9	1.3
SIS	896	900	0	11.6	11.6	0	10	10	1.0
Others	3,046	3,030	-1	50.2	51.2	2	-	-	4.5
Total	66,390	74,220	-	1,118.3	1,144.5	-	-	-	100.0
Year-to-Year Growth (%)		11.8			2.3				

NA = Not applicable
NR = Not ranked
Source: Dataquest (March 1997)

Table 3
Mobile PC Graphics Controller Market Share

	1995 Units (K)	1996 Units (K)	Change (%)	1995 Revenue ($M)	1996 Revenue ($M)	Change (%)	1995 Rank	1996 Rank	Market Share (%)
Chips & Technologies	5,549	6,380	15.0	105.4	134.0	27.1	1	1	46.6
Cirrus Logic	1,900	2,500	31.6	41.8	52.5	25.6	2	2	18.2
Trident Microsystems	410	2,170	429.3	8.2	43.4	429.3	4	3	15.1
NeoMagic	5	1,070	213.0	0.2	37.5	186.5	7	4	13.0
Philips	2,000	300	-85.0	38.0	5.4	-85.8	3	5	1.9
Others	1,414	758	-46.4	27.3	14.9	-45.3	-	-	5.2
Total	11,278	13,178	16.8	220.9	287.7	30.3	-	-	100.0
Year-to-Year Growth (%)		16.8			30.2				

Source: Dataquest (March 1997)

Deskbound products dominate the overall market, so these rankings are quite similar to the overall rankings. Two key differences exist:

- ATI edged out Trident for the No. 3 spot based on revenue, even though Trident shipped more units.
- Chips & Technologies is absent because of its focus on the mobile market.

The mobile market rankings are quite different from the other rankings. Chips & Technologies commands the lion's share of this market, with almost 50 percent of the revenue. However, the real success stories this past year have been the newer entrants to the market.

- Trident grew its shipments and revenue over 400 percent to establish itself as a major vendor in this segment.
- NeoMagic Corporation's shipments and revenue exploded with the success of its first integrated DRAM and graphics product, the MagicGraph128.

Mobile graphics ASPs increased primarily because of NeoMagic's influence. NeoMagic's ASPs are much higher because the price includes the embedded memory for the frame buffer. The trend toward greater use of embedded memories should continue to drive ASPs higher over the next several years.

1996 Graphics Market Overview

The market for PC graphics controllers in 1996 grew about 7 percent on a revenue basis, with unit shipment growth approaching 13 percent. The market suffered from two trends: an inventory overhang at the end of 1995 and delays in the shift to 3-D.

Unit shipment growth for graphics controllers usually mimics PC unit growth. However, in 1996, inventory issues changed the market dynamics. The inventory overhang from 1995 caused OEMs to order fewer chips during the first months of 1996, even though they were still producing add-in boards and PCs. The relative balance of foundry capacity and semiconductor demand made the problem worse, because lead times for new orders were reduced. OEMs were able to reduce their inventories considerably without running too much risk of parts shortages. The result was low order rates as OEMs worked their inventories down. These low order rates resulted in greater price competition for the 2-D products as vendors searched for new customers to boost their revenue.

Revenue growth for the PC graphics market was lower than unit growth because of the delays in the market shift from 2-D to 3-D products. 3-D acceleration is the key for most vendors to pull their ASPs back up to historical levels. Product delays on the hardware side and a dearth of compelling software titles limited the market for integrated 3-D graphics chips in 1996. Only S3 and ATI shipped high volumes of 3-D graphics chips last year. As a result, most vendors competed for business with older, 2-D products and had to accept lower prices.

Dataquest Perspective

The good news for the PC graphics market is that 1997 looks rosier than 1996. All major vendors have produced (or at least announced) 3-D accelerated graphics controllers, and ASPs should increase as these new parts replace the older, 2-D products. Also, unit growth should return to the high teens and mimic the growth for PC unit shipments. Strong unit growth coupled with rising ASPs could drive revenue growth for 1997 higher than 20 percent. A new PC graphics controller forecast will be published in Dataquest's upcoming *PC Graphics, Audio, and Video Market Trends* report (PSAM-WW-MT-9701).

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Perspective

Personal Computer Semiconductors and Applications Worldwide

Dataquest Predicts

Quarterly x86 Forecast: Send in the Clones

Abstract: *We have adjusted our chip forecast up slightly to reflect the strong fourth quarter sales most vendors experienced. This forecast focuses on the overall impact x86 clones are likely to have over the next several years.*
By Nathan Brookwood

Will x86 Clones Spell Baaad News for Intel?

Recent news that a Scottish scientist has successfully cloned a sheep led many to pause and reflect on the nature of life and the implications of technology. Clearly the efforts Advanced Micro Devices and Cyrix have made to clone Intel's cash cow are less momentous from a historical perspective. However, the folks at Intel must be almost as concerned about their (until now unique) high-tech ability to turn refined sand into gold by delivering chips that run increasingly complex PC programs at increasingly rapid rates in increasingly higher volumes at more or less constant prices.

In this revision to Dataquest's quarterly forecast for the x86 processors that power the personal computer market (and, increasingly, the workstation and midrange server markets), Dataquest explores the potential impact that AMD's K6 may exact on Intel's business. Unlike prior incursions, when AMD arrived with too little (fab capacity) or too late (with competitive performance), this time, bolstered by the technology boost it received via its NexGen acquisition, AMD may actually have a gun that shoots real bullets. Over the next few quarters, the market will measure AMD's skills as a marksman, while Intel gets to test whether the "Intel Inside" shield it has created at great expense can fend off the invading hordes.

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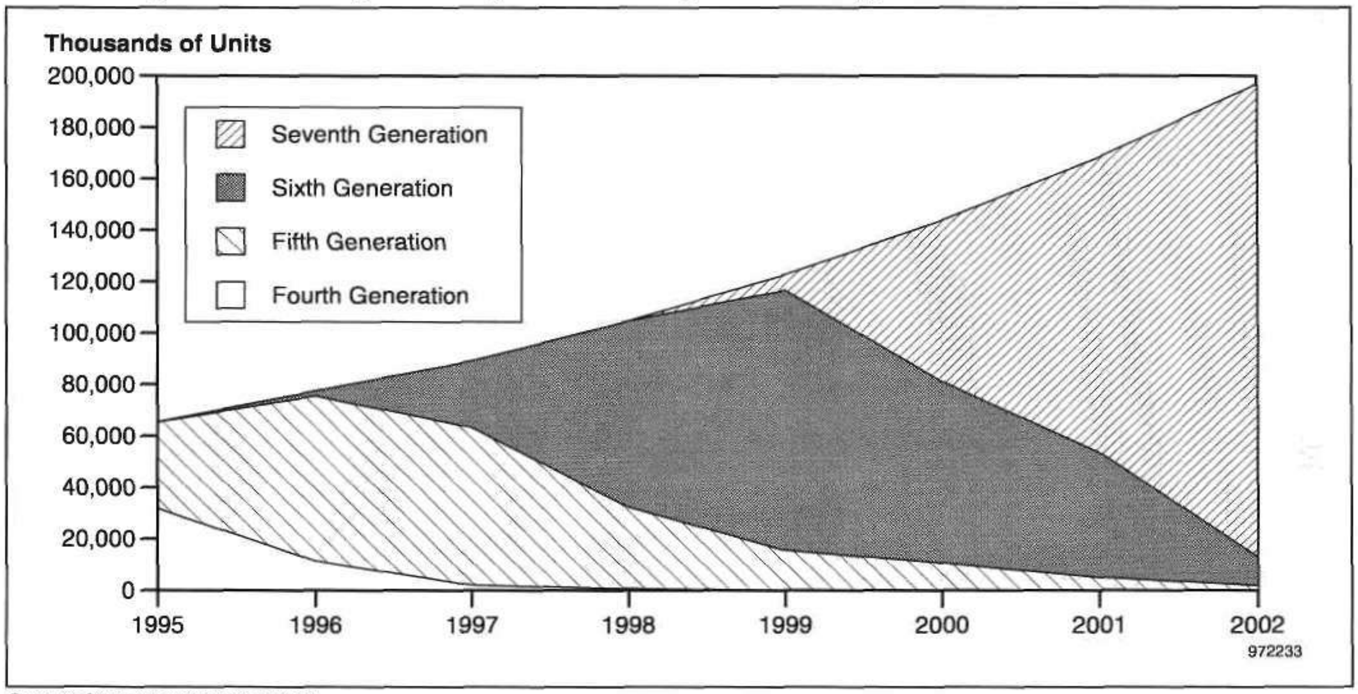
Our forecast begins, as always, with the personal computer shipment forecast created by Dataquest's Computer Systems and Peripherals group. Based on a strong Windows NT upgrade cycle in the commercial sector, along with increased PC penetration in developing economies, that group projects growth in PC unit shipments of 17 percent per year over the next three years. Dataquest's official personal computer forecast will not be extended beyond the year 2000 until later this year. For the purposes of this microprocessor forecast, the Semiconductors group has assumed unit shipment growth will continue at 17 percent in the years 2001 and 2002. (We plan to realign these later years during the next forecast cycle.) This unit demand continues to drive a robust PC industry, which in turn drives a major portion of the semiconductor industry. Table 1 and Figure 1 and Table 2 and Figure 2 detail our assumptions for PC unit volumes by microprocessor type and associated revenue for the MPUs consumed in these systems.

Table 1
x86 Microprocessor Shipments by Generation, 1996 through 2002 (Thousands of Units)

	1995	1996	1997	1998	1999	2000	2001	2002
Fourth Generation	31,804	11,400	2,087	733	0	0	0	0
Fifth Generation	33,599	64,200	61,324	31,656	15,585	10,733	5,048	1,969
Sixth Generation	100	2,000	25,770	72,345	101,056	70,528	48,547	11,212
Seventh Generation	0	0	0	0	6,074	62,563	114,679	183,699
Total	65,503	77,600	89,181	104,734	122,716	143,824	168,274	196,880

Source: Dataquest (March 1997)

Figure 1
x86 Microprocessor Shipments by Generation, 1996 through 2002



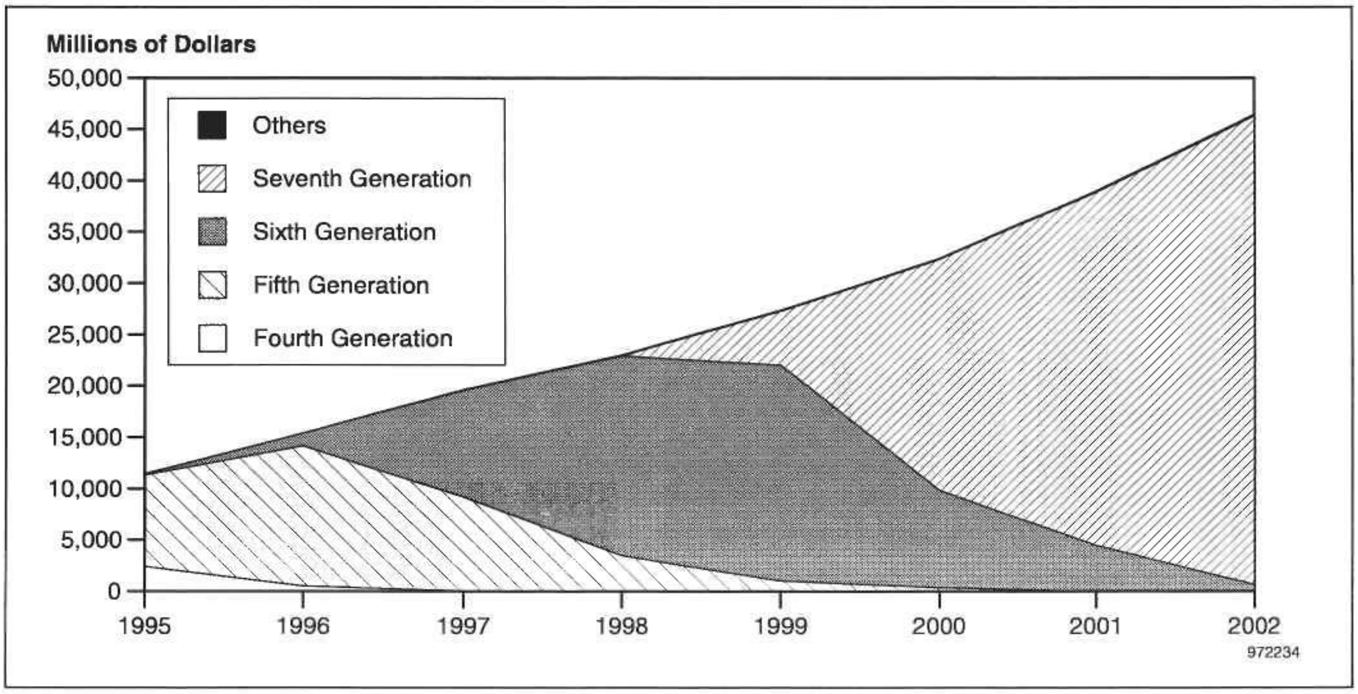
Source: Dataquest (March 1997)

Table 2
x86 Microprocessor Revenue by Generation, 1996 through 2002 (Millions of Dollars)

	1995	1996	1997	1998	1999	2000	2001	2002
Fourth Generation	2,433	518	73	23	0	0	0	0
Fifth Generation	8,910	13,629	9,139	3,462	1,019	390	0	0
Sixth Generation	90	1,250	10,356	19,457	21,008	9,465	4,489	664
Seventh Generation	0	0	0	0	5,275	22,479	34,373	45,611
Others	9	15	67	79	92	108	126	148
Total	11,443	15,412	19,634	23,020	27,394	32,442	38,988	46,423

Source: Dataquest (March 1997)

Figure 2
x86 Microprocessor Revenue by Generation, 1996 through 2002



Source: Dataquest (March 1997)

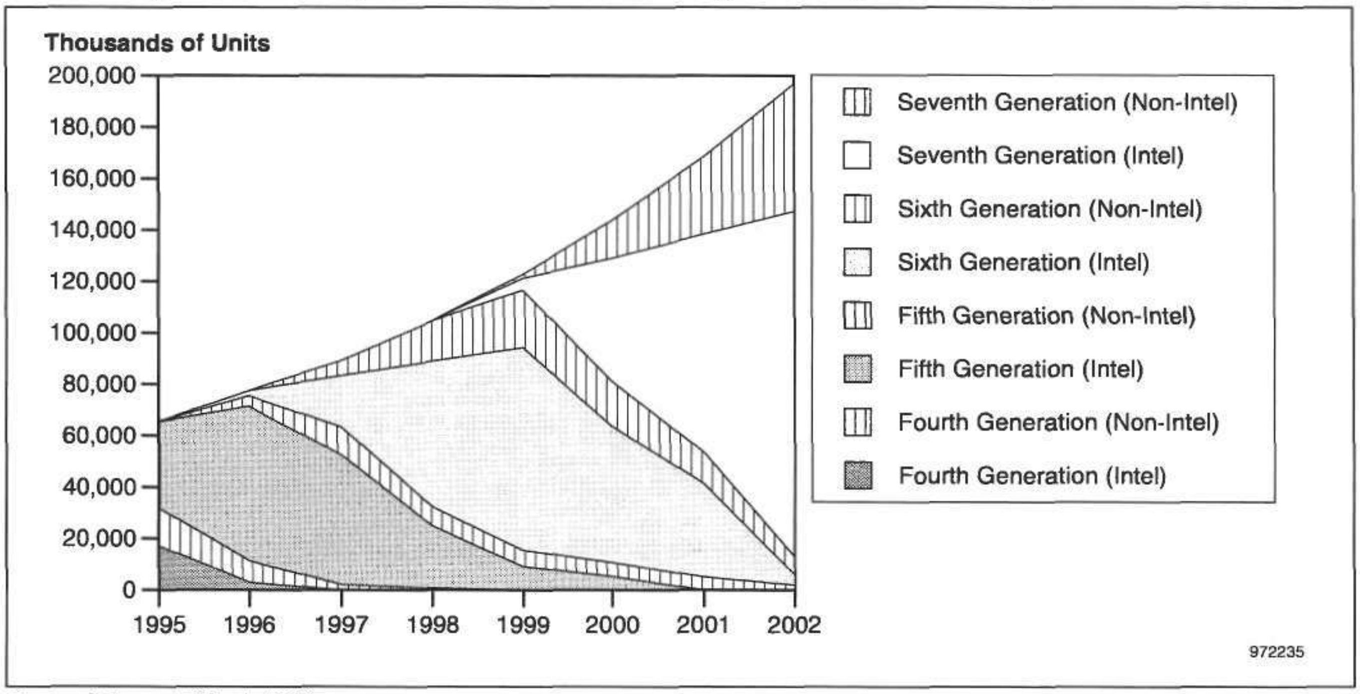
In past forecasts, Intel dominated the market to such an extent that it made little sense to assess other vendors' likely market share. Given the unique nature of the microprocessor market, which has been in many regards a "one company" market for several years, our new forecast specifically addresses the Intel and non-Intel (that is, clone) segments of the market as they may develop. Table 3 divides the processor unit shipments from Table 1 into two groups—those shipped by Intel, and those shipped by other x86 vendors. Figure 3 displays this data, sorted by microprocessor generation, while Figure 4 sorts the same data into "Intel" and "clone" categories. Historically, Intel led its competitors by several years in ramping production volume for each generation, but this gap shrinks significantly with the sixth generation. Table 4 divides the microprocessor revenue forecast into Intel and clone categories. Figures 5 and 6 display this data. In the past, the clones' late arrival to the market has restricted their ability to charge the same type of premium prices as Intel. Although Cyrix demonstrated in 1996 that prices cannot be set solely on the basis of performance, Dataquest does anticipate a significant increase in the average selling prices (ASPs) of x86 clones.

Table 3
x86 Microprocessor Shipments by Vendor, 1996 through 2002 (Thousands of Units)

	1995	1996	1997	1998	1999	2000	2001	2002
Intel								
Fourth Generation	17,157	3,000	0	0	0	0	0	0
Fifth Generation	33,549	60,000	50,453	24,272	9,265	5,303	0	0
Sixth Generation	100	2,000	20,000	56,635	78,753	53,035	36,347	4,149
Seventh Generation	0	0	0	0	4,633	47,731	84,810	134,159
Total	50,806	65,000	70,453	80,907	92,650	106,070	121,157	138,308
Non-Intel								
Fourth Generation	14,647	8,400	2,087	733	0	0	0	0
Fifth Generation	50	4,200	10,871	7,384	6,320	5,429	5,048	1,969
Sixth Generation	0	0	5,770	15,710	22,304	17,493	12,200	7,063
Seventh Generation	0	0	0	0	1,442	14,832	29,869	49,540
Total	14,697	12,600	18,728	23,827	30,065	37,754	47,117	58,572

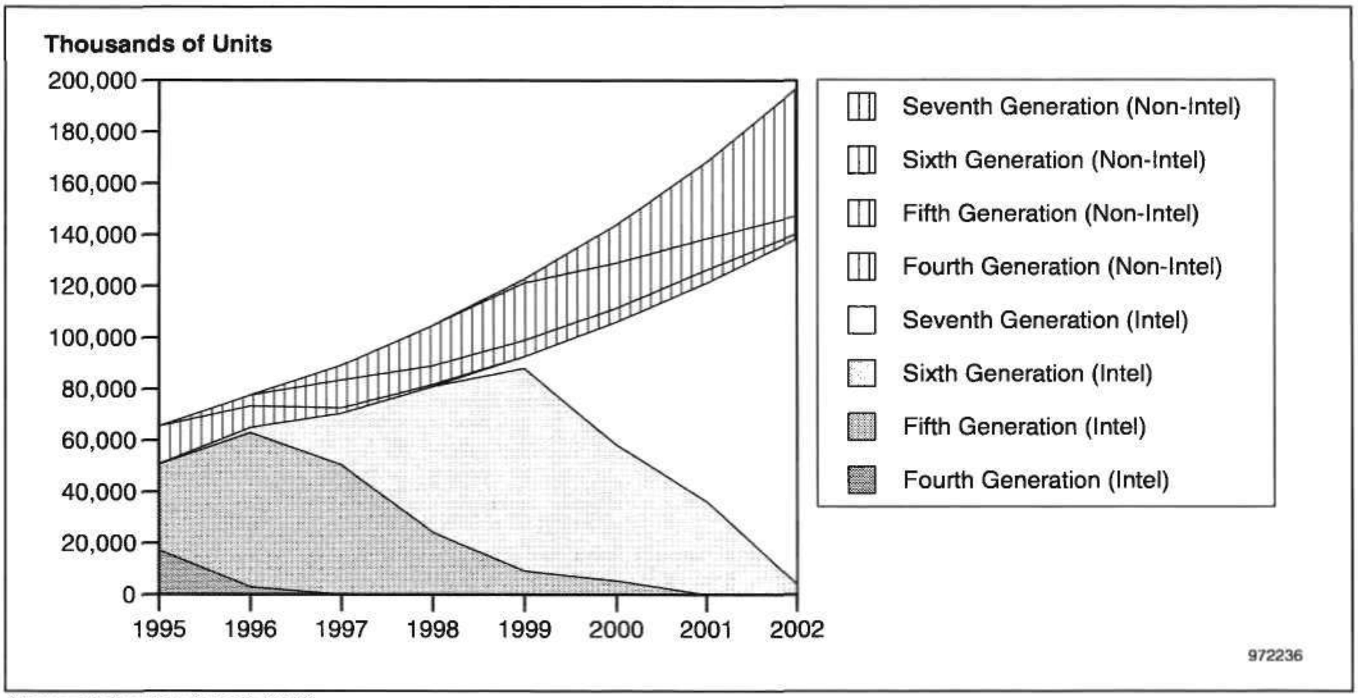
Source: Dataquest (March 1997)

Figure 3
x86 Microprocessor Shipments by Generation by Vendor, 1996 through 2002



Source: Dataquest (March 1997)

Figure 4
x86 Microprocessor Shipments by Vendor by Generation, 1996 through 2002



Source: Dataquest (March 1997)

Table 4
x86 Microprocessor Revenue by Vendor, 1996 through 2002 (Millions of Dollars)

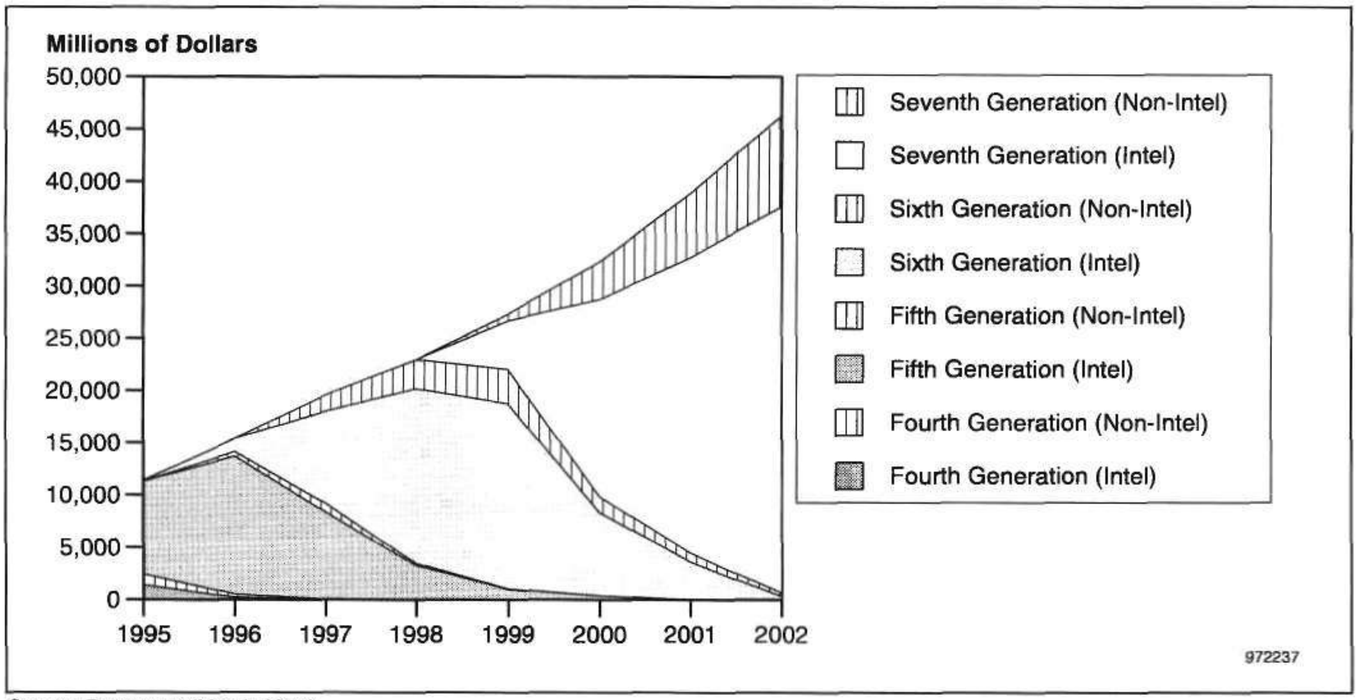
	1995	1996	1997	1998	1999	2000	2001	2002
Intel								
Fourth Generation	1,407	225	0	0	0	0	0	0
Fifth Generation	8,890	13,200	8,325	3,277	973	390	0	0
Sixth Generation	90	1,250	8,800	16,707	17,719	7,955	3,635	311
Seventh Generation	0	0	0	0	4,633	18,854	28,242	36,894
Total Revenue	10,387	14,675	17,125	19,984	23,325	27,199	31,876	37,205
Non-Intel								
Fourth Generation	1,026	293	73	23	0	0	0	0
Fifth Generation	20	429	814	185	46	0	0	0
Sixth Generation	0	0	1,556	2,749	3,288	1,510	854	353
Seventh Generation	0	0	0	0	643	3,625	6,131	8,717
Total Revenue	1,046	722	2,442	2,958	3,977	5,135	6,985	9,071

Source: Dataquest (March 1997)

Can x86 Clones Simultaneously Decrease Prices and Increase ASP?

For Intel's investors, one of the company's most attractive talents has been its ability to aggressively drive down the prices of each individual product while simultaneously increasing the average price at which it sells all its products. (Do not try this by yourself at home, unless you have a trained professional to supervise the experiment.) If Intel's competitors are to succeed on a long-term basis, they too must master this difficult juggling act. Our forecast of average selling prices for the sector as a whole, as well as Intel and the cloners separately, suggests that several can play the same game, as long as the players perform in a reasonably disciplined manner. Table 5 and Figures 7, 8, 9, and 10 spell out our assumptions regarding ASPs for the market as a whole, along with the separate behavior over time of the Intel and non-Intel ASPs. Dataquest anticipates that Intel will maintain a significantly higher ASP than its competitors, although both should be able to increase their respective ASPs.

Figure 5
x86 Microprocessor Revenue by Vendor by Generation, 1996 through 2002

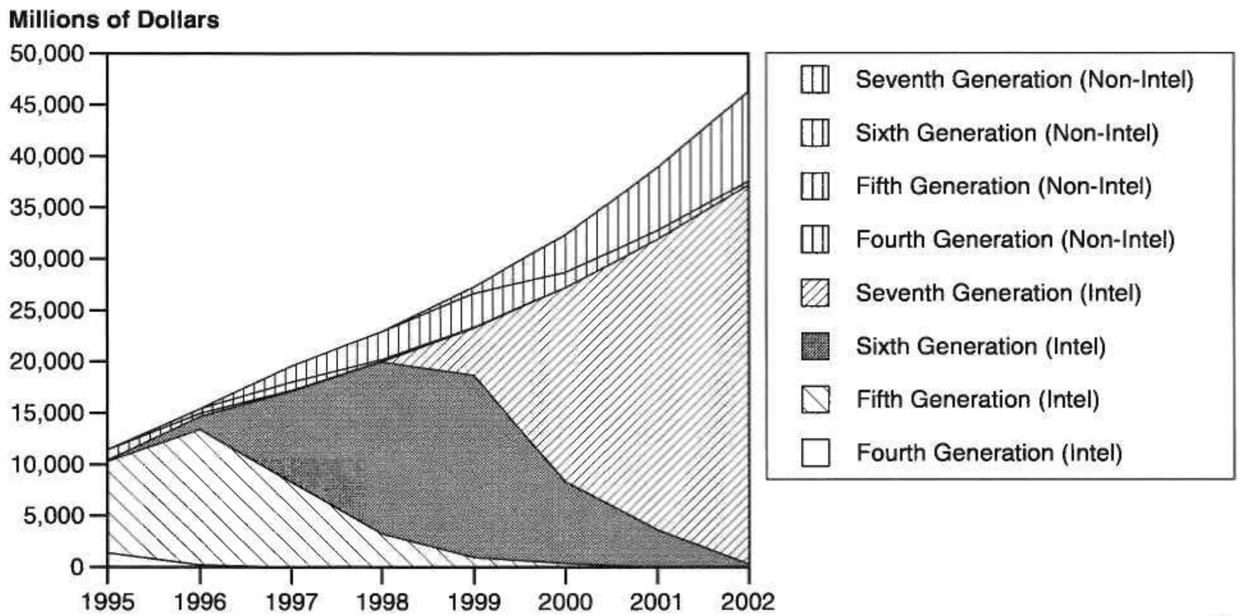


Source: Dataquest (March 1997)

Just Say "No" to Socket Stealing

As the market for PC microprocessors heats up, life will become a bit more complicated for the vendors that integrate systems. For several years, there has existed a high degree of interchangeability for basic system components; chassis from vendors A and B could accommodate motherboards from vendors X and Y, which, in turn, could accommodate processors from vendors A, C, or I. Much of the spade work to create this infrastructure was originally performed to support Intel-branded CPUs, and this simplified the task for chip vendors that followed in Intel's wake. Clone vendors simply designed their chips to work in sockets designed for Intel's products, a practice known as "socket stealing." In its newer offerings, Intel employs a variety of intellectual property measures that preclude the continuation of this practice. Competitors and manufacturing managers will soon look at the period up to now as "the good old days."

Figure 6
x86 Microprocessor Revenue by Generation by Vendor, 1996 through 2002



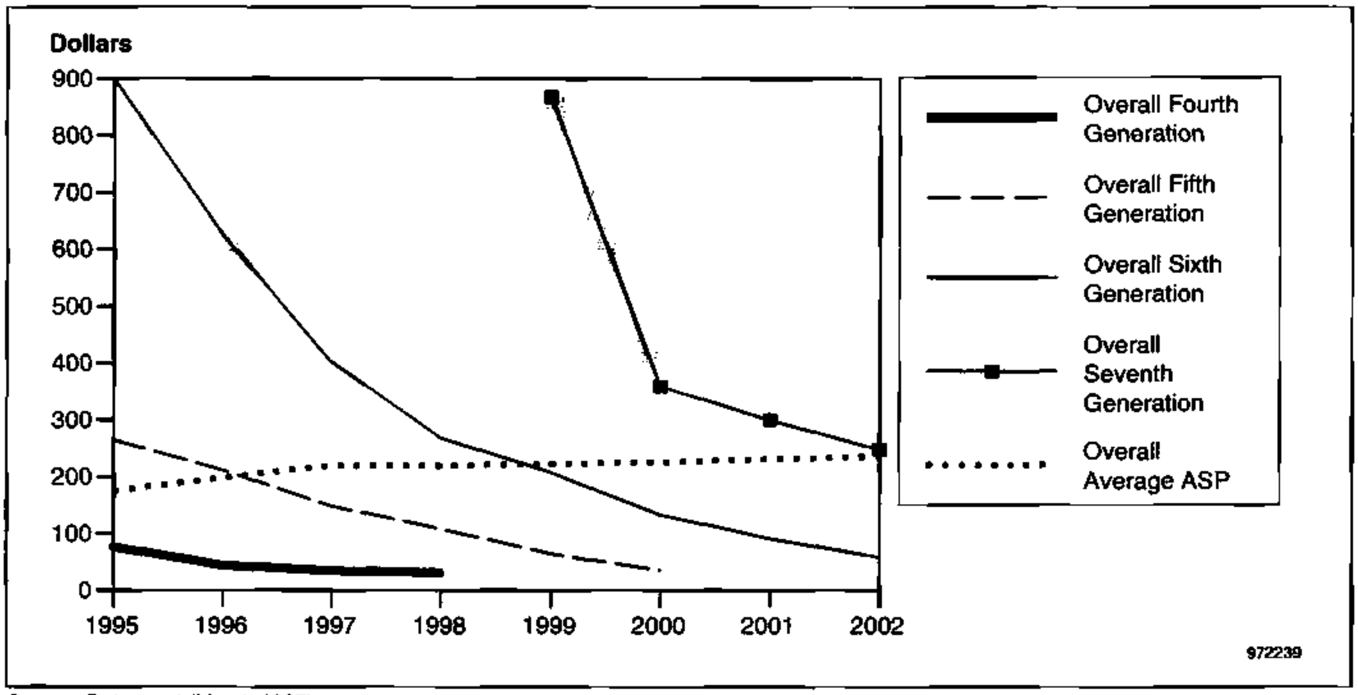
Source: Dataquest (March 1997)

Table 5
x86 Average Selling Prices, 1996 through 2002 (Dollars)

	1995	1996	1997	1998	1999	2000	2001	2002
Intel								
Fourth Generation	82	75	75	75	75	0	0	0
Fifth Generation	265	220	165	135	105	74	0	0
Sixth Generation	900	625	440	295	225	150	100	75
Seventh Generation	0	0	0	0	1,000	395	333	275
Average ASP	204	226	243	247	252	256	263	269
Non-Intel								
Fourth Generation	70	35	35	32	0	0	0	0
Fifth Generation	400	102	75	35	30	0	0	0
Sixth Generation	0	0	270	175	147	86	70	50
Seventh Generation	0	0	0	0	446	244	205	176
Average ASP	71	57	130	124	132	136	148	155
Overall								
Fourth Generation	77	45	35	32	0	0	0	0
Fifth Generation	265	212	149	109	65	36	0	0
Sixth Generation	900	625	402	269	208	134	92	59
Seventh Generation	0	0	0	0	868	359	300	248
Average ASP	175	199	220	220	223	226	232	236

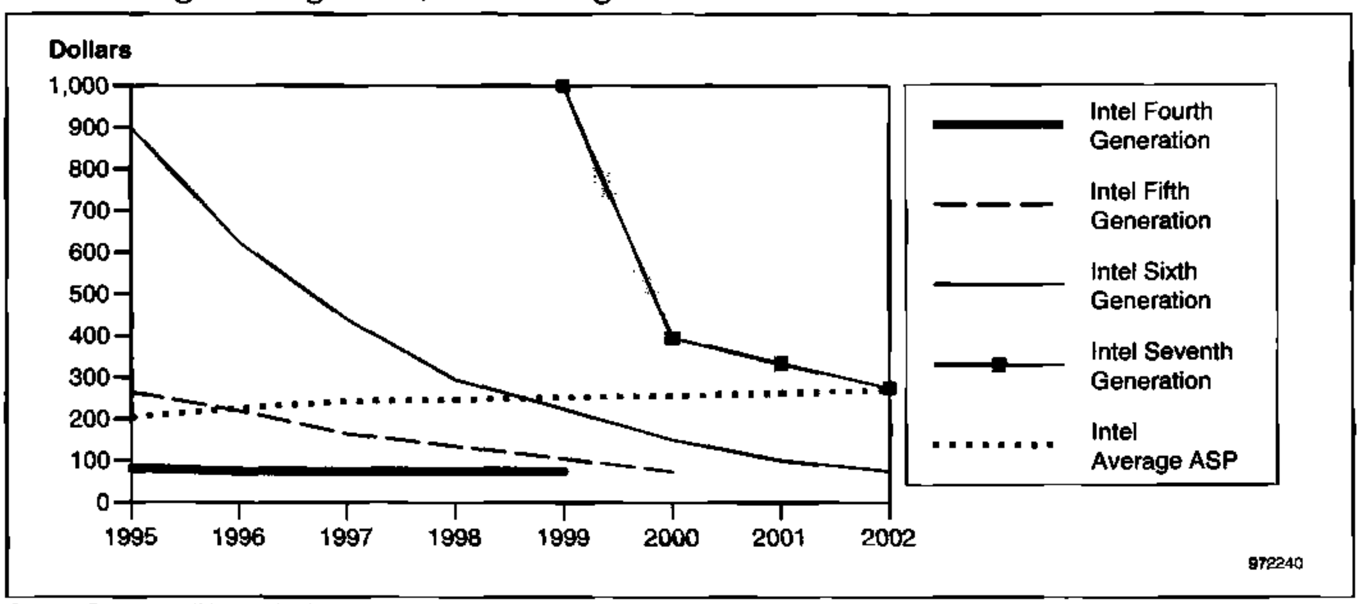
Source: Dataquest (March 1997)

Figure 7
x86 Average Selling Prices, 1996 through 2002



Source: Dataquest (March 1997)

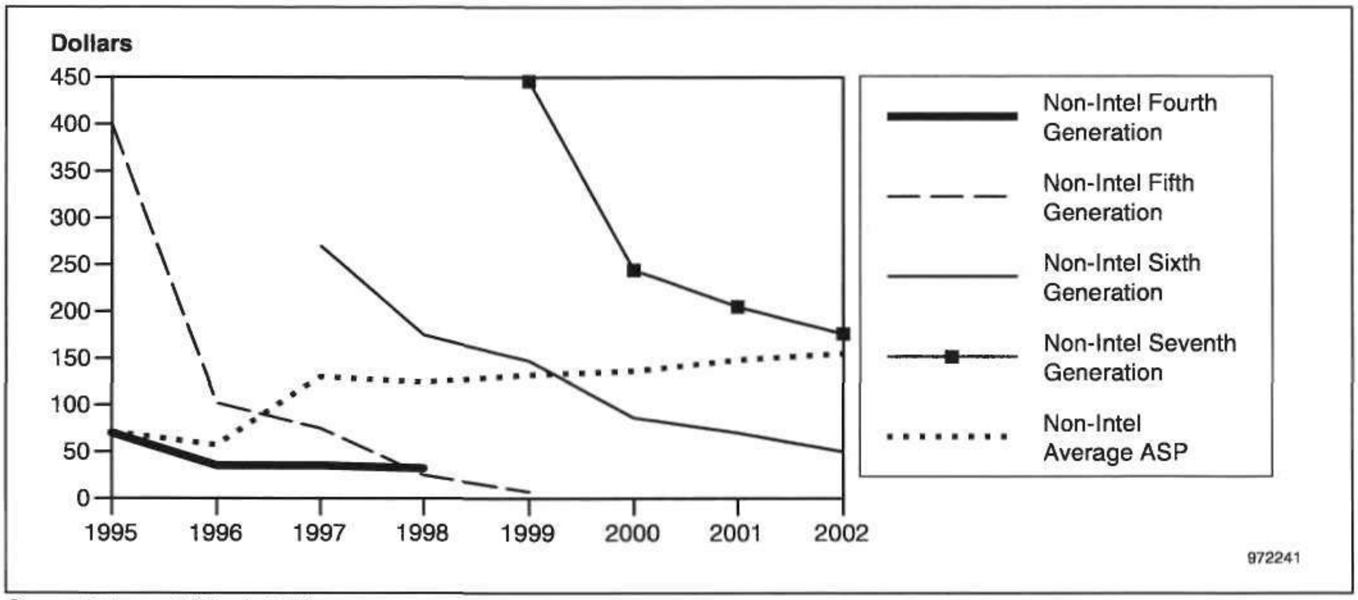
Figure 8
Intel Average Selling Prices, 1996 through 2002



Source: Dataquest (March 1997)

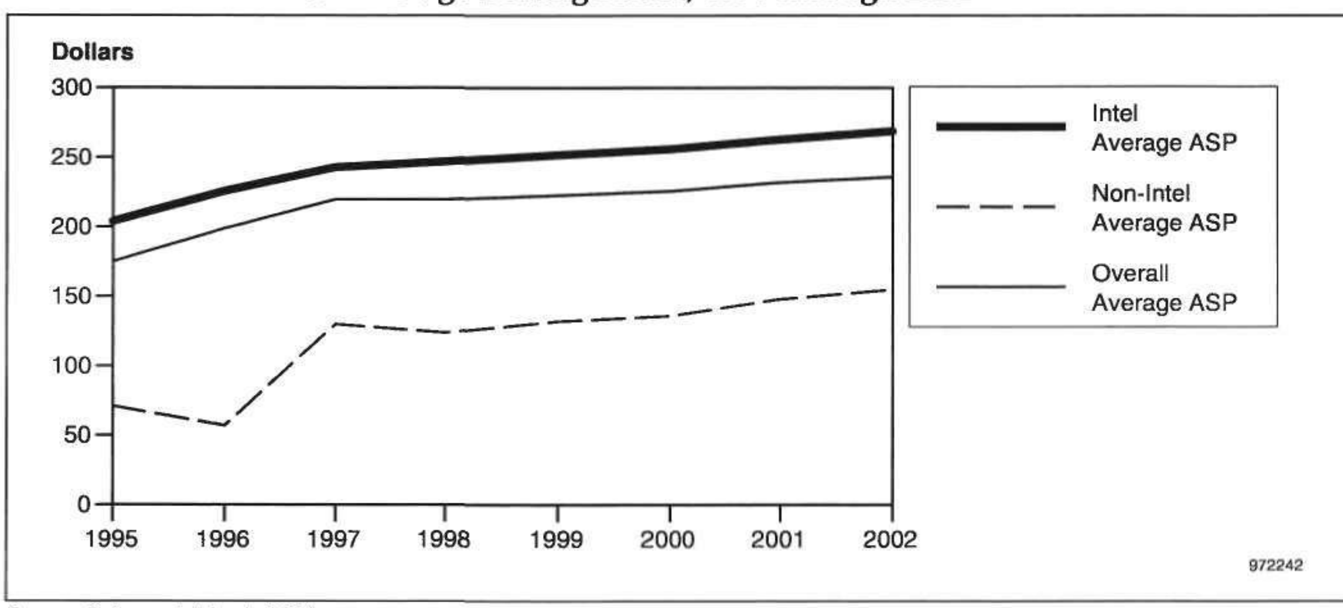
To cover the full range of processor options, vendors will need specific motherboards for Pentium, Pentium Pro, and Pentium II. They must also plan to overhaul their initial Pentium II boards later this year, when Intel starts to roll out AGP, its new high-end graphics port for Pentium II systems.

Figure 9
Non-Intel Average Selling Prices, 1996 through 2002



Source: Dataquest (March 1997)

Figure 10
Intel versus Non-Intel Average Selling Prices, 1996 through 2002



Source: Dataquest (March 1997)

Cyrix and AMD plan to stay with the current Pentium scheme (known as Socket 7), and system vendors should be able to stretch their current Pentium platforms to accommodate the clones. Even here, a change will be mandated later in the year, when AMD and other (non-Intel) chipset vendors introduce new Pentium-class chipsets that incorporate AGP.

Some x86 clones, notably the new Cyrix MediaGX product, require unique motherboards, and this complicates the picture even more. Table 6 describes all these choices, and Table 7 provides our forecast for the mix of these platforms over the next several years. Figure 11 displays these results graphically.

Table 6
Description of x86 Platform Alternatives, 1996-2002

Designation	MPUs Supported	Description
Socket 3	Intel 486, AM486, Cy486, AMx586, Cy5x86	ZIF socket for classic CPGA 486; AMD x586 and Cyrix 5x86 also used this pinout
Socket 7	Intel Pentium, Cy 6x86, Cy-M2, AMD K5, AMD K6	ZIF socket for Intel P54/P55. Dataquest includes the earlier Socket 4 and Socket 5 products in this category.
Socket 8	Intel Pentium Pro	ZIF socket for Pentium Pro Dual-Cavity Package. Incorporates Intel proprietary P6 Bus
Slot 1	Intel Pentium II	Single-edge connector (SEC) for cartridge that contains Pentium II and associated cache. Incorporates Intel proprietary P6 Bus
Proprietary	NexGen Nx586, Cyrix MediaGX	Unique pinout that requires custom-designed motherboard

Source: Dataquest (March 1997)

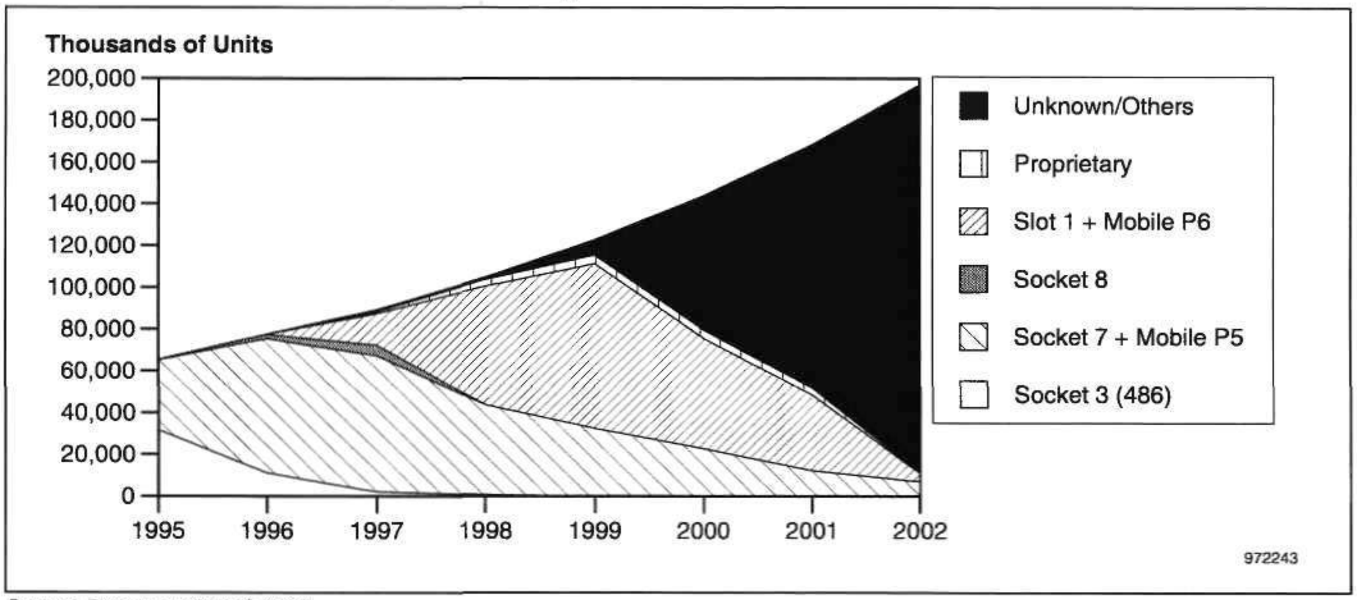
Table 7
x86 Platform Alternatives, 1996 through 2002 (Thousands of Units)

	1995	1996	1997	1998	1999	2000	2001	2002
Socket 3 (486)	31,678	11,200	2,087	733	0	0	0	0
Socket 7 + Mobile P5	33,599	64,200	65,266	43,072	32,489	22,796	12,200	7,063
Socket 8	100	2,000	5,000	0	0	0	0	0
Slot 1 + Mobile P6	0	0	15,000	56,635	78,753	53,035	36,347	4,149
Proprietary	0	0	936	3,247	4,172	3,991	3,365	0
Unknown/Others	126	200	892	1,047	7,302	64,002	116,361	185,668
Total	65,503	77,600	89,181	104,734	122,716	143,824	168,274	196,880

Source: Dataquest (March 1997)

As Intel gently nudges its customers to migrate to Pentium II platforms, the traditional Pentium platforms based on the Socket 7 design will increasingly become the domain of the non-Intel chip providers. AMD and Cyrix share a common interest in keeping this platform competitive with enhancements Intel plans for its P6 products, and both vendors could benefit from collaborative efforts in this regard. At the present time, however, such collaboration appears unlikely. Table 8 and Figure 12 display the extent to which these non-Intel processors will increasingly be plugged into the bus originally designed by Intel for its Pentium processor family.

Figure 11
x86 Platform Alternatives, 1996 through 2002



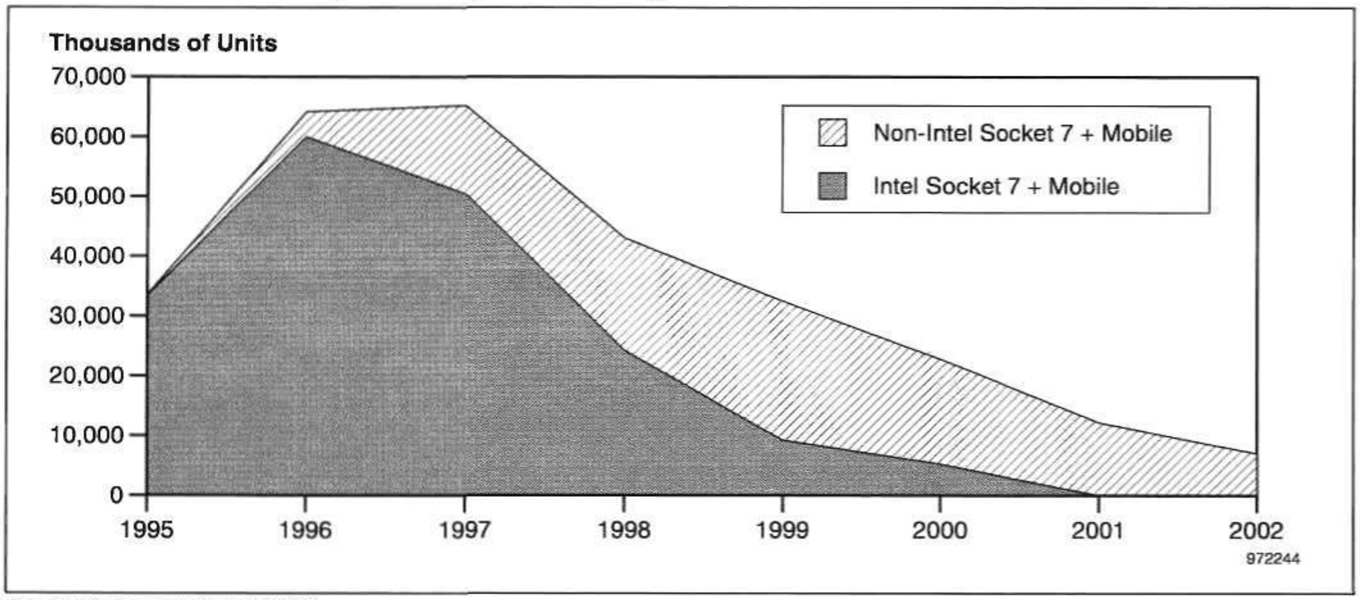
Source: Dataquest (March 1997)

Table 8
Socket 7 Utilization by Vendor, 1996 through 2002 (Thousands of Units)

	1995	1996	1997	1998	1999	2000	2001	2002
Intel Socket 7 + Mobile	33,549	60,000	50,453	24,272	9,265	5,303	0	0
Non-Intel Socket 7 + Mobile	50	4,200	14,813	18,800	23,224	17,493	12,200	7,063
Total Socket 7 + Mobile	33,599	64,200	65,266	43,072	32,489	22,796	12,200	7,063

Source: Dataquest (March 1997)

Figure 12
Socket 7 Utilization by Vendor, 1996 through 2002



Source: Dataquest (March 1997)

Sixth-Generation Transition to Gather Momentum

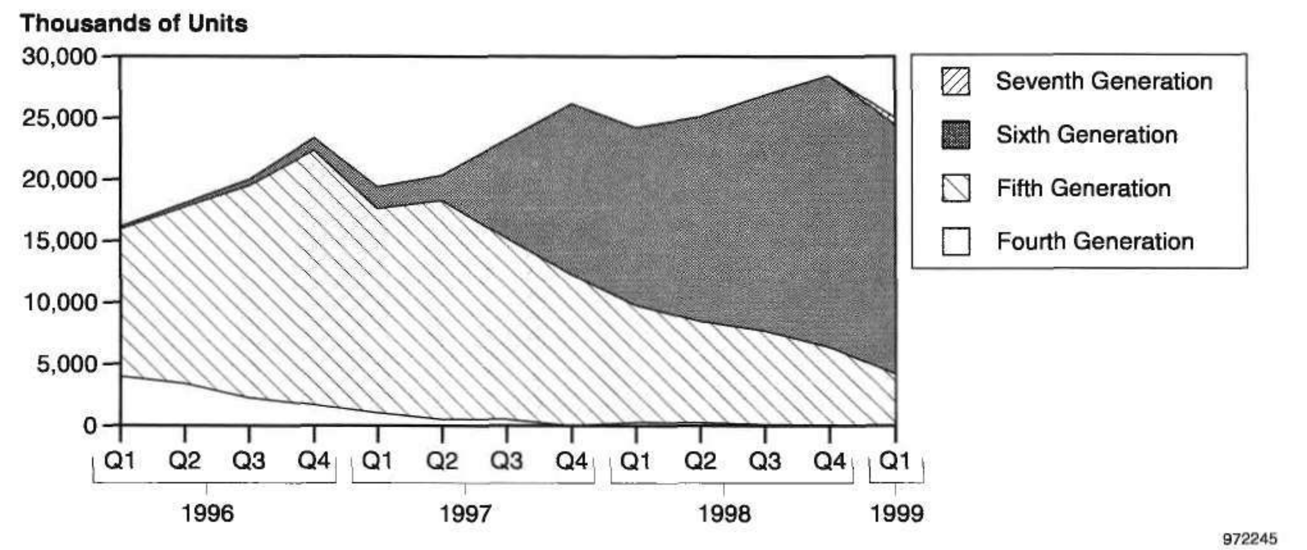
Vendors come and platforms go, processors traverse generations, and changing seasons drive the complex rhythm of the market. Table 9 and Figure 13 describe this ebb and flow as Dataquest expects it to proceed over the next eight quarters.

Table 9
x86 Microprocessor Quarterly Shipments by Generation, 1996 through 1999 (Thousands of Units)

	Fourth Generation	Fifth Generation	Sixth Generation	Seventh Generation
First Quarter 1996	3,990	11,960	200	0
Second Quarter 1996	3,420	14,352	300	0
Third Quarter 1996	2,280	17,222	500	0
Fourth Quarter 1996	1,710	20,666	1,000	0
First Quarter 1997	1,043	16,558	1,804	0
Second Quarter 1997	522	17,784	2,062	0
Third Quarter 1997	522	14,718	7,989	0
Fourth Quarter 1997	0	12,265	13,916	0
First Quarter 1998	293	9,497	14,469	0
Second Quarter 1998	257	8,231	16,639	0
Third Quarter 1998	110	7,597	19,171	0
Fourth Quarter 1998	73	6,331	22,065	0
First Quarter 1999	0	4,208	20,211	607

Source: Dataquest (March 1997)

Figure 13
x86 Microprocessor Quarterly Shipments by Generation, 1996 through 1999



Source: Dataquest (March 1997)

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Perspective

Personal Computer Semiconductors and Applications Worldwide

Market Analysis

Personal Computer Chip Market Quarterly Outlook: Demand Strong, Inventories Down

Abstract: *This quarterly update looks at the health of the personal computer market for semiconductor products. We exited 1996 with good demand and low inventories, and initial indications suggest a strong 1997, in which Intel's competitors should fare better than last year.*
By Nathan Brookwood

A Strong Personal Computer Market Continues to Drive Semiconductor Sales

Semiconductor vendors serving personal computer-related markets, with the obvious exceptions of DRAM and SRAM suppliers, turned in respectable performances during the last quarter of 1996, and Dataquest expects solid growth to continue throughout 1997. Last year's strong finish is all the more remarkable in light of the relatively modest slate of new technology-driven product introductions during the course of the year. The excitement of Windows 95 waned, and the media told buyers to wait for MMX technology, whatever that might be. Vendors compensated for the lack of new whiz-bang features by driving performance to new heights and prices to new lows. Buyers found this a tough formula to resist, unless they could talk themselves into waiting for MMX, Klamath, or any of the other new technological goodies waiting over the horizon.

Not surprisingly, the stronger a vendor's product portfolio and momentum, the better it did in 1996, and vice versa. Table 1 attempts to capture some of the more interesting measures in this regard. At one extreme, Intel reported its highest margins in memory, record revenue, and shrinking

Dataquest

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(For Cross-Technology, file in the Semiconductor Application Markets binder.)

Table 1
Personal Computer Semiconductor and System Vendor Performance, Fourth Quarter 1996

	Revenue ($K)			Q4/96 Percentage from		Gross Margin (%)			Inventory (Days)		
	Q4/96	Q3/96	Q4/95	Q3/96	Q4/95	Q4/96	Q3/96	Q4/95	Q4/96	Q3/96	Q4/95
Microprocessor Vendors											
Advanced Micro Devices	496,800	457,000	595,029	9	-17	29	26	39	39	44	38
Cyrix Corporation	72,100	33,100	39,100	118	84	21	34	8	39	213	31
Intel Corporation	6,440,004	5,142,000	4,580,000	25	41	63	57	48	49	56	75
Motorola Inc.	7,685,002	6,498,000	7,298,000	18	5	25	22	26	50	61	59
Peripherals Vendors											
Analog Devices Inc.	292,100	304,647	280,769	-4	4	49	50	51	128	129	103
ATI Technologies	164,000	116,000	119,000	41	38	29	28	24	32	26	60
Cirrus Logic Inc.	253,309	236,030	295,783	7	-14	38	38	33	74	88	76
ESS Technology Inc.	76,679	60,138	31,389	28	144	51	51	64	79	96	116
LSI Logic Corporation	301,788	300,195	349,601	1	-14	45	42	49	49	56	70
National Semiconductor	661,500	566,100	711,600	17	-7	35	30	44	55	69	69
Rockwell International	2,608,003	2,661,003	3,094,000	-2	-16	25	24	25	82	92	76
S3 Inc.	132,063	119,440	103,536	11	28	41	39	40	63	65	63
VLSI Technology Inc.	183,573	182,959	182,311	0	1	42	40	40	47	51	50
3Com Corporation	820,002	706,968	563,544	16	46	55	54	53	57	63	66
System Vendors											
Apple Computer Inc.	2,129,000	3,003,000	3,148,000	-29	-32	19	21	15	25	25	66
Compaq Computer Corporation	5,422,003	4,481,002	4,701,000	21	15	24	24	22	25	39	53
Dell Computer Corporation	2,412,000	2,019,000	1,538,775	19	57	22	22	18	12	12	31
Gateway 2000 Inc.	1,552,831	1,202,933	1,245,233	29	25	20	19	18	20	19	20
IBM	23,140,004	18,062,002	21,920,000	28	6	40	40	42	53	60	45

Source: Dataquest (March 1997)

inventories. At the other extreme, Advanced Micro Devices Inc. continued to struggle to turn itself around, following its earlier problems bringing its K5 processor to market with competitive performance. It saw its revenue drop 17 percent, while margins fell, inventories built, and red ink flowed. S3 Inc. and ATI Technologies Inc. turned in strong performances, largely at the expense of Cirrus Logic Inc.. In the systems arena, Dell Computer Corporation, Compaq Computer Corporation, and Gateway 2000 Inc. all displayed strength, while Apple Computer Inc.'s results continued to suggest that the company still has more work to do to turn itself around.

On a relative basis, the situation improved over the third quarter for all but a very few vendors. Gross margins improved by a few points, and inventories contracted by a few days. All in all, 1996 finished much better than 1995, and far better than the weak start of 1996 might have suggested. Most important, system vendors exited the year with modest inventories, thus precluding the need for a messy correction like the one that marred the start of the year. Even at Apple, where revenue fell by 32 percent from the final quarter of 1995, inventories sat at only 25 days, compared with the bloated 66 days for the prior year.

Processors and Core Logic: Intel Stuns, Cyrix and AMD Stunned

Intel Corporation blew through everyone's expectations. Fourth quarter sales rose 41 percent from 1995's fourth quarter and rose 25 percent from the September quarter. Gross margins, at 63 percent, increased dramatically over the 48 percent tallied in 1995. Net income did not quite reach $2 billion, but as they say in baseball, "wait until next year." Intel explained its success in terms of "a favorable product mix," which means it sold lots of fast Pentium processors (with much higher margins than the slower Pentiums) and fewer of the low-margin motherboards that dragged its margins down in 1995. During the first quarter, Intel made several noteworthy additions to its line. It finally launched the Pentium Processor with MMX Technology, the catchy new name it assigned to its P55C microprocessor. The new processor's larger caches increase its performance about 15 percent, even at the same clock speeds as earlier models. Although larger caches do most of the work, 57 new multimedia instructions get most of the glory. The new instructions improve the CPU's ability to handle video, graphics, and audio functions and should ultimately lower the price of entry-level systems.

Throughout the Christmas selling season, there had been much speculation regarding the impact the anticipated MMX announcement would have on fourth quarter sales and first quarter returns and exchanges. Now that we are through the worst of this transition, it appears that the concerns were overstated. System vendors have moved to the new MMX models with scarcely a hiccup, and consumers decided not to go through the hassle of returning or exchanging the systems they found under their Christmas trees in order to get the absolutely latest technology. Well, the election was over, and the newspaper reporters needed *something* to write about.

In February, Intel introduced a new mobile module intended to let notebook vendors more quickly assimilate new processors into their lines. The new scheme places the microprocessor and supporting components on a daughtercard. System vendors can now incorporate new processor modules (almost) as easily as desktop vendors plug in a new processor. It would be easy for AMD or Cyrix Corporation to adopt this new module format and thus gain technical entry to the mobile market. (Neither has given any indication of its intent to do so, however.)

Along with the new mobile module, Intel introduced its 430TX chipset with synchronous DRAM capability, a feature its predecessor (the 430HX) lacked. Intel's Pentium Pro and Klamath chipsets will not support SDRAM until the second half of the year, with the expected launch of its 440LX chipset. Following that introduction, system vendors will have the ability to use SDRAM with all configurations, from the least expensive Pentium systems to the fastest Pentium IIs. This should pave the way for a massive shift from EDO to SDRAM memory technology by the end of the year.

During the quarter, AMD displayed increasing indications that its microprocessor act is finally coming together. It began shipping its AMD-K5-PR166 processor and announced that Acer America will use this part in its AcerEntra value-priced desktop computer line. AMD also commenced sampling its K6 microprocessor, intended to compete with Intel's Pentium Pro, and hinted that the product might be launched in the second quarter, more or less on the schedule presented immediately following the NexGen acquisition in 1995.

The new, post-Mr. Rogers Cyrix gave off renewed signs of life, as the company introduced its MediaGX processor, which lets PC manufacturers deliver fully featured systems at price points below $1,000. Compaq incorporated the MediaGX into its new $999 Presario 2100. Cyrix spent most of 1996 in a futile search for a customer with a recognizable brand. For Cyrix, Compaq's use of the MediaGX processor represents a new degree of acceptance within the OEM community and demonstrates that major system vendors will use microprocessors that lack the "Intel Inside" logo when it makes technical and business sense to do so. For Compaq and the industry, the lasting impact of the Presario 2100 may be that it legitimizes the sub-$1,000 PC category.

3-D: Coming Soon to a Personal Computer near You

3-D graphics is becoming pervasive. It is still unclear what killer apps other than PC gaming will drive PC buyers to demand 3-D acceleration, but the fact is that PC buyers will get 3-D whether they demand it or not. 3-D acceleration will spread like wildfire through desktop PCs over the next two years and will start in notebook PCs in the second half of this year. The software developer who creates the killer 3-D app for commercial markets will likely be nominated for a Nobel Prize by the 3-D hardware developers and Intel.

The established 3-D suppliers, S3 and ATI, now are shipping enhanced versions of their initial products, VIRGE GX and DX for S3 and RAGE II for ATI. Cirrus has finally begun volume shipments of Laguna3D. Others, like Trident Microsystems, have begun sampling aggressively priced desktop 3-D accelerators. Specialty players like 3Dfx, 3Dlabs, and Rendition are all trying to mark their niches. The market eagerly awaits the arrival of Auburn, Intel's AGP-based 3-D controller, being developed jointly by Intel, Lockheed-Martin, and Chips & Technologies. Dataquest anticipates that, unlike Intel's entry into the core logic chipset market, where it quickly dominated, established graphics market will prove more resistant to Intel's graphics entry. We do not expect any single player, even Intel, to achieve a dominant position with regard to 3-D offerings.

Two suppliers have announced LCD-enabled 3-D graphics products, and others are sure to follow. You are at risk if you do not have 3-D acceleration in your notebook graphics road map for product introductions in 1997 and volume shipments by early 1998. Trident Microsystems Inc., an established notebook graphics supplier, and ATI Technologies, an established 3-D supplier, have both announced products. Trident's Cyber9397 LCD graphics controller includes more of the 3-D pipeline than ATI's 3-D notebook chip. ATI is using 3-D as its entry into the mobile graphics market.

A Wave of New Digital Audio Products

Time is running out for the traditional "FM synthesis" technology used to generate sounds on personal computers. Wave table technology makes better music but has commanded too much of a premium for entry-level systems. Software running on MMX-enabled processors sounds better than FM-generated sound and should toll the knell of this technology. Suppliers of hardware-based wave table devices still have a future; even with MMX, hardware wave table sounds better than software wave table.

During the quarter, Crystal Semiconductor Corp. introduced the industry's first single-chip solution that offers high-quality wave table synthesis for PC multimedia applications. The CS9236 integrates the entire wave table synthesizer system—Musical Instrument Digital Interface (MIDI) controller, synthesis engine, sample ROM, effects processor, and effects RAM—into a single integrated circuit.

Watch This Space for Future Announcements

At last month's International Solid-State Circuits Conference, Intel's designers presented a paper on their as-yet-unannounced processor known as Klamath, a 7.5 million transistor Pentium Pro follow-on that runs at speeds up to 400 MHz. Intel plans to manufacture this chip on its current high-volume 0.35-micron process and then, for an encore, will shrink it to 0.25-micron geometries. Intel's willingness to claim that the part can run at speeds up to 400 MHz (albeit under far-from-ordinary operating conditions), suggests an increased confidence in process and processor. Dataquest anticipates that the initial commercial versions of this part will run at speeds well below 300 MHz, but the head room potential of this new MPU should make it an impressive competitor. Watch for an announcement in May or June.

At that same conference, Advanced Micro Devices revealed technical details regarding its forthcoming K6 MPU, intended to compete with Intel's Klamath. The K6, derived from the Nx686 AMD acquired with NexGen last year, has the potential to put AMD right back in the mainstream microprocessor market, if AMD continues its smooth execution and launches the product on schedule next quarter. A few weeks later, at the Robertson, Stephens and Company conference in San Francisco, AMD threw down the gauntlet and suggested it hopes to achieve a 30 percent share of the market by the year 2000. Watch for an announcement in April or May.

Also at ISSCC, The IBM/Motorola Somerset design group discussed their new G3 PowerPC, a product heretofore spotted only on road maps. Motorola has previously indicated that it expects this new chip to be shipping in systems by the middle of this year.

At the recent Macworld Expo show, Exponential Technology Inc. announced that it had completed a $13.2 million, third round of venture financing and would soon commence manufacturing its PowerPC microprocessor. It intends to ship production units of the 466-, 500-, and 533-MHz chip in the second quarter. Apple and several Mac clone vendors have already indicated their intent to pop this new CPU into high-end products soon after it hits the market. This new chip should offer users of compute-intensive Mac applications like PhotoShop the opportunity to turbocharge their environments and improve their productivity, way beyond what folks sitting at Wintel-based systems can achieve. In the leapfrog contest for the most CPU performance, the Exponential 704 should let Apple and Mac clones make one heck of a leap. Watch for a second quarter announcement.

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Perspective

Personal Computer Semiconductors and Applications Worldwide

Product Analysis

WebTV: An Early Example of Convergence between Computing and Consumer Electronics

Abstract: *Speculation about the convergence of computing and digital consumer electronics is creating quite an industry buzz. Many semiconductor vendors who traditionally supply the PC industry are asking how they can tap the consumer electronics market as new digital consumer products hit the streets. This Perspective examines the semiconductor content of a WebTV Internet terminal as an indicator of future convergence opportunities for PC semiconductor suppliers.*

By Geoff Ballew

What Is WebTV?

WebTV Networks Inc. is a California-based company that has a vision of millions of consumers surfing the Internet with low-cost terminals instead of PCs. The company is working to make this vision become reality by licensing a reference design for a low-cost Internet terminal as well as providing online services, including Internet access, for those terminals. The basic idea is a set-top box that sells for about $300 and connects to the user's TV for a display. A user purchases a WebTV terminal, hooks it up to a TV and a standard telephone line and is automatically connected to the WebTV online service. The service is required but is priced competitively with other online services at $19.95 per month for unlimited access.

Revenue for WebTV Networks comes from both license fees for the reference design as well as monthly service revenue from the users themselves. The reference design includes a custom chip manufactured by NEC as well as many off-the-shelf components. Two consumer electronics companies, Sony

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and Philips, have licensed the WebTV reference design so far and both companies had product in the retail channel for Christmas 1996.

What's Inside a WebTV box?

Dataquest performed a system teardown specifically to answer this question. The heart of the system is a microprocessor and a large ASIC containing system logic and the graphics processor. Memory (ROM, flash, and SGRAM) and a handful of peripheral ASSPs round out the system. Figure 1 illustrates the board layout of the Sony WebTV design. Following is a list of the major semiconductor components in the Sony WebTV terminal:

- MIPS R4640 with DSP enhancements
- Custom graphics processor with system logic
- 2MB mask ROM, two 8Mb chips, 512Kx16 organization
- 2MB flash memory, two 8Mb chips, 512Kx16 organization
- 2MB SGRAM, two 8Mb chips, 128Kx32x2 organization
- Controllerless V.34 modem chipset
- Keyboard controller
- TV encoder

What Does a WebTV Box Cost?

The Sony WebTV product was introduced at a retail price of $329 and dropped below $300 in January. The cost to produce a WebTV terminal is much lower, and, in fact, is low enough to provide some margin for the OEM as well as the retailer. In this respect, the WebTV terminal is more like a PC than some other digital, consumer electronics products. Two consumer electronics products that are often sold at a loss (or at least near cost) are home video game consoles and satellite set-top boxes. WebTV terminals do not appear to be following this "razor-blade" marketing (give buyers the razor handle, then sell them blades for profit).

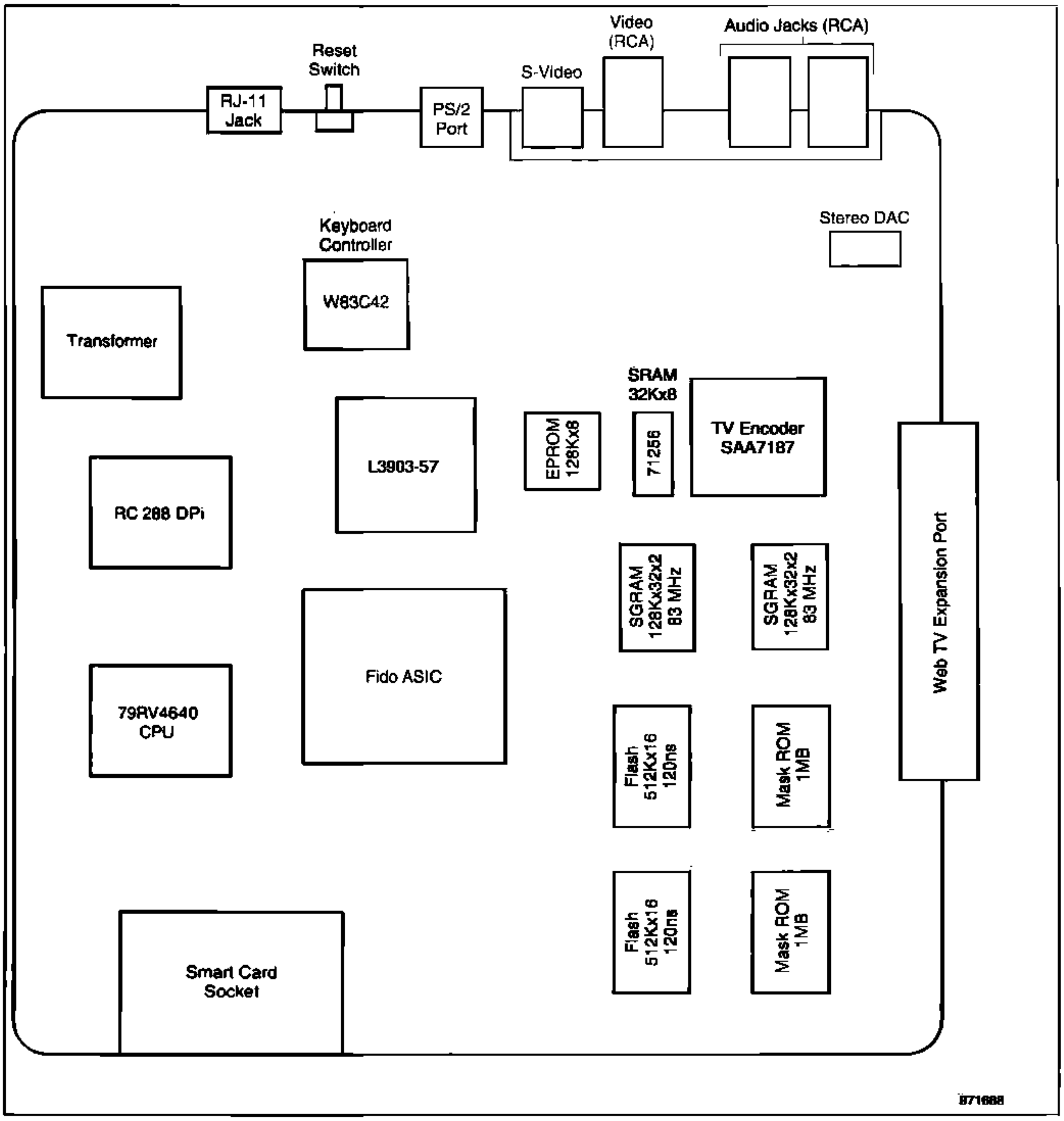
System Costs

Dataquest believes the manufacturing cost of the Sony WebTV product to be well under $200. Figure 2 shows the estimated costs by major subsystem and Table 1 presents the actual dollar estimates.

Semiconductor Opportunity

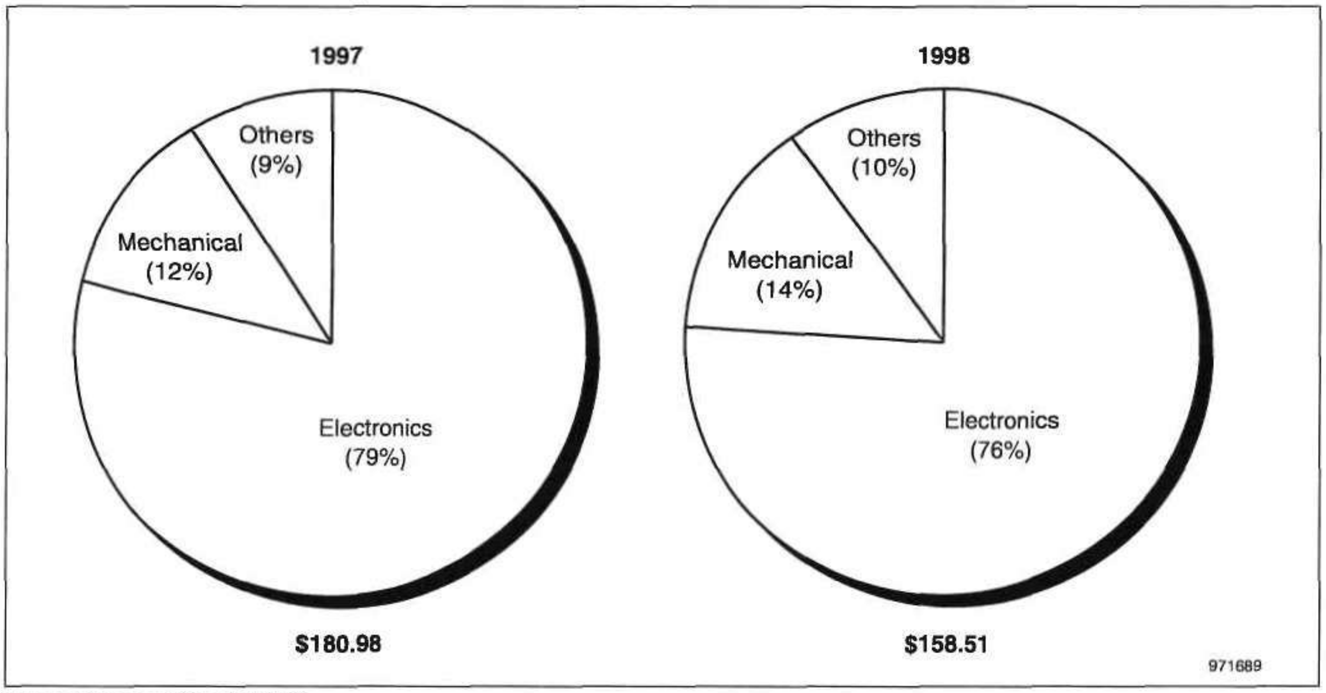
The semiconductor content of the Sony WebTV terminal is two-thirds of its production cost. Microcomponents provide most of the functionality and command the lion's share of the semiconductor dollars. Memory is also a vital part of the system. ROM is used to store the operating software with flash memory for software updates and new features.

Figure 1
Board Layout of the Sony WebTV Design



Source: Dataquest (March 1997)

Figure 2
Estimated Costs for Sony WebTV Terminal



Source: Dataquest (March 1997)

Table 1
Estimated Costs for Sony WebTV Terminal (Dollars)

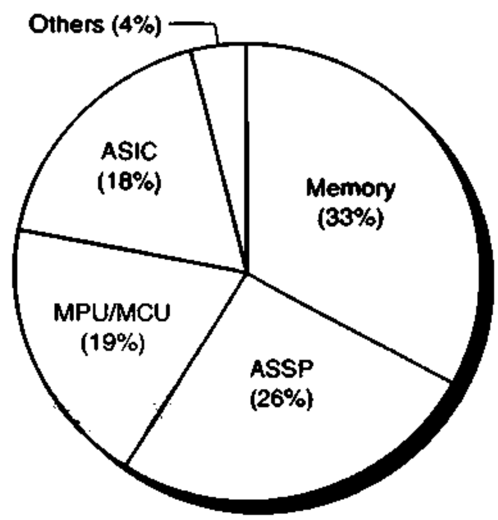
	1997	1998	Two-Year Average
Electronics			
Audio Subsystem	3.43	3.36	3.40
Central Electronics Subsystem	65.70	56.40	61.05
Communications Subsystem	28.48	21.94	25.21
Graphics Subsystem	14.26	12.22	13.24
Printed Circuit Boards (PCBs)	5.88	5.76	5.82
Power Subsystem	4.90	4.80	4.85
Processor	20.16	16.13	18.14
Total Electronics	142.82	120.62	131.72
Mechanical			
External Cables	7.65	7.65	7.65
Mechanical Subsystem	8.88	8.74	8.81
Remote Control	5.16	5.06	5.11
Total Mechanical	21.69	21.45	21.57
Assembly	10.00	10.00	10.00
Packaging	5.00	5.00	5.00
Publications	1.47	1.44	1.46
Grand Total	180.98	158.51	169.74

Source: Dataquest (March 1997)

Semiconductor Content per System

Figure 3 shows the distribution of semiconductor content among several product categories with the actual data listed in Table 2. The comparison of costs between 1997 and 1998 assumes that the components do not change even though minor upgrades, such as a 56K modem instead of V.34, are likely. These numbers exclude the semiconductor content of the power supply and remote control.

Figure 3
Semiconductor Content for Sony WebTV Terminal (Dollars)



Source: Dataquest (March 1997)

Table 2
Semiconductor Content for Sony WebTV Terminal (Dollars)

	1997	1998	Change (%) 1997-1998
ASSP	30.39	23.83	21.6
Memory	40.07	33.25	17.0
MPU/MCU	22.16	18.13	18.2
ASIC	21.79	17.43	20.0
Others	4.74	4.71	0.6
Total	119.15	97.34	18.3

Source: Dataquest (March 1997)

Overall Market Opportunity

The size of the semiconductor market for a given application, such as Internet terminals, is important, but is not the focus of this document. The bigger picture comes from using the WebTV terminal as an example of many digital consumer electronics products. Dataquest classifies many new, digital consumer products as "next-generation" consumer electronics products. This category includes digital cable set-top boxes, digital satellite set-top boxes, DVD video players, video CD players, home video game consoles, HDTV receivers, digital cameras, and other products.

The Dataquest forecast for the total ASIC and ASSP semiconductor revenue for these products is $2.6 billion in 1997. The forecast climbs to $5.6 billion for the year 2000 with ASSP revenue topping $4 billion in that same year. That $4 billion segment is a new part of consumer electronics semiconductor market where traditional PC semiconductor suppliers might compete effectively. Even marginal penetration of this $4 billion market could boost a company's revenue by tens or hundreds of millions.

Sockets: Who Has Them

The WebTV design is a mix of ASIC and standard product semiconductor devices. This variety opens the door of opportunity for virtually all major semiconductor suppliers to compete and potentially supply components. The high level of integration and high pin count for the custom graphics processor does limit the competition for that socket to top-tier ASIC suppliers. A much broader opportunity exists for the ASSPs and memory products. Suppliers who traditionally sell semiconductors for PCs will find opportunity to compete for the modem chipset, keyboard controller, TV encoder, and audio DAC. The memory components are commodity products, but the 5V-write feature of AMD's flash memory is critical because this design does not include a 12V supply like the PC. Table 3 shows the suppliers of key semiconductor components.

Table 3
Semiconductor Suppliers for Sony's WebTV Terminal

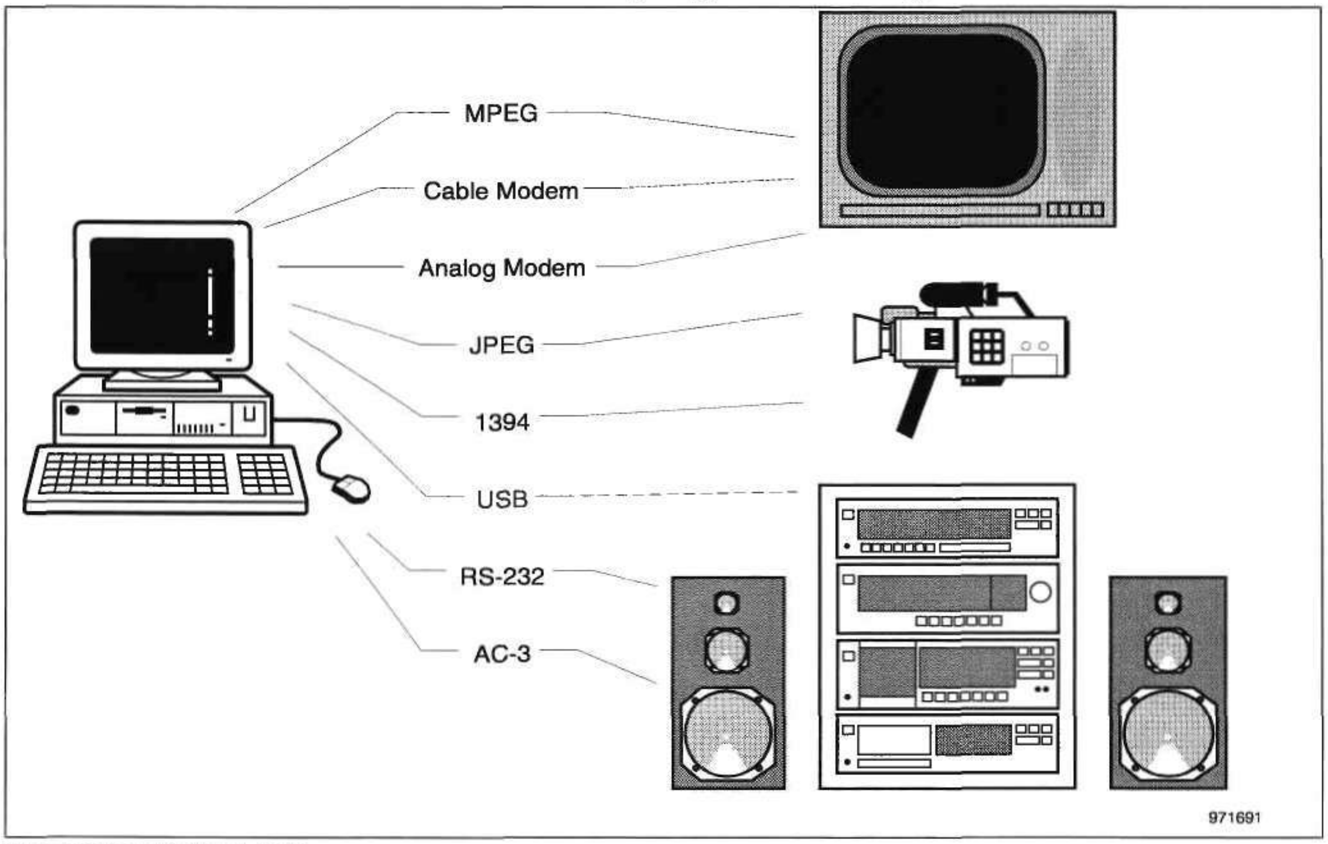
Product	Supplier
Microcomponents	
MPU	IDT
Graphics Processor (ASIC)	NEC
Modem Chipset	Rockwell Semiconductor
Keyboard Controller	Winbond
TV Encoder	Philips Semiconductor
Audio DAC	Asahi Kasei
Memory	
SGRAM	NEC
Flash	AMD
ROM	Samsung

Source: Dataquest (March 1997)

Opportunity for PC Semiconductor Suppliers

This new, digital consumer market does offer opportunity for PC semiconductor suppliers because many of the same technologies are required in each market. PC semiconductor companies are accustomed to driving the latest technology and standards into products at commodity prices. Additionally, they are adapted to providing incremental improvements to products and aggressively competing for design-wins every six months. Figure 4 shows a number of digital technologies that overlap the PC and consumer electronics markets.

Figure 4
PCs and Consumer Electronics Share Many Digital Technologies



Source: Dataquest (March 1997)

Dataquest Perspective

WebTV is an exciting example of the convergence of computing and consumer electronics. It demonstrates an opportunity for PC peripheral chipset suppliers to sell to a new market—the consumer electronics market—as that market incorporates more digital technologies. This market is not a panacea for market expansion, though, because of the historical and continuing differences between the PC and consumer electronics markets.

PC semiconductor markets are characterized by standard products interfacing via standard interfaces. At this time there is no equivalent to the PCI bus for consumer electronics. Standard interfaces do exist in the consumer electronics world, but they do not have the ubiquity that bus architectures in the PC world have. Consumer electronics is largely a mixture of ASIC and ASSP while the PC semiconductor market is easily characterized as ASSP.

Semiconductor suppliers who currently sell to the PC market and wish to target the consumer electronics market should proceed with cautious optimism. Dataquest recommends that PC semiconductor suppliers evaluate their core competencies with respect to those that differentiate them from their traditional competitors as well as have impact for consumer markets.

One specific example is TV output for PC graphics chips. Trident Microsystems probably has the best TV output of the major graphics vendors and may be able to leverage this feature for consumer electronics applications. Another example is PC audio. Crystal Semiconductor sells audio components into the PC market as well as the consumer and professional audio markets based on the quality of their DACs. Familiarity with both sides of the audio chip market could give Crystal an edge in the convergence markets. Other vendors should critically evaluate their own core competencies for specific examples and only pursue those areas where they can clearly differentiate themselves.

Bringing a "me-too" solution to the convergence market is unlikely to be rewarding. Those products that truly offer differentiation are the tickets to success in this emerging market.

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Perspective

Personal Computer Semiconductors and Applications Worldwide

Market Analysis

1996 Microcomponent Revenue Increases 16 Percent

Abstract: *Paced by rapid growth in compute microprocessor and DSP sales, revenue for the microcomponent segment of the semiconductor market grew 16 percent, to $40.1 billion in 1996. This segment also includes sales of microcontrollers, which grew more slowly than the segment overall, and microperipherals, which matched the segment's growth rate.*
By Nathan Brookwood

MOS Microcomponents Grow to $40.1 Billion

Sales in the MOS microcomponent segment of the semiconductor industry grew 16 percent in 1996, to $40.1 billion. Microprocessors are the biggest portion of the microcomponent segment (43 percent), and the 21 percent growth in this category accounted for more than half of the segment's overall increase. Sales of digital signal processors (DSPs) grew more rapidly than microprocessors on a percentage basis, but from a considerably smaller base. Microperipherals, a catchall category that includes display and sound controllers, core logic, and communications devices, grew at the same rate as the segment as a whole and accounted for 24 percent of overall sales. Microcontrollers grew more slowly than the segment overall, but still turned in positive growth of 5 percent over 1995.

This 16 percent growth, far lower than last year's 33 percent, still compares favorably with the growth tallied in other semiconductor markets, especially the memory segment, which shrank 33 percent from the prior year. Given the lack of major new technology introductions that characterized the year, along with the 1995 inventory overhang and correction in the first quarter, most vendors displayed more than respectable gains.

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The microcomponent segment represents a broad collection of devices, rather than a coherent set of products based on a common technology or used in a common set of applications. None of the major vendors selling into this segment categorizes itself as "a leader in the microcomponent market." Consequently, any meaningful analysis of the segment must be performed on a category-by-category basis. Table 1 shows the breakdown of microcomponent revenue into its four constituent categories.

Table 1
Preliminary Constituent Components of Microcomponent Revenue, 1995 to 1996

	1995 Revenue	1995 Market Share (%)	1995 Revenue	1995 Market Share (%)
Microprocessor	14,279	41	17,283	43
Microcontroller	10,250	30	10,790	27
Microperipheral	8,316	24	9,591	24
Digital Signal Processor	1,669	5	2,468	6
MOS Microcomponent	34,514	100	40,132	100

Source: Dataquest (February 1997)

When viewed on the basis of regional consumption (defined by Dataquest as the location to which an individual component is delivered), the heavy concentration of electronics manufacturing and assembly operations in the Asia/Pacific region skews these consumption figures a bit. Microprocessor revenue, heavily influenced by the sales of x86 devices for use in personal computers, better reflects regional end-user consumption, because these devices tend to be added to the computer at the final assembly stage, just prior to delivery to an end-user or distribution channel. The geographic regions specified in the columns of Table 2 represent consumption within that region (as defined above). The four regions total to the worldwide figures in the leftmost columns.

Table 3 displays Dataquest's preliminary revenue estimates for the leading suppliers of microcomponents. Not until the seventh position, formerly held by Advanced Micro Devices Inc., does a change occur from the 1995 rankings. AMD and IBM Corporation both dropped out of the top 10 vendors in this segment because of their weak sales of x86-compatible microprocessors. Both appear poised for a rebound in this area in 1997.

Table 2
Preliminary MOS Microcomponent Revenue and Growth, 1995 to 1996

	Worldwide			Americas			Japan			Europe, Africa, and Middle East			Asia/Pacific		
Category	1995	1996	Change (%)	1995	1996	Change (%)	1995	1996	Change (%)	1995	1996	Change (%)	1995	1996	Change (%)
MOS Microcomponent	34,514	40,132	16	12,431	14,000	13	7,830	8,863	13	7,001	8,451	21	7,252	8,818	22
Microprocessor	14,279	17,283	21	6,806	7,600	12	1,690	2,242	33	3,197	4,191	31	2,586	3,250	26
Microcontroller	10,250	10,790	5	2,048	2,214	8	4,140	4,257	3	2,030	2,082	3	2,032	2,237	10
Microperipheral	8,316	9,591	15	2,982	3,364	13	1,726	1,866	8	1,226	1,536	25	2,382	2,825	19
Digital Signal Processor	1,669	2,468	48	595	822	38	274	498	82	548	642	17	252	506	101

Source: Dataquest (February 1997)

Table 3
Preliminary Top 10 Companies' Factory Revenue from Shipments of MOS Microcomponents to Worldwide Markets (Millions of US Dollars)

1996 Rank	1995 Rank		1995 Revenue	1996 Revenue	Percentage Change	1996 Market Share (%)
1	1	Intel	12,397	15,988	29.0	39.8
2	2	Motorola	2,997	3,153	5.2	7.9
3	3	NEC	2,061	2,212	7.3	5.5
4	4	Hitachi	1,441	1,685	16.9	4.2
5	5	Texas Instruments	1,254	1,630	30.0	4.1
6	6	Toshiba	1,094	1,177	7.6	2.9
7	10	Rockwell	738	1,085	47.0	2.7
8	12	Philips	662	1,035	56.3	2.6
9	7	Mitsubishi	982	930	(5.3)	2.3
10	9	Cirrus Logic	887	741	(16.5)	1.8
		All Others	10,001	10,496	0	26.2
		Total Market	34,514	40,132	16.3	100.0

Source: Dataquest (February 1997)

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Perspective

Personal Computer Semiconductors and Applications Worldwide

Product Analysis

Opening the Window on Handheld PCs

Abstract: *The central processor running the personal computer has been relatively unattainable to microprocessor vendors, apart from Intel, Advanced Micro Devices, Cyrix, IBM, and Motorola, and the list may be narrowing further. Now Microsoft may have opened a little window for the outsiders to participate in at least a related CPU opportunity in handheld PCs. Windows CE may unify these devices with personal digital assistants and high-end organizers, providing greater momentum for such handy products.*
By Tom Starnes

PCs to Go

The early versions of the new crop of handheld personal computers built around Microsoft's new Windows CE were shown at the COMDEX/Fall '96 show. More were shown at the Winter Consumer Electronics Show, although exactly why these would be expected to used by your average consumer is not clear. A pocket-size PC with a familiar, if cramped, Windows and Office interface and operation certainly seems more like an office-on-the-go than something to take to Uncle Bill's house to demonstrate one's personal financial security plan. These PCs are from 4 x 6 x 3/4 inches to 4 x 9 x 1 inch in size, weigh ounces rather than pounds, and fit easily into a breast pocket, or possibly into a shirt pocket.

The new handheld PCs have particular advantages not afforded the numerous prior versions of pocket PCs. Foremost among these is the new operating system. These new handheld PCs are based on the Microsoft Windows CE operating system and its hardware platforms. Tapping a touch screen with a stylus performs the mouse actions, while a tiny QWERTY keyboard gives the nimble a way of typing a letter, responding to e-mail, entering data or formulas into a spreadsheet, or entering another phone

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number in the phone list. The pen has to be juggled without being dropped, and the keyboard would encourage hunt-and-peck rather than touch typing because it is so compressed, so there is a price to pay for shrinking a PC below ergonomic limits. Perhaps carpal tunnel syndrome (CTS) will not have time to develop when using these devices, with simple cramping of the hand muscles and chafing of the fingertips limiting extensive use before CTS can set in.

Windows CE

Windows CE generally operates like a desktop Windows, so that's nice. Plus, Microsoft's extremely popular Excel and Word are provided in pocket versions that provide the core functionality of the full-size version. Although a plethora of fonts and formats and table capabilities are not available in the word processor and charting and what-if capabilities do not exist on the spreadsheet little brother, the basics of these programs are still there (although tables and charts seem pretty fundamental to any modern user).

Transfer of programs between the Windows CE machine and the desktop is straightforward, with a translation program converting full Word and Excel files to or from the pocketable, compressed file structure before download or after upload. Unfortunately, the features that the pocket application can not deal with are completely lost in the translation, so that a table in the original Word document gets converted to tab-delimited lines. When reopened on the desktop, it must be manually converted back to a table and all of the formatting must be reapplied. The user would be encouraged to keep in mind the lowest common denominator and perform the more sophisticated functions only when sure that the file would no longer be manipulated on the handheld PC.

However, the blessing and encouragement of Microsoft and its Windows CE operating system become a unifying seal of approval to this new class of handhelds. With Microsoft assuring some level of compatibility, Microsoft-supplied applications that mimic desktop favorites, and a measured interface for third parties developing programs assuring that programs will be usable on a multitude of devices, the unified handheld PCs have a healthy chance of survival.

Are these handheld PCs going to take a noticeable piece of the laptop PC sales? Not likely. The handheld may pare off the small piece of laptops where ultimate size rules over capabilities, although most of that should already be served by the previous versions of pocket PC-like products. Those previous handheld designs are the products with the greatest likelihood of losing sales to the Windows CE-based PC. The closer links to the "real" PC and the uniformity of the platform for the software should attract the market to the Windows CE handhelds.

Laptops still have a significant advantage over the Windows CE-based handheld PCs of full-size keyboard, handy pointer device, large, color display, disk drives, and absolute compatibility with the desired software. Although docking stations are costly, with them, the laptop becomes a desktop and has the tremendous advantage of having the entire set of files available at or away from the desk. Sitting on a plane or train, laptop users can work on essentially all of their projects with all of the utility of the main office. With the new handheld PCs, each file desired must be manually transferred to the handheld. If a critical file was not copied across, it will not be available when it is needed while flying over Kansas.

In truly embedded applications, such as cellular phones, copiers, and automobiles, it is not readily obvious that Windows CE has significant advantages over the many other operating systems available, especially those designed for a real-time environment. Dataquest will be watching this area for further enlightenment.

Processor Opportunities in PCs

There is a big opportunity for processor vendors that have otherwise been unable to participate effectively in the PC world without fully compatible x86 processors. The Windows CE operating system and the applications that play on it are designed to be compiled separately to any of the authorized microprocessor architectures. This allows a MIPS processor to run one handheld PC, while the Hitachi SH processor can run another. The advantages of one processor or architecture over another may be very evident, or may be found to depend on the actual application in which it is used, or may depend on a given critical factor such as battery life or communications speed. But there is opportunity for a variety of platforms with truly different strengths in this kind of product, with many processor vendors participating.

The next few months will show many handheld PCs becoming available, and certainly many more making their debut. Already Hewlett-Packard is showing a $500 palmtop that the company thinks will be out in April 1997 and that looks remarkably like the Hitachi model. Casio, Compaq, LG Electronics, NEC, and Philips were also showing Windows CE handhelds. Most of these devices include Windows CE as well as Pocket Excel, Pocket Word, a personal information manager, e-mail software, and a browser, which mostly come from Microsoft. They have IrDA ports and PCMCIA Type II slots for input/output. Hitachi and MIPS RISC processors are popular in the first batch of these devices, and 2MB to 4MB of memory are included. Characteristics of typical handheld PCs include:

- Vendors
  - Hewlett-Packard, Hitachi, Casio, Compaq, LG Electronics, NEC, Philips
- Processors
  - 40 MHz Hitachi SH-3
  - 33 MHz NEC V_R4101 (MIPS)

- Memory
  - 2MB and up
- Additional features
  - 480 x 240 display, IrDA, PCMCIA II
- Software
  - Windows CE, Pocket Word, Pocket Excel, Personal Information Manager, e-mail, Web browser
- Available
  - First half 1997, $500

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Dataquest
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Perspective

Personal Computer Semiconductors and Applications Worldwide

Market Analysis

Can Network Computers Topple the Wintel Paradigm?

Abstract: *Dataquest weighs in with its view of the network computer/personal computer debate. We predict that the PC will absorb the more attractive attributes of the network computer and emerge the winner.*
By Nathan Brookwood

Summary

Over the years, the interplay between evolving technology and economics has driven major shifts in computer system design. Each new generation has led to increases in both user autonomy and the range of available technical alternatives. Some now argue that the costs associated with supporting the current range of choices have reached excessive levels and mandate a need for simplification. The network computer concept promises lower costs, but introduces limits on end-user autonomy. Will computer users accept this proposition in large enough numbers to shift the market?

Hyperactive marketers and the media have applied the title "network computer" (NC) to a wide variety of devices, ranging from personal computers connected in a network to set-top boxes that permit network surfing on home TVs. Dataquest divides the world of network clients into three broad classes: fat clients, thin clients, and very thin (anorexic) clients. These clients vary with regard to their dependency on network resources and their ability to redirect their function via changes to their operating software. The "official" NC definition specifies functions rather than components and could lead to a variety of proprietary implementations and postsales compatibility issues.

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Bandwidth restricts the NC to sites with access to high-speed (1 Mbps and beyond) communications links, and this in turn precludes deployment in residential and small office/home office (SOHO) environments. Dataquest does not anticipate a significant change in this constraint during the next five years.

The NC may decrease the acquisition cost of desktop hardware, but it will increase LAN bandwidth requirements (and expense). Savings in administrative and support costs may also prove elusive. Reductions in end-user operational expenses may be achievable, but similar reductions can be achieved by applying "best practices" to the current Wintel paradigm.

Part of the NC's appeal stems from its promise to make computers easier to use and easier to administer. Centralized storage for programs and data plays a key role in achieving this simplification but comes at the cost of performance and potential service outages. Some users may avoid this class of solution because they fear for the privacy of the data they store on a server not under their direct control. Some of the NC's ease of use stems from the reduced feature sets of initial NC applications. Earlier attempts at feature-reduced products (MS Works, Claris Works) have fared poorly against feature-rich suites.

The underlying properties of the network computer and the environment in which it must operate place severe constraints on the manner in which it can be deployed. The bandwidth issue blocks large-scale NC deployment in the home, regardless of any other NC strengths or weaknesses. Office and educational environments typically possess the necessary infrastructure and make more promising targets.

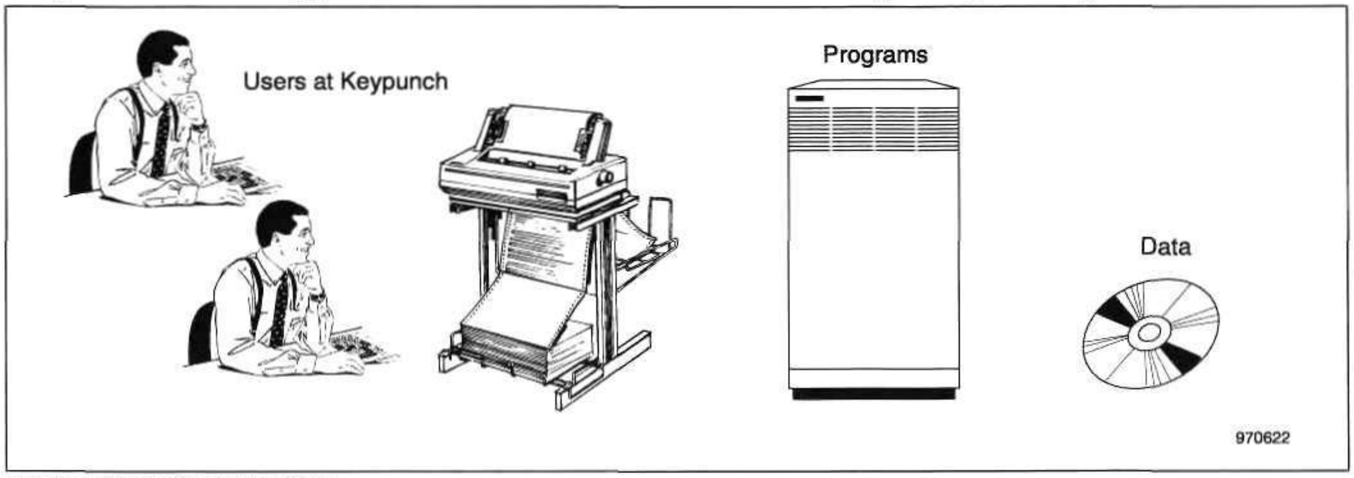
The network computer offers neither the economic nor the functional improvements needed to displace current solutions. The ever-evolving personal computer will absorb many key attributes of the network computer as it continues to dominate the computing landscape. Dataquest anticipates that a new category of lower-cost, easier-to-support personal computers, based on trailing-edge technology, will emerge from the PC/NC brouhaha.

Computing Paradigms

Over the past 40 years, the interplay between evolving technology and economics has driven several major shifts in computer system design. Each new generation led to increases in both user autonomy and the range of available technical alternatives at dramatically reduced unit prices. Some now argue that the cost of supporting the current choices dwarfs the acquisition cost, and mandates a need for simplification. The network computer concept promises lower costs but introduces limits on end-user autonomy.

System designers have applied countless techniques to solve one basic problem. Simply stated, a computing system must unite a user, a program, and data. Figures 1 through 6 outline the six major evolutionary stages that the computer industry has undergone. Figure 1 illustrates the first stage, when early systems combined programs and data in (very large) boxes and used punched cards and printed output to link users with the data. After 40 years, we have made the boxes smaller and we have replaced much of the paper with a keyboard and display.

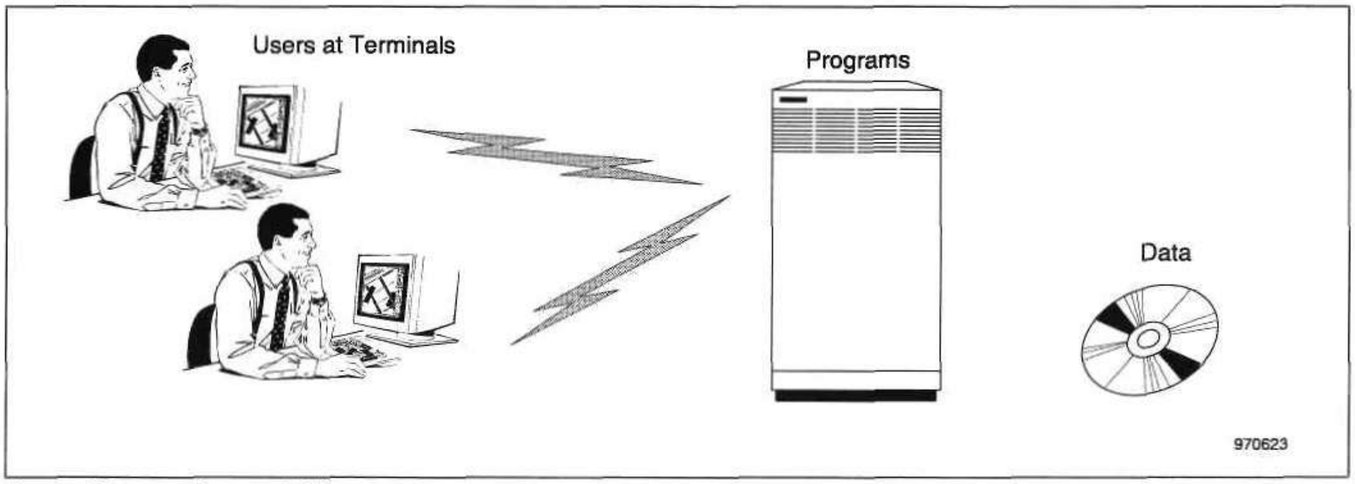
Figure 1
Stage I: Users at Keypunch Stations Use Mainframe via Paper Input/Output



Source: Dataquest (January 1997)

Advancing technology allowed suppliers to make boxes faster and cheaper than the early computing relics now in the Smithsonian Institution. Differing rates of technological improvement for the various hardware and software components used to construct computers impact the overall shape of these systems and largely determine their most cost-effective configurations. In the next stage, as shown in Figure 2, remote terminals and communications links replaced the mail carts and trucks formerly used to transfer the user's data to and from the central site. These remote terminals constituted the initial wave of thin clients, although they hardly seemed thin at the time. The software that drove these remote terminals resided at a central site and came in flavors labeled as time-sharing, real-time, and transaction processing. All three varieties had the property that system responsiveness degraded as the number of online users increased, and it fell off a cliff at or beyond a particular user load. They lacked "scalability" and suffered from overloads caused by predictable events like the influx of users logging in at the same time or returning from lunch and checking their mail.

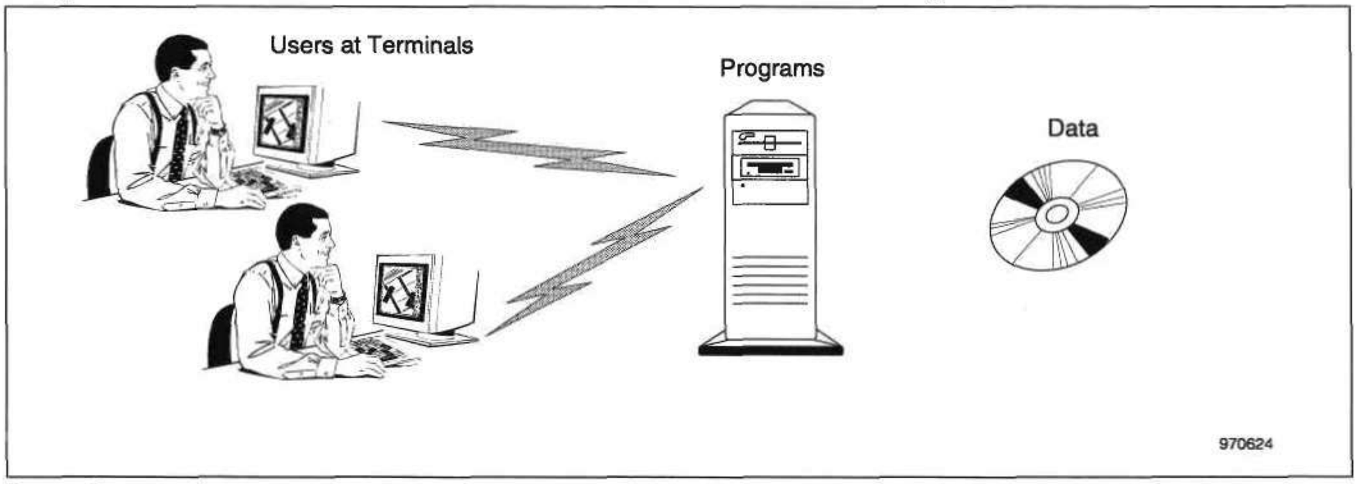
Figure 2
Stage II: Users at Interactive Terminals Use Mainframe via Communications Facilities



Source: Dataquest (January 1997)

Suppliers applied technological advances to drive the performance of high-end systems even higher on one hand, while creating less expensive, low-end systems on the other. As hardware prices dropped from $1 million to $100,000, organizations advanced to the third stage, shown in Figure 3, where they could afford to replicate central sites, as long as these sites had no need to update shared data. (Applications with a shared-update requirement remained at Stage II.) Terminals attached locally to these replicated sites could operate at higher speeds than those attached over communications lines, improving system responsiveness. Reliability increased, the impact of failures was often restricted to a single site, and individual sites gained increased autonomy. Most users regarded this as progress. The response time problems inherent in shared-resource Stage II systems remained in these Stage III environments.

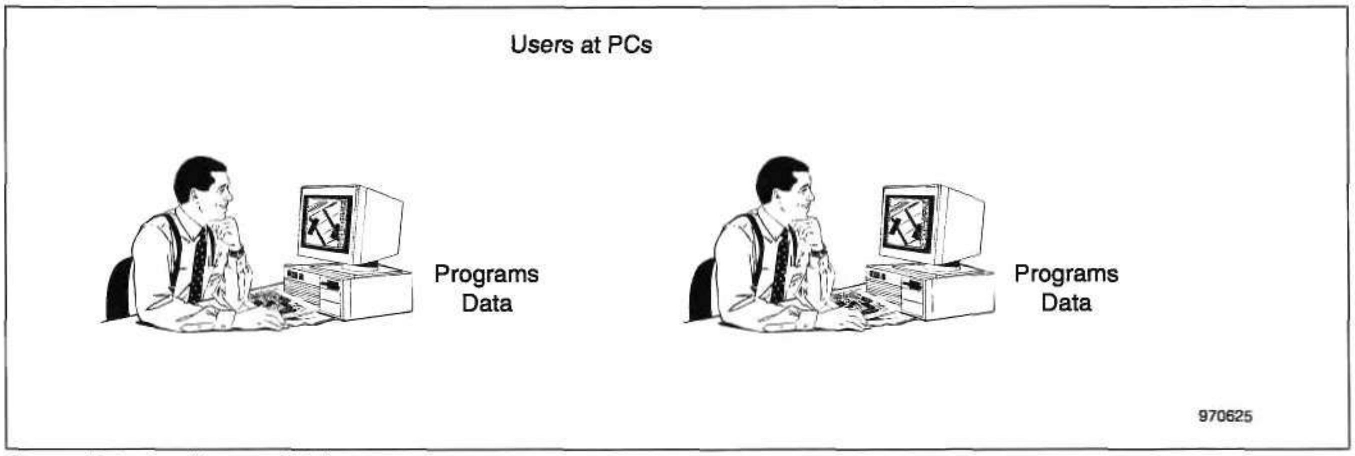
Figure 3
Stage III: Users at Interactive Terminals Use On-Site Minicomputer



Source: Dataquest (January 1997)

Stage IV began when the advent of inexpensive 16- and 32-bit microprocessors enabled the construction of $10,000 workstations and $5,000 personal computers, another tenfold reduction in system prices. These devices, shown in Figure 4, united individual users with their programs and data, greatly increasing their autonomy (and sometimes leading to chaos). The emergence of open systems environments like DOS and UNIX enabled the emergence of packaged software products, increasing the range of choices even more and sometimes leading to even more chaos.

Figure 4
Stage IV: Users at Personal Computers Interact with Private Local Data

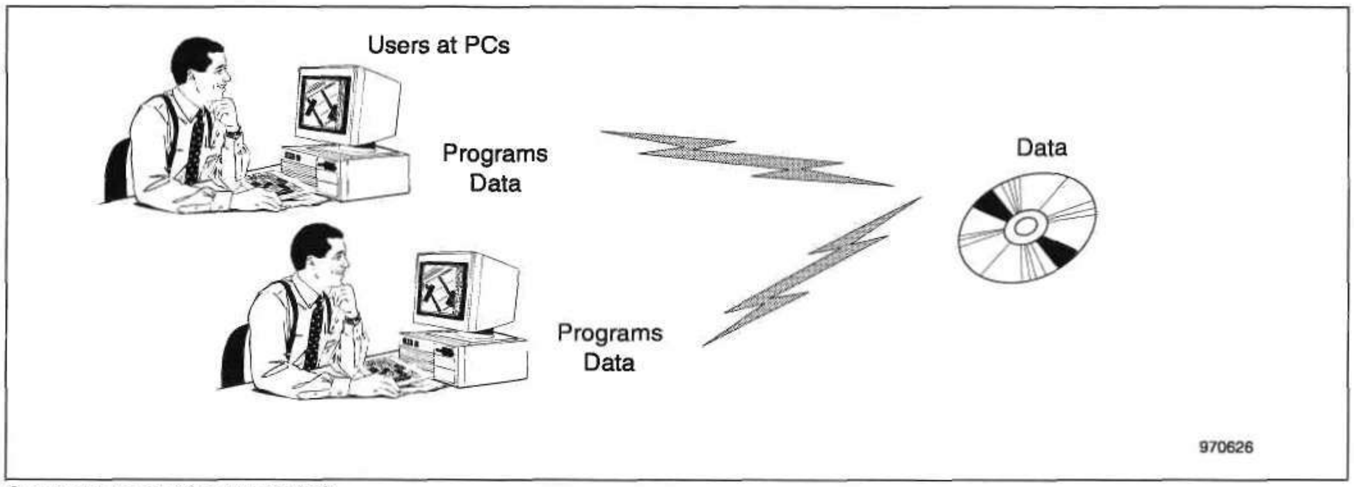


Source: Dataquest (January 1997)

In Stage V, as illustrated in Figure 5, network operating systems (like Sun's NFS and Novell's NetWare) and inexpensive Ethernet hardware allowed users to combine the autonomy they were growing to love with the access to shared data that they could not achieve on standalone systems. MIS departments that had once run mainframes suddenly got involved in operating the local area networks (LANs) that connected these systems.

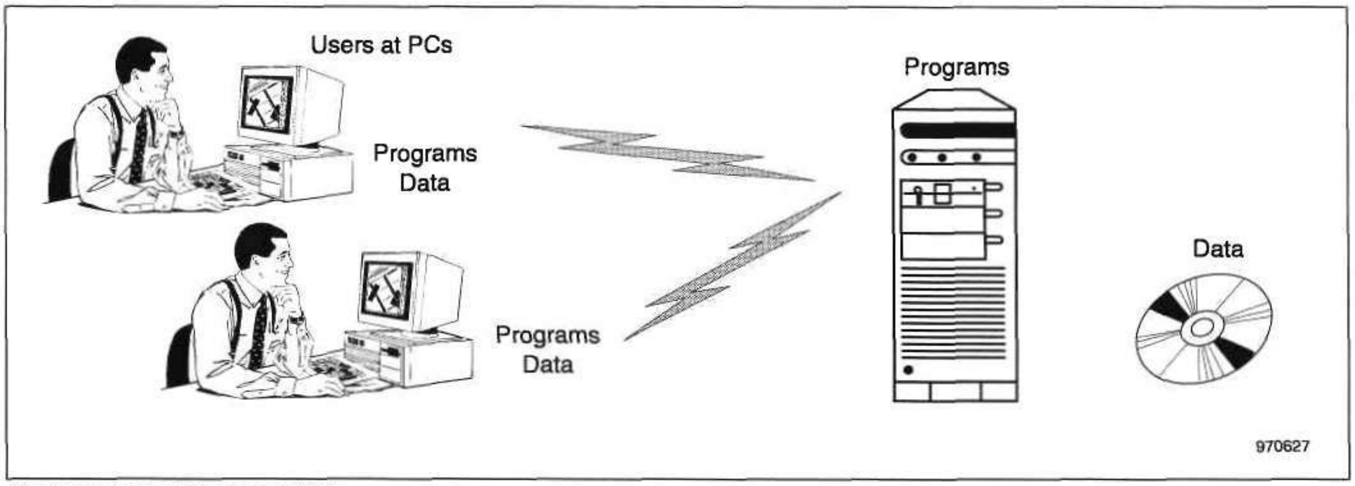
As users tackled increasingly complex problems, the weaknesses of the Stage V, PC-centric view began to emerge and led to the deployment of the sixth (and current) stage, sometimes referred to as client/server computing. As shown in Figure 6, programs on a central system manipulate data local to that site and communicate with each user's set of programs and data, stored on that user's desktop. This approach provides enormous flexibility but carries much overhead and complexity. Suppliers used improvements in price and performance to conceal much of this complexity and jammed more and more hardware and software into boxes they sold at relatively constant prices. Nevertheless, the complexity oozed out into many aspects of the program's interface and greatly increased support expenses.

Figure 5
Stage V: Users at Personal Computers Interact with Private Local Data and Shared Data on Server



Source: Dataquest (January 1997)

Figure 6
Stage VI: Users at Personal Computers Interact with Private Local Data and Shared Data and Programs on Server



Source: Dataquest (January 1997)

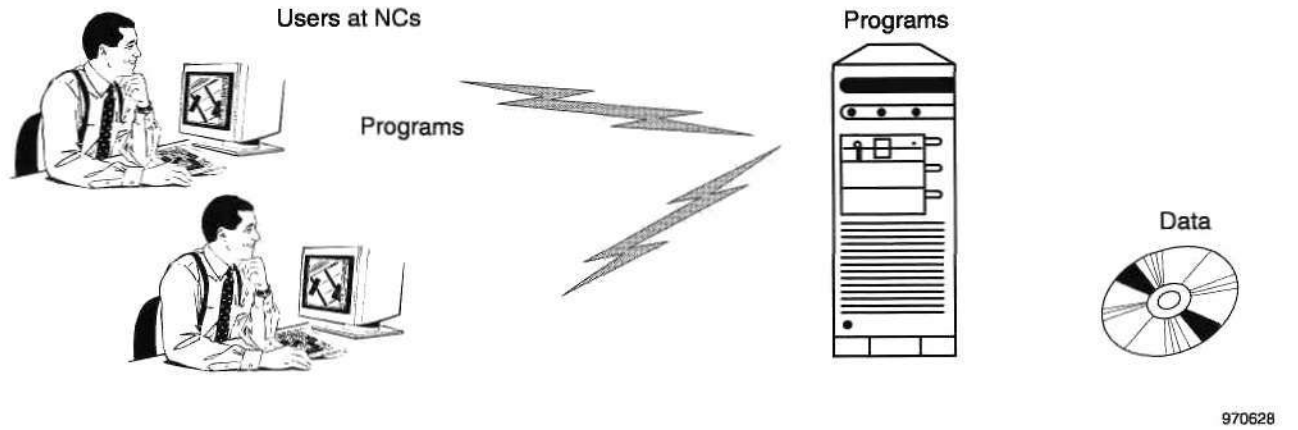
Over the past 14 months, the proponents of the network computer have advanced the argument that the current Rube Goldberg client/server scheme can be greatly simplified, thus reducing overall costs with no sacrifice in capability. The network computer concept, as shown in Figure 7, would represent a seventh major paradigm and contains several (somewhat orthogonal) elements:

- Relocate the user's local data to a central server, thus eliminating the need for a local hard disk for data storage
- Store the user's programs at a central server, thus eliminating the need for a local hard disk for program storage

- Store the user's programs in a "machine-independent" manner that accommodates a wide range of network clients
- Create these programs in a highly modular fashion that minimizes the need to load large blocks of code over the network when (in practice) only small sections of that code ever need to be executed
- Remove the floppy drive (or other program loading device) from the system, thus precluding users from adding programs or applications that may not be essential to their assigned tasks

This Perspective examines the feasibility of such a computing model, along with the impact that such changes would have on users and suppliers.

Figure 7
Stage VII? Users at Network Computers Interact with Shared Data, Private Data, and Programs on Server



Source: Dataquest (January 1997)

Will the Real Network Computer Please Stand Up?

Summary

Hyperactive marketers and the media have applied the title "network computer" (NC) to a wide variety of devices, ranging from personal computers connected in a network to set-top boxes that permit network surfing on home TVs. Dataquest divides the world of network clients into three broad classes: fat clients, thin clients, and very thin (anorexic) clients. These clients vary with regard to their dependency on network resources and their ability to redirect their function via changes to their operating software. The "official" NC definition specifies functions rather than components and could lead to a variety of proprietary implementations and postsales compatibility issues.

Three Classes of Network Clients

The three classes of clients are:

- Fat clients are attached to networks but operate autonomously. They use the network primarily to access shared data or other resources and can be modified through software programming (stored locally or on the network) to handle a variety of tasks. These systems can continue to operate (on local data) even if they lose their network connections. Personal computers and workstations attached to local area networks constitute the majority of fat clients deployed today.
- Thin clients are attached to networks and cannot operate autonomously. They can be modified through software programming to handle a variety of tasks but must use the network for all program storage as well access to long-term data, shared data, or other resources. These systems cannot operate if the network or server supporting them fails. Diskless personal computers and workstations constitute the majority of thin clients in use today. Oracle Corporation's Network Computer, Sun's JavaStation, and IBM's NetStation all fall into this category, as does the Microsoft/Intel "network personal computer," which contains a hard disk but does not rely on this disk for "persistent" (that is, permanent) storage of data or programs.
- Very thin (anorexic) clients are attached to networks and cannot operate autonomously. They use the network for access to long-term data, shared data, or other resources. They typically contain code fixed in ROM to handle a single function and cannot be adapted easily to handle additional functions or to accommodate new standards. This category includes set-top boxes (like WebTV) and specialized terminals (like Xterms and WinTerms) that handle only the display presentation and input components of distributed applications. Dataquest anticipates that a generation of "network-aware" appliances, including games, environmental control systems, printers, and toasters, will eventually emerge within this category.

The Real Network Computer

Although hyperactive marketers have applied the designation to many different devices, this report focuses on the network computer as defined by Oracle in its "Network Computer Reference Profile." In the interest of providing designers with the broadest range of technical opportunities, Oracle's profile specifies the functions and standards with which the NC must conform rather than specifying the particular components with which it should be built (that is, it would specify a "fastener" instead of a "#8 screw"). These functions include a screen, a keyboard, a pointing device, an audio output device, a network interface, and the ability to run Java programs. The profile says nothing about the native architecture of the NC microprocessor, and early vendors have based initial designs on SPARC (JavaStation), PowerPC (IBM NetStation), and ARM. Were the NC to achieve broad acceptance (an outcome Dataquest regards as highly unlikely), the lack of specific processor definition could create a free-for-all among processor vendors, with dire consequences for the established x86 players.

Although a broad, functional definition for a device as complex as a computer system gives designers the maximum flexibility, it also creates opportunities for a wide range of compatibility issues. It could preclude the sort of vigorous competition that has brought down the costs of most elements of today's PC, and lead to an environment in which system vendors revert to proprietary buses and peripheral interfaces, thus increasing the costs of aftermarket upgrades and enhancements. Software vendors are also likely to encounter a more difficult testing environment, and a higher probability that configuration-specific software problems may develop following a product's general release.

Infrastructure Issues

Summary

Bandwidth restricts the NC to sites with access to high-speed (1 Mbps and beyond) communications links, and this in turn precludes deployment in residential and small office/home office (SOHO) environments. Dataquest does not anticipate a significant change in this constraint during the next five years.

Communications Bandwidth

The thin client concept depends on the notion that software modules are stored on a central server and loaded on demand over the network. This approach assures that users always run currently sanctioned software releases and eliminates the need for system administrators to visit individual systems to perform software upgrades. This approach to dynamic software distribution solves the "version skew" problem, but introduces other problems and limitations.

The need to load applications, even small applications (applets) over the network adds traffic to the network and increases the overall loading; this may impact system performance. Fat clients store software locally, thus avoiding the network loading problem but creating the '"skew" problem. An obvious solution, already proposed in the Microsoft/Intel NetPC specification, adds a hard disk cache for data and programs. When the user invokes an application, the operating system checks to see if it has the latest version on its hard disk and, if not, downloads it. Of course, adding a hard disk negates some of the hardware cost savings the NC offers, but such costs contribute little to the economic arguments advanced for NCs.

Communications bandwidth poses even greater problems if the targeted environment lacks a LAN or other high-speed access to a network server. Dataquest anticipates that even by the year 2000, the installed base of cable modems and asymmetric digital subscriber line (ADSL) modems capable of supporting diskless NCs in North America will total less than 9 million units. Table 1 summarizes our recent forecast for this market.

The lack of high-bandwidth pipes into most residential and small business establishments effectively precludes the NC from participation in either the consumer market or the SOHO market in the foreseeable future and restricts

NC deployment to those sites where LANs exist or can be installed at reasonable cost. This factor severely limits the appeal and growth prospects of the network computer.

Table 1
North American Sales of High-Performance Modems (Thousands of Units)

	1994	1995	1996	1997	1998	1999	2000
Cable	6	13	25	80	210	540	900
Cable Installed Base	6	19	44	124	334	874	1,774
ADSL	-	-	50	350	1,000	1,700	3,700
ADSL Installed Base	-	-	50	400	1,400	3,100	6,800

Source: Dataquest (March 1996)

Economic Issues

Summary

The NC may decrease the acquisition cost of desktop hardware but will increase LAN bandwidth requirements (and expense). Savings in administrative and support expenses may also prove elusive. Reductions in end-user operational expenses may be achievable, but similar reductions can be achieved by applying "best practices" to the current Wintel paradigm.

Only Minor Reductions in Acquisition Expense

Much of the initial brouhaha regarding the network computer stemmed from its anticipated $500 price, substantially below the $2,000 price point of the typical personal computer. As Table 2 illustrates, the NC's cost savings, relative to a low-end personal computer, from a capital expenditure standpoint, are not nearly so dramatic ($600 versus $1,100). These savings result from the elimination of hard and floppy disk drives, the use of less DRAM, and the avoidance of the so-called "Intel tax" and "Microsoft tax" implicit in the Wintel model.

The Intel/Microsoft NetPC proposal eliminates the floppy drive and simplifies the motherboard, compared with current PC designs, and could shave the price of a workable PC by $100, to $1,000 from $1,100. Some of the savings result from the use of trailing-edge x86 microprocessor technology; if the NC or NetPC initiatives succeed in removing the social stigma associated with deploying new systems with more mature MPUs (less powerful, at lower average selling prices), they will have accomplished much.

Clearly, some organizations may underuse their personal computers and deploy them mainly as high-tech replacements for dumb terminals. Such organizations may find they can waste less money by deploying NCs for these functions. Dataquest finds problematic the proposition that the installed base of dumb terminals will provide an attractive target for NC sales. Diskless NCs, at $600, remain substantially more expensive than low-end dumb terminals that sell for less than $400. To use advanced features of the NC, the customer must modify existing (and often very old) application programs. Many applications that formerly used dumb terminals have evolved to use specialized, embedded input/output devices in lieu of the general-purpose terminals, further reducing the size of the potential replacement market the NC might address.

Table 2
Cost Comparisons: Low-End PC, NC, Terminal, and Variations (Dollars)

	Low-End PC	NetPC	NC with Hard Disk	NC	Terminal
Case and Power Supply	25	25	25	25	20
Keyboard	15	15	15	15	15
Mouse	5	5	5	5	5
Display	150	150	150	150	150
Display Controller	25	25	25	25	15
Display Memory	10	10	10	10	0
Motherboard and Core Logic	75	60	50	50	15
LAN Interface	20	20	20	20	0
Audio Controller	20	20	20	20	0
Memory	80	80	20	20	10
Processor	100	75	40	40	15
Hard Disk	125	125	125	0	0
Floppy Disk	20	0	0	0	0
Subtotal (Components)	670	610	505	380	255
Labor plus Margin	335	305	253	190	128
Expected Retail Hardware Price	1,005	915	758	570	383
Expected Retail Software Price	100	100	50	50	0
Expected Total Price	1,105	1,015	808	620	383

Source: Dataquest (January 1997)

As the NC's theoretical cost savings from hardware simplification have dwindled, NC advocates turned their attention to other costs associated with the Wintel model of PC deployment, and they often cite the Gartner Group's "total cost of ownership" (TCO) model in this cause. Table 3 presents the major components of the Gartner model, as estimated by Gartner today and as they might appear following the implementation of a series of "best practices" recommendations. The Gartner model suggests that these costs (on an annualized basis) can be lowered from $11,900 to $8,800. Over $2,000 of this $3,100 annual savings comes from reductions in "end-user operational expenses," a category that includes costs associated with training (formal and informal), figuring out how to use specific program features, "futzing" (that is, tinkering) with fonts and other graphical elements within documents or work products, and playing games. NC proponents argue that the more streamlined applications proposed for the NC will inherently achieve these savings, and more. Some Wintel proponents counter that this is throwing the baby out with the bath water.

Table 3
Five-Year PC/LAN Costs (Dollars)

Cost Component	Base Case	Best Practices
Capital	12,311	11,808
Technical Support	12,393	10,180
Administrative	7,477	5,530
End-User Operations	27,257	16,261
Total	59,438	43,779
Total per Year	11,888	8,756

Source: Gartner Group

Organizational deployment of network computers would impact the figures in Table 3 in the following manner:

- Capital expenditure: The lower acquisition cost of the NC will be offset by the need for greater LAN bandwidth to support the NC, thus absorbing any potential cost savings.
- Technical support: NC proponents argue that the reduced complexity of NC applets will simplify support requirements and allow a centralized MIS staff to administer the network without the need to visit individual systems. Wintel advocates argue that an NC-based network has many more critical points of failure that can impact usage, and this will force a more rapid response-time requirement for many problems that can be handled less urgently in a Wintel environment. Wintel proponents also argue that the software installation tasks that today require support personnel to visit individual systems can be automated so they can be performed over the network. Any overall savings are likely to be minor.
- Administrative expense: This category of expenses will be little impacted by PC or NC deployment architectures.
- End-user operations: This category accounts for almost half the total cost of ownership and represents the most fertile area for cost savings. NC proponents argue that end users waste time using frivolous features of bloated applications to enhance presentations and reports in a manner that adds little or no value to those work products. NC applets omit these features and thus improve productivity. Such arguments may be technically correct but are wholly irrelevant. Individuals and the organizations of which they are a part should be free to decide the role that form, as opposed to substance, plays in their operational and decision-making activities. The notion that organizations should adopt technologies that preclude these trade-offs, simply eliminating the elaborate formatting capabilities of today's applications, is inconsistent with the principles of free society and is unlikely to achieve broad acceptance in an era of ever-increasing employee empowerment. All in all, it appears unlikely that the NC can reduce this class of expense substantially beyond the "best case" assumptions Gartner determined for the Wintel model.

Usability Issues

Summary

Part of the NC's appeal stems from its promise to make computers easier to use and easier to administer. Centralized storage for programs and data plays a key role in achieving this simplification but comes at the cost of performance and potential service outages. Some users may avoid this class of solution because they fear for the privacy of the data they store on a server not under their direct control. Some of the NC's ease of use stems from the reduced feature sets of initial NC applications. Earlier attempts at feature-reduced products (MS Works, Claris Works) have fared poorly against feature-rich suites.

Network Availability

The personal computer's operational autonomy allows most PC users to make use of their systems whether or not they are connected to a network and whether or not that network is operating. Online connections play a key role in some applications, including Internet access, exchanging electronic mail, and accessing shared databases. Users who depend on these functions care little if their machine remains operational when the network becomes unavailable—they cannot complete their tasks in any event. This dependency on network availability plays a key role in the network computer's utility in various markets.

For PC users who must have online access to handle their work, the NC's network dependence is not an issue. Some users may experience increased productivity, as their data will be stored centrally, and repairing a failure in an individual desktop system will be no more difficult than changing a light bulb. For other users, capable of performing some or all of their tasks in an offline environment, the switch to an NC could introduce a fatal susceptibility to network failures, events that create minor annoyances for most PC users. Each organization must evaluate this risk, based on its own requirements. Dataquest anticipates that many organizations will find this risk unacceptable and will avoid NC solutions on this account alone.

Most mobile environments must be capable of standalone operation (at least part time), and this requirement precludes the NC from meaningful participation in this segment.

Downloading Delays (the World-Wide Wait)

The modern PC retains hundreds of megabytes of state information on its hard disk and can access any of this information in milliseconds. The NC moves all this information to a network server and introduces both queuing and transit delays in its access. Much of this delay results from the need to download programs each time they are needed, even though these programs (unlike some data) rarely change. The time required to load large documents over the World Wide Web via a dial-up modem causes some users to interpret the "www" in most Web addresses as "worldwide wait."

The PC's local state information causes problems, especially when different users retain and execute different versions of a program on their disks. This "version skew" problem complicates the lives of developers and MIS support organizations. The NC eliminates this problem by loading the latest version of a program each time the user starts that program. In the case of programs that change infrequently (if at all), this creates extra delays and network traffic. Adding a hard disk to the NC and using this disk as a cache for active programs eliminates the extra traffic but increases the cost of the system hardware. This may prove to be an acceptable trade-off, as it eliminates the version skew problem without adding unnecessary network traffic. The Intel/Microsoft NetPC platform intends to take this path.

Privacy and Security—Real and Perceived

The NC's lack of hard and floppy drives forces users to store all data on a central server. This practice most likely improves data security (at least data gets backed up), but many users prefer the illusion that maintaining physical possession of their data increases the safety of that data and reduces the likelihood that the data will be viewed by unauthorized eyes. (Would anyone prefer to maintain a database of e-mail correspondence with a lover on a centralized server, where it might be subpoenaed in the course of a divorce trial, or on a floppy in an out-of-the-way drawer?) This preference will limit the NC's eventual acceptance to those without sin, a group Dataquest estimates to be statistically insignificant.

Hard Disk Economics

Storage on the inexpensive IDE disk drives used in today's desktop personal computers typically costs far less (currently $0.10 per megabyte) than the same amount of storage on a centralized server (currently $0.15 to $0.25 per megabyte). Expenses associated with the operation and administration of the centralized server further exacerbate this disparity. Knowledge workers often find it convenient to retain large amounts of non-mission-critical information to facilitate their jobs; loss of such information may inconvenience the worker, but will not adversely affect the organization. By forcing users to store all data on a central site, the organization pays a premium rate for all information storage, however important or unimportant that information may be in practice. To limit such expenses, organizations sometimes apply quotas to the amount of disk storage available to each user. These quotas force users to spend time managing files and contribute to the "futz factor" expenses discussed earlier.

The End of Software Feature Creep?

Many software packages achieve ungainly proportions as developers vie on the basis of features and add new functions to address new markets. The standard version of Microsoft's Office 95 suite now occupies almost 100MB on the hard disk of any system on which it is installed. Proponents of the network computer strike a responsive chord when they suggest that most users only need or want 20 percent of the features included in these packages. They propose the creation of lean and mean Java-based applets to replace these bloated collections of legacy functionality. Corel's efforts to recode its Corel Office suite in Java are cited as a leading indicator of this new era.

The concept of reducing the complexity and size of these packages rates as high as the concept of reducing the U.S. federal deficit and proves just as problematic. Hardly anyone needs more than 20 percent of the features in such a package, and almost everyone agrees on the first 15 percent. Unfortunately, the other 5 percent varies from user to user and market to market, and no group of users appears willing to give up the small set of features that makes the product more useful to them. Just as politicians hope to outgrow their deficits rather than confront this pain head-on, software developers prefer to devote part of the overall improvement in hardware price and performance rather than alienate some subset of customers, and customers have supported such decisions via their purchases.

The oft-cited Corel Java suite may find initial acceptance with only a small fraction of the features of today's more mature products. If it gains broad market acceptance, its users will pressure Corel for increased capabilities, and it too may start down that slippery slope. Corel may deflect these requests by redirecting NC users seeking more functionality to the larger PC suite, but such a strategy presumes the existence of a more "bloated" version of the package.

Earlier attempts at feature-reduced products (MS Works, Claris Works) have fared poorly against feature-rich suites. Should the slimmed-down Java version of Corel Office prove more successful, Dataquest would expect to see such functionally reduced products re-emerge in the Wintel space.

NC Markets

Summary

The underlying properties of the network computer and the environment in which it must operate place severe constraints on the manner in which it can be deployed. As noted above, NCs will operate poorly (if at all) in no- and low-bandwidth environments, and this precludes their use in most home and small office environments (because they lack the necessary host servers and LANs). As noted earlier, there are no quick fixes for increasing bandwidth into homes (or other geographically dispersed facilities). The bandwidth issue blocks large-scale NC deployment in the home, regardless of any other NC strengths or weaknesses. Office and educational environments typically possess the necessary infrastructure, and make more promising targets.

Home: No; Office: Maybe; Education: Yes

Office environments with LANs and servers (or high-speed access to servers and the Internet) provide a more hospitable NC environment. The organization must assess the impact of the NC on network traffic, especially under peak loading conditions, and should also evaluate what impact (if any) a network outage will have on the user's ability to complete non-network-related tasks. Given the broad penetration of Windows-based office applications, NC solutions that permit users to operate in a pseudo-Windows environment (such as that offered by the Citrix Systems Winframe environment that allows Windows NT to more closely replicate a classic "time-sharing" environment) may prove attractive.

The educational market, especially in the K-12 segment, offers the best fit with the NC's needs and benefits. The LAN infrastructure is readily available, if not already in place, and requires no new technology or regulatory changes before implementation. Price sensitivity ranks high in the customers' buying behavior; given fixed budgets, lower price often translates into higher unit volumes. Response-time delays or temporary service outages have a minor economic impact. Privacy and data security issues typically matter less here than in most other computing applications. This market currently lacks a base of relevant applications software and development tools, as would any new alternative platform. Dataquest expects that if the network computer succeeds at all, it will succeed in this segment.

Can the NC Shift the Computing Paradigm and Topple Wintel?

Summary

The network computer offers neither the economic nor the functional improvements needed to displace current solutions.

What Does It Take to Shift a Paradigm?

A review of past shifts in the computing paradigm, as outlined in Table 4, suggests that not all shifts are created equal. Revolutionary shifts, driven by massive changes in system economics, reorder the vendor landscape and create new opportunities for the technologically astute vendors leading the charge. Evolutionary shifts, driven by new functions, push user buying cycles but are less likely to perturb vendor positions. The advent of minicomputers and distributed processing created opportunities for Digital Equipment Corporation and Wang and turned the mainframe market from a growth to a replacement business. The rise of the personal computer did to minicomputers what they had earlier done to mainframes and created opportunities for Apple, Compaq, Intel, and Microsoft. In years to come, will we look back on the advent of the NC as revolutionary, evolutionary, or insignificant?

The NC offers little, if any, savings from a hardware acquisition standpoint. Its principal benefit lies in the hope that it will be less expensive to support because of its constrained functionality, compared with today's typical personal computer. Even here, Dataquest anticipates that such costs will differ little from those generated by traditional PCs, and any savings will be hard to measure, at best.

Moreover, whatever financial savings the NC does generate come at the expense of user autonomy. Today's computer user can trade off system price against performance and network availability; NC-based solutions depend more on centralized resources, and this makes them more sensitive to network outages and loading.

Given that the NC, striped of its hype, provides only limited potential for cost savings, provides little, if any, functionality that cannot be achieved within the current PC/client/server paradigm, and reduces end-user autonomy, Dataquest is hard pressed to find a compelling argument for its long-term success. We conclude that once the dust settles, the computing landscape will continue to be populated largely with (somewhat dusty) personal computers.

Table 4
Computing Paradigm Transitions

Shift	Driver	Impact on Installed Base	Impact on User Autonomy
Mainframe to Timesharing	New function (online access to data)	Evolutionary	Small increase (continued dependence on centralized hardware and software)
Timesharing to Distributed Processing	Economics (minimum system price drops from $1 million to $100,000)	Revolutionary	Big increase (independence from centralized hardware and software)
Distributed Processing to Personal Computer	Economics (minimum system price drops from $100,000 to $5,000)	Revolutionary	Very big increase (off-the-shelf hardware and software)
Personal Computer to Networked PC	New functions (e-mail, access to shared data)	Evolutionary	Little impact
Networked PC to Client/Server	New function (manage complexity)	Evolutionary	Little impact
Client/Server to Network Computer?	New function (eliminate complexity)	Revolutionary	Big decrease (dependence on centralized hardware and software)

Source: Dataquest (January 1997)

A Likely NC Scenario

Summary

The ever-evolving personal computer absorbs many of the key attributes of the network computer as it continues to dominate the computing landscape. Dataquest anticipates a new category of lower-cost, easier to support personal computers, based on trailing-edge technology, will emerge from the PC/NC brouhaha.

NetPC Usurps the NC Concept

Although Dataquest does not expect the NC to displace the current PC paradigm, many of the points raised in the PC/NC debate will impact the shape of future PCs. We anticipate the following effects:

- The Microsoft/Intel NetPC initiative will absorb many of the NC's promised benefits. The "zero administration" component of this initiative will address some of the support cost issues and allow support organizations to install and update the user's software configuration from a central site.

- For some users, the role of the system's hard disk will evolve from that of the primary location for a user's programs and data into that of a cache for programs and data stored on a server. When making changes to the centrally stored version of a program or data, the out-of-date copies stored in disk caches around the network will be invalidated and the updated versions will be retrieved. Changes made by the user to local (cached) data on a disk will be reflected in updates to the centrally stored copy. All of a user's permanent state information (now referred to as "persistent" data, regardless of the user's own persistence) will be stored centrally. The user will be able to log in and access all this information from any system in the network, a key argument for the NC.
- System vendors will introduce new "PC lite" configurations based on trailing-edge technology and optimized for low cost. These may appear as sealed boxes that contain x86-clone microprocessors, low-end 2-D graphics solutions, limited main memory and disk storage, a narrow range of LAN adapters, and little else. As noted in Table 2 above, such systems (including monitors) can be sold profitably at prices under $1,100, and with some effort, under $1,000. Price-sensitive customers will choose these configurations instead of a more restricted NC device.

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Perspective

PC Semiconductors and Applications Worldwide

Market Analysis

Surfing the Net at Twice the Speed: 56-Kbps Technology Promises New Life for Analog Modem Chipset Market

Abstract: *New analog modem technology that nearly doubles downloading performance will give the market for modem chipsets a boost in both units and revenue. The new technology increases the downloading speed from 33.6 Kbps to 56 Kbps. Chipset suppliers are charging forward with new products in order to differentiate themselves from each other, but issues of standards and interoperability will complicate this market until a new ITU standard is ratified for the faster operation. The higher performance will also postpone the transition from analog communications services to digital alternatives such as ISDN, cable modems, and xDSL. This document provides an overview of the strategies of key vendors as well as the market impact of 56-Kbps modem technology on the modem chipset market.*
By Geoff Ballew

PC Users Want More Bandwidth

Most home PC users are frustrated by low performance when connecting to the Internet. Inside a PC, data can be moved or processed at speeds measured in megabytes per second, but communication over a modem is about 1,000 times slower. Fast modem speeds are measured in kilobits per second, and the difference between those numbers is obvious to anyone who has connected to the World Wide Web and waited while their favorite Web page downloads. This problem is getting worse as multimedia content on the Web continues to grow. The connected PC is generally not limited by processor speed or memory but by the relatively slow modem connection. High-speed communications is necessary to address this problem and make PC users happier and more productive when using the Internet.

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56.6-Kbps Modems Offer a Performance Boost

Many different technologies are capable of providing higher-speed communications for PCs, but almost all of them face significant roadblocks. The latest enhancement to standard analog modems offers a moderate performance increase for downloading information with far less impact on infrastructure and a far lower cost than alternative solutions. Some analog modems are now capable of 56.6-Kbps operation, almost twice as fast as the fastest V.34 modems at 33.6 Kbps. These modems are asymmetric in terms of performance, though; downloading speed can be 56.6 Kbps, but uploading speed is still limited to 33.6 Kbps. For this reason, the target market for these modems is Internet connectivity rather than general connectivity for high-speed, two-way communication such as videoconferencing. The road to 56.6-Kbps modems does have some potholes as vendors of chips and modems wrestle with issues of interoperability and standards as they race to provide this higher level of performance.

Solutions Today; Standards Tomorrow

The leading vendors of modems and modem chipsets are moving forward with 56.6-Kbps products before a new standard is established. This is both good and bad for end users. The good news is that faster modems are available today and will work with standard telephone lines. The bad news is that modems from different vendors may not be compatible, so there is some risk in buying a modem that is incompatible with the user's Internet service provider (ISP). For vendors of modems and modem chipsets, the transition from 33.6 Kbps to 56.6 Kbps is an opportunity to gain (or lose) market share. These vendors cannot wait until the International Telecommunications Union (ITU) ratifies a new modem standard, because the standards process takes time, and a standard may not be finalized until early to mid-1998. Until a new standard is reached, modem buyers (whether retail or OEM) must balance the benefit of higher performance with compatibility issues.

Compatibility Will Impact Market Share Winners and Losers

Compatibility between modems is extremely important but is by no means assured until the ITU ratifies a 56-Kbps standard. A PC user may have a 56-Kbps modem, but if it is not compatible with the equipment used by that user's ISP, communication will be limited to V.34 speeds (33.6 Kbps maximum). A new modem standard will solve this problem, but not until 1998.

A lack of compatibility could slow down the modem market in two ways. Consumers may postpone retail purchases of 56-Kbps modems unless they know which modems are compatible with their favorite ISP. PC OEMs may also adopt a wait-and-see attitude and simply continue bundling V.34 modems in their standard configurations. To combat this issue, modem and modem IC suppliers are scrambling to build support for their own 56-Kbps protocols.

Two major technologies have emerged to address the compatibility issues, but the two are not interoperable, so modem and modem chip suppliers are forced to choose sides. U.S. Robotics has a proprietary technology called x2; Rockwell and Lucent have one called K56flex. Together, Rockwell and U.S. Robotics supply the modem technology for over 90 percent of the remote access server (RAS) equipment (that is, the modems used by ISPs) in use today. Rockwell has a market share advantage because its technology is used in about 70 percent of RAS modems, compared with just over 20 percent for U.S. Robotics. Alliances or license agreements with at least one of these two companies are therefore critical for suppliers of modem chipsets. Otherwise, users of modems based on those chipsets will have great difficulty finding a compatible ISP, and the user will end up connecting at V.34 speeds instead of 56 Kbps.

Vendor Strategies Include Alliances

The strategies of the dominant suppliers of modems and modem ICs are interesting blends of technology and strategic alliances. The strategies of several key players are discussed here.

U.S. Robotics

U.S. Robotics has taken an aggressive stance with respect to 56-Kbps modems. The company announced in October 1996 that many of its modems were upgradable to 56-Kbps operation by changing the software inside the modem. This upgradability immediately differentiated U.S. Robotics modems from those of other suppliers. Called x2, U.S. Robotics' new modem technology nearly doubles the downloading speed of a V.34 modem. The company went one step further by announcing "free" upgrades to 56 Kbps for certain V.34 modems purchased between November 25 and the end of 1996. Shipping and handling charges are applicable, so the upgrade is not really free, but the charge is less than $10.

The fact that many U.S. Robotics modems sold during 1996 are upgradable does not mean that all of them will be upgraded. Some models are easier to upgrade than others. Many of the Sportster modems sold in 1996 have socketed ROM chips that must physically be replaced to upgrade the software. Some other U.S. Robotics modems, such as the Courier V.everything, have flash ROM and can be upgraded without any hardware changes.

U.S. Robotics was able to make upgradable modems because it uses programmable digital signal processors (DSPs) from Texas Instruments for many of its products instead of standard modem chipsets. This makes U.S. Robotics unique among modem suppliers to the mass market and positions the company as a technology supplier as well as a modem supplier. The company has already licensed x2 technology to Cirrus Logic, Texas Instruments, and Cardinal Technologies.

Rockwell

Rockwell is the largest supplier of modem ICs in the world and was the industry leader for the transition from 14.4-Kbps to 28.8-Kbps modem chipsets. The transition from V.34 to 56 Kbps leaves Rockwell vulnerable to losing some of its market share. Rockwell's V.34 chipsets are not programmable like the TI DSPs that U.S. Robotics uses for many of its modems. A consequence of this is a relative delay for 56-Kbps modems based on Rockwell's chipsets with K56Plus, Rockwell's proprietary 56-Kbps technology. Rockwell expects to have 56-Kbps chipsets available in first quarter 1997, so modems based on those chipsets should be available in second quarter 1997. In the meantime, U.S. Robotics is already shipping modems that are upgradable to 56 Kbps via downloadable software.

Rockwell is pursuing a product strategy that minimizes the compatibility risk of shipping chipsets before a 56-Kbps standard is ratified. This strategy has two major components: programmability and interoperability with another proprietary standard. Rockwell's new modem chipset is upgradable via downloadable software, so modems based on that chipset will be upgradable to the ITU standard when it is ratified. This is critical for prestandard chip sales because it provides insurance against product obsolescence. Also, Rockwell has formed an alliance with Lucent Technologies to develop a modem protocol that will ensure interoperability between their products before a standard is reached. The new protocol will be called K56flex, drawing from Lucent's V.flex2 and Rockwell's K56Plus protocols, which are proprietary.

The Rockwell/Lucent alliance is fascinating because these two companies have been fierce competitors in previous battles over modem standards. Their decision to team up against U.S. Robotics reveals how much market clout U.S. Robotics has gained as a modem technology provider since the V.34 standards battle.

Lucent Technologies (formerly AT&T Microelectronics)

Lucent is the second-largest supplier of modem ICs but had only one-quarter of the revenue that Rockwell did in 1995. The company has strong relationships with key PC OEMs such as Compaq, Hewlett-Packard, and Toshiba and sells to seven of the top 10 modem suppliers, according to company press releases.

Lucent is taking the 56-Kbps technology one step further than other vendors by increasing the uploading speed as well as the downloading speed. The Venus chip from Lucent will offer 40-Kbps performance for uploading data, while other 56-Kbps modem chipsets are limited to 33.6 Kbps for upstream communication. The higher upstream performance and interoperability with Rockwell chipsets should strengthen Lucent's position in the market because this increases performance without compromising compatibility.

The company's modem chipsets leverage its expertise in programmable DSP, and the forthcoming chipsets will be software upgradable. This upgradability, coupled with the interoperability agreement with Rockwell, helps to protect Lucent against incompatibility until a 56-Kbps standard is established.

Texas Instruments

TI's modem IC revenue has been driven upward by U.S. Robotics' success. U.S. Robotics doesn't buy many traditional chipsets from TI, but it does buy analog front-end chips paired with programmable DSPs. Selling ICs to the biggest modem maker in North America clearly has its advantages. The company has licensed U.S. Robotics' x2 technology for 56-Kbps operation, so TI chipsets sold to other modem vendors should be compatible with U.S. Robotics x2 modems before a new standard is reached.

Cirrus Logic

Cirrus Logic's modem market share has slipped over the past couple of years as competition for V.32 bis (14.4 Kbps) chipsets increased in 1995 and Cirrus's schedule for its V.34 chipset continued to slip. The shift to 56 Kbps is an opportunity for the company to bolster its position in the market for 1997, but timely execution is important. Cirrus has licensed the x2 technology from U.S. Robotics and therefore has chosen to side with U.S. Robotics rather than the Rockwell/Lucent camp for prestandard 56-Kbps technology.

Sierra Semiconductor

Sierra exited the modem chipset business in 1996 because of the competitive pressures in the market for V.34 chipsets. The company was the fourth-largest supplier of modem ICs in 1995, with $80 million in revenue.

Modem and Modem Chipset Market Shares

Tables 1 and 2 provide market share information for the modem and modem chipset markets. Information on the 1996 market share will be published during the spring and summer of 1997.

Table 1
Top Five Vendors of Modems by Unit Shipments in North America

Vendor	1995 Units (K)	Market Share (%)
U.S. Robotics/Megahertz	4,438	23.6
Maxtech/GVC Technologies Inc.	2,610	13.9
Hayes Microcomputer Products Inc.	1,542	8.2
Boca Research	1,034	5.5
Zoom Telephonics	921	4.9
Others	8,284	44.0
Total	18,829	100.0

Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (January 1997)

Table 2

Top 10 Vendors of Modem ICs by Worldwide Revenue (Millions of Dollars)

1995 Rank	1994 Rank	Company	1994 Revenue	1995 Revenue	Percentage Change	1995 Market Share (%)
1	1	Rockwell	494.0	701.0	41.9	58.0
2	2	AT&T (Lucent)	105.0	175.0	78.6	14.5
3	3	Texas Instruments	51.4	116.0	125.5	9.6
4	4	Sierra Semiconductor	41.5	79.1	90.6	6.5
5	6	Silicon Systems	14.2	34.9	145.8	2.9
6	4	Cirrus Logic	40.0	30.0	-25.0	2.5
7	8	Analog Devices	8.9	21.8	146.0	1.8
8	7	Toshiba	12.0	12.0	0	1.0
9	9	Motorola	7.3	10.6	44.6	0.9
10	10	Exar	5.0	7.0	40.0	0.6
		Other Companies	19.9	20.9	5.0	1.9
		Total	799.2	1,208.3	493.0	100.0

Note: Includes chipsets, standalone functions, DSPs for modem use; includes fax-only modem ICs
Source: Dataquest (January 1997)

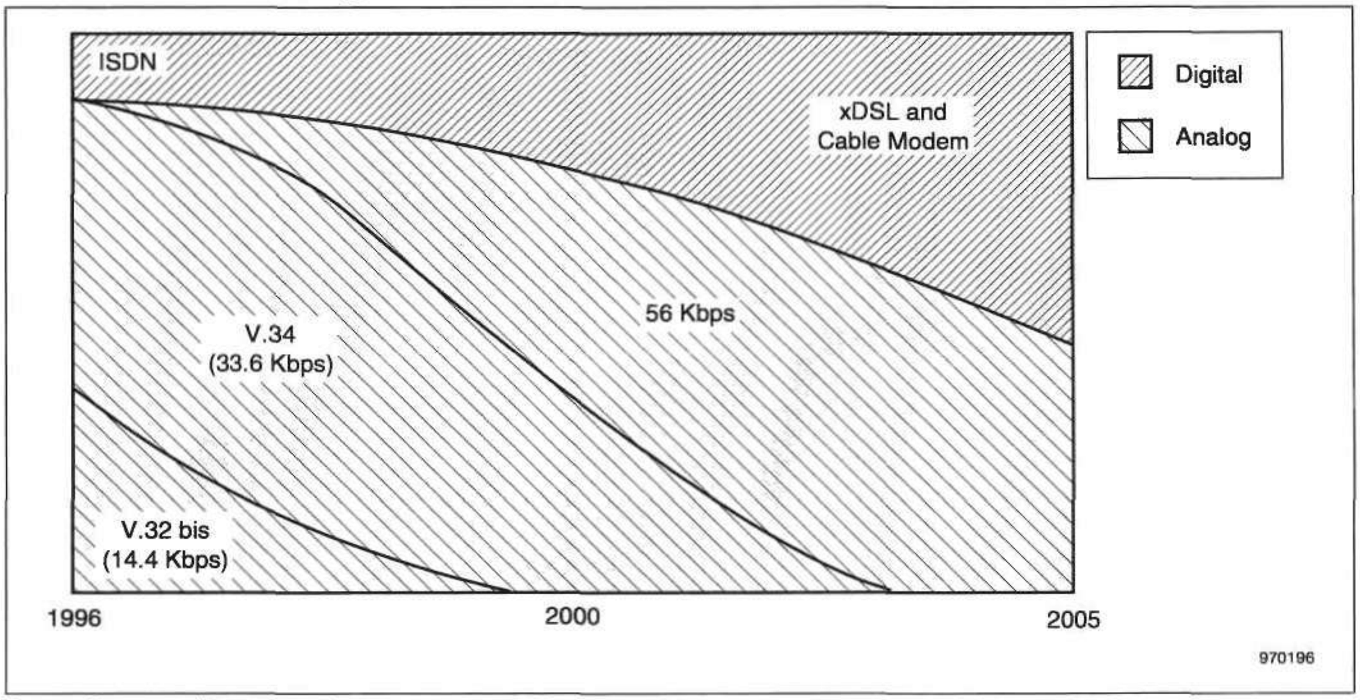
Road Map for Analog Modems versus Alternate Solutions

The transition from standard analog modems to alternative solutions is inevitable but will not happen until after the year 2000. Analog modems have advantages in terms of cost and the ability to work with existing telephone network infrastructure (cabling as well as central office equipment). These advantages are offset by limitations on performance that will eventually drive users and service providers to higher-performance alternatives such as integrated services digital network (ISDN), cable modems, and xDSL (a term that refers to several digital subscriber loop, or DSL, technologies). These alternatives offer higher performance today but face significant barriers in terms of cost, availability, and network infrastructure.

Retail prices for ISDN terminal adapters (TAs) have fallen to less than $200 from more than twice that at the beginning of 1996. ISDN service remains substantially more expensive than plain old telephone service (POTS) and is still only 128 Kbps rather than the megabits per second performance possible with cable modems and xDSL modems. Unfortunately, those other solutions are four to six years from widespread deployment. A recent Dataquest forecast estimated that the installed base of xDSL lines would be only 6.2 million worldwide by the year 2000. That means that the market dynamics between analog and digital will really be a battle between analog and ISDN for the next few years.

Dataquest expects analog modems to dominate the modem market for several years because of the cost and infrastructure issues surrounding ISDN and its relatively small performance advantage (a bit more than twice as fast as a 56-Kbps modem). That could change if the telephone companies (telcos) get more aggressive about ISDN and price it more competitively against POTS. ISDN is more established in Europe than in other regional markets. Another swing factor is the cable TV companies. If they get aggressive about offering Internet services over the cable network, then the telcos may speed up the introduction of xDSL services to protect their business in areas with cable TV access. Figure 1 presents Dataquest's view of how the transition from analog modems to alternative solutions will evolve.

Figure 1
Transition from Analog Modems to Alternate Solutions



Source: Dataquest (January 1997)

Tables 3 and 4 show the Dataquest unit and revenue forecast for modem chipsets. This forecast is a revision of the spring 1996 forecast to reflect the 56-Kbps market opportunity. The availability of 56-Kbps modems should raise the unit demand for modem chipsets. Some V.34 modem users will choose to upgrade to 56 Kbps even though they would not upgrade to a digital modem. This upgrade cycle will cost the digital modem market some unit sales but represents a net increase in total units. Dataquest's previous forecast showed slower growth from 1998 to 2000 because analog modem performance was expected to stagnate at V.34. The continual doubling of analog modem performance over the past several years resulted in many modem users buying new modems for performance reasons. The 56-Kbps technology allows that trend to continue and therefore boosts the market opportunity for retail modems as well as the chips inside them.

Revenue is higher than the previous forecast because of higher unit shipments as well as the higher average selling prices (ASPs) for 56-Kbps chipsets. Revenue growth is slow because of competitive pressures that will keep prices declining almost as fast as unit shipments increase.

Table 3
Unit Forecast for Modem Chipsets (Thousands of Units)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Digital (End-User Nodes)	1,850	4,073	5,806	6,290	6,514	8,143	9,985	19.6
Analog (V.34, V.32 bis, and 56 Kbps)	14,020	30,995	40,154	51,888	63,389	71,322	77,168	20.0
Total	15,870	35,068	45,960	58,178	69,903	79,465	87,153	20.0

Source: Dataquest (January 1997)

Table 4
Revenue Forecast for Modem Chipsets (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Digital (End-User Nodes)	35	77	100	103	102	121	141	13.0
Analog (V.34, V.32 bis, and 56 Kbps)	525	921	938	1,147	1,152	1,137	1,139	4.3
Total	560	998	1,038	1,250	1,254	1,258	1,280	5.1

Source: Dataquest (January 1997)

Dataquest Perspective

Suppliers of modem chipsets should enjoy a profitable and growing market as PC users demand faster communications services. This market does face a number of technology shifts, and each one is an opportunity to win or lose market share. The first major transition is from V.34 to 56-Kbps analog modems. This transition involves risk regarding compatibility between products from different suppliers until a standard is ratified. A far more risky transition will occur between the year 2000 and 2005 as the modem market shifts from analog to digital modems, with a comparable transition for the modem chipset market. It is unclear which digital technology will prevail, but xDSL is the most likely, followed by cable modem and then ISDN. Suppliers of modem chipsets should be prepared to supply chips for all of these technologies until a leader is more obvious.

A key factor to watch for in the transition from V.34 to 56 Kbps is the attitudes of PC OEMs toward prestandard 56-Kbps modems. Confusion about compatibility may cause the PC OEMs (as well as end users) to adopt a wait-and-see attitude. Commitments made by the top five PC OEMs to bundle prestandard 56-Kbps modems with consumer PCs should be received with optimism. Two early announcements were made at the Winter Consumer Electronics Show (CES) on January 9. Compaq Computer and modem maker Hayes each announced they would have products on store shelves in the first quarter of 1997 that use 56-Kbps chipsets from Lucent.

Compaq will bundle the 56-Kbps modems with some PC models, while Hayes will offer 56-Kbps modems for retail sale. If the modems bundled by PC OEMs overwhelmingly favor one prestandard protocol (x2 from U.S. Robotics or the K56flex from Rockwell and Lucent), proponents of the other technology may be forced to the bargaining table to negotiate prestandard interoperability. That could speed up the standards-setting process and result in a new standard sooner (early 1998) rather than later (late 1998).

Key factors to watch for in the transition from analog to digital modems are the infrastructure investments of existing and potential service providers and the competitive dynamics between the cable companies and the telcos. This transition is unlikely to occur before the year 2000, but competitive pressures among service providers could speed things up. A strong commitment by the telcos to price ISDN more competitively and ensure enough capacity to meet demand would help the transition to digital technologies. Another scenario might be that the telcos push aggressively to roll out xDSL services because of the competitive threat (real or imagined) from the cable companies. These two scenarios are most likely to be mutually exclusive because of the infrastructure investment required to support these services.

The most likely impact of 56-Kbps modem technology on the market is, first, higher modem chipset revenue driven by higher ASPs and greater unit shipments and, second, the postponement of the transition from analog to digital modems.

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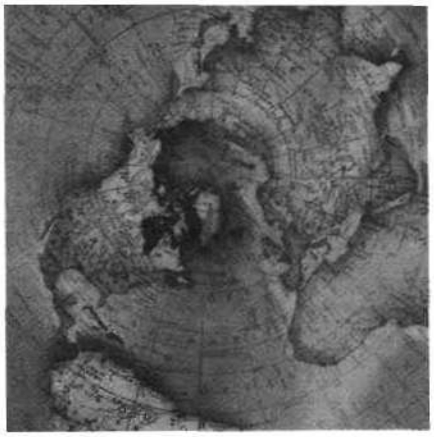
Market Trends



Dataquest

Codependency Defined: PCs and Semiconductors

Market Trends

Program: Personal Computer Semiconductors and Applications Worldwide
Product Code: PSAM-WW-MT-9703
Publication Date: October 6, 1997
Filing: Market Trends

Codependency Defined: PCs and Semiconductors

Market Trends

Program: Personal Computer Semiconductors and Applications Worldwide
Product Code: PSAM-WW-MT-9703
Publication Date: October 6, 1997
Filing: Market Trends

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Chapter 1

Executive Summary

Semiconductors are the life blood of the PC industry. Sure. there is software, a case, and often a CRT, but quite simply, *megahertz sells.* The semiconductor market continues to fuel the PC market with faster microprocessors, bigger memory chips, and faster peripheral chipsets; but, as a victim of its own success, the semiconductor industry has also found itself dependent on that same PC market for its own growth.

PCs are the largest single application for semiconductors and as such consume acres of chips every year. However, PCs play a much larger role than just raw demand for volumes of silicon chips; they require some of the fastest and most advanced chips on the face of the Earth. In other words, semiconductor vendors must push the limits of technology to provide the killer chips that help fuel the PC market growth. Profits from the sales of those killer chips are fed back into the system to fund the development of newer products with higher megahertz and more megabytes for the same low price—that is, for the next round of killer chips. This cycle is a critical driver of both the PC and semiconductor markets.

The PC market, counting motherboards and handheld PCs, is forecast to grow at a compound annual growth rate (CAGR) of 16.2 percent on a revenue basis from 1996 to the year 2001, with Japan and Asia/Pacific exhibiting higher growth than other regions. Semiconductor revenue per PC will grow much faster than PC revenue. Dataquest expects PC semiconductor revenue to grow 23.0 percent over the same period, giving semiconductor vendors an even larger slice of the PC market pie.

This level of growth will create opportunities for semiconductor vendors to sell a variety of chips into the PC market. Microprocessors and memory products top the list for sheer magnitude of revenue, but opportunities abound in graphics, audio, and communications, too. Overall semiconductor content in PCs will grow to $127.1 billion in the year 2001, more than doubling from the $44 billion mark in 1996.

Project Analyst: Geoff Ballew

Chapter 2

Introduction and Methodology

This document is the second in a series of three that provide reference information and analysis about the markets for semiconductor devices in personal computers. The three books are graphics and audio controllers (PSAM-WW-MT-9701), this volume (PSAM-WW-MT-9703), which includes a model of total semiconductor content for PCs and a third book covering microprocessors and core logic chipsets (PSAM-WW-MT-9702). Specific areas of information discussed in this volume include:

- PC system market size in revenue, units, and average selling price (ASP)
- PC system market and product feature trends
- Hardware architecture trends and semiconductor device opportunities
- Semiconductor content and market forecast
- Listings of key OEMs

The information in this report is gathered from both primary and secondary sources. Primary sources include surveys and interviews of industry vendors and customers, combined with analyst knowledge and opinions. Secondary sources include governmental and trade sources on sales, production, trade, and public spending. Semiconductor content assumptions are based on both surveys of producing OEMs and physical teardown evaluations by Dataquest analysts of representative personal computers.

The forecast methodology is based on various methods and assumptions, depending upon the specific market. To form a solid basis for projecting system demand, capital, government, and consumer spending, assumptions are made for various regions of the world. For specific markets, saturation and displacement dynamics are considered, as well. Key exogenous factors such as new software introductions, exchange rate changes, and government policies are also considered. Semiconductor content forecasts are based upon interviews of system marketers and designers (including makers of enabling semiconductor technology) along with an analysis of historical trends.

Chapter 3
Personal Computer and Workstation Markets

Market and Production Trends

Personal Computers

Market and production trends in PCs and workstations are as follows:

- PC unit shipments are expected to show a 16.2 percent CAGR over the next five years. PC market revenue should post slightly higher growth at 17.2 percent CAGR.
- Regional growth for PCs highlights some important dynamics.
  - The United States is dominated by a replace-and-upgrade cycle with significant potential for upgrades to the aging base of 486 and Pentium PCs sold to consumers from 1993 to 1995.
  - Europe is likely to lag behind other regions for PC market growth because of economic and social issues surrounding home PCs.
  - Japan and Asia/Pacific will buoy the home PC market growth as many consumers purchase their first PC.
- Mobile PC shipments will grow faster than the overall market, but deskbound systems will continue to dominate the computing platform because of their lower manufacturing costs, the ability to handle robust configurations with large amounts of storage, and their role in offering the fastest and latest computing technologies.
- Notebooks have enjoyed solid unit growth because of their ability to replicate desktop environments, and growth for 1997 should top 22 percent on a unit basis. Larger LCDs, bigger hard disks, and integrated CD-ROM drives continue to narrow the performance gap between desktop and notebook PCs. Revenue growth will come under pressure as declines in ASP offset the unit shipment gains for this year.
- Ultraportable and notepad shipments continue to grow but may be surpassed by handheld PCs as the second largest mobile category, behind notebooks, in 1999. Ultra-portable ASPs, like those of traditional notebooks, are expected to decline this year, limiting revenue growth to just a few percent despite a forecast of almost 20 percent unit growth.
- Shipments of laptops and transportable units rose last year after sharply declining in 1995. This resurgence in sales of transportable PC will continue through the year 2001 when shipments will top 160,000 units.
- In the world of mobile computing, handheld devices continue to promise function and mobility, but face size, weight, and cost issues. Dataquest has defined two categories for these handheld devices, but only the handheld computer category is covered by this document.
  - Expandable organizers—These are computers that typically measure 3.0 x 6.0 x 0.75 inches and weigh less than a pound. They are distinguished by the capability to have the user add applications and memory, and the fact that expansion is proprietary to a particular device or family. The operating systems typically are proprietary.

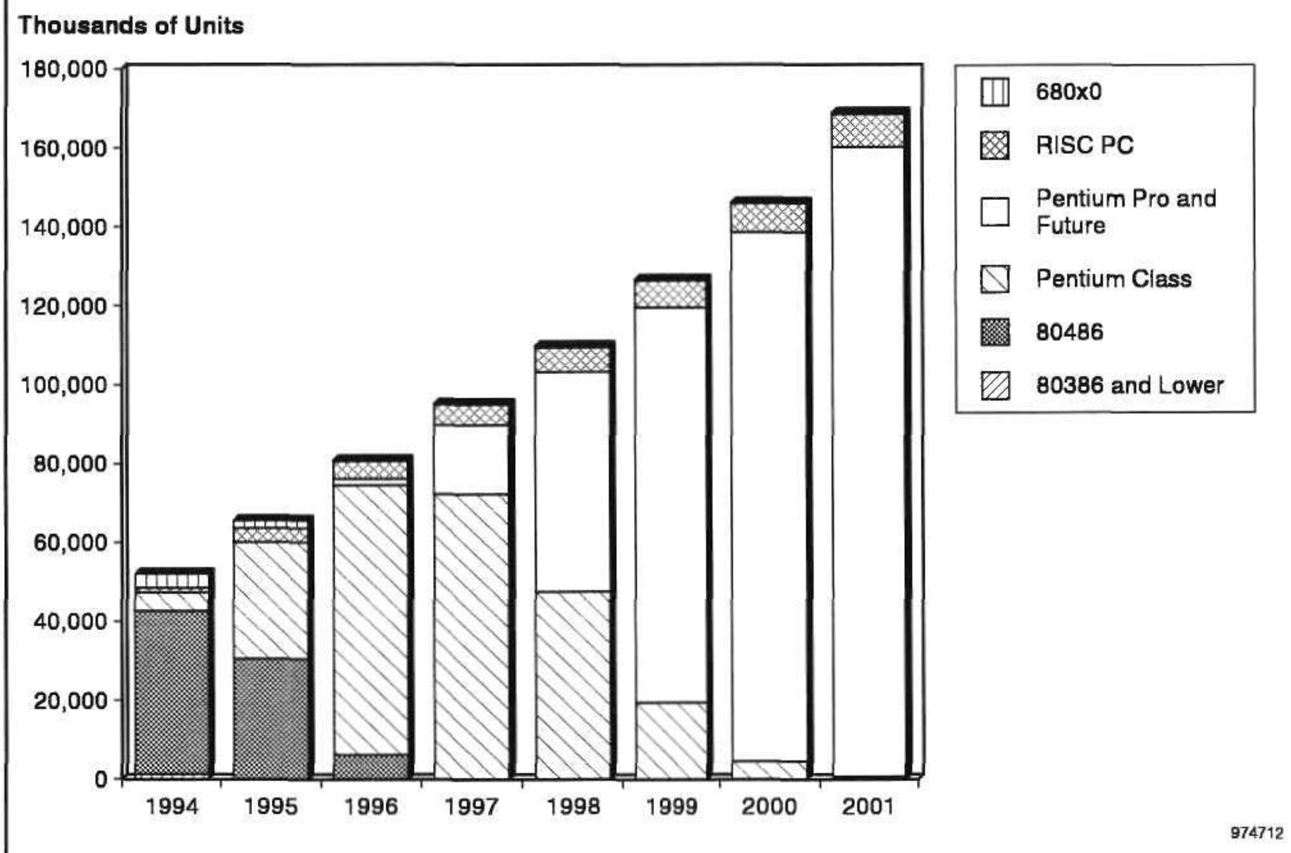
The market for these devices is expected to peak at more than 500,000 unit shipments in 1995 and then slowly shrink to fewer than 400,000 by 1999.

- Handheld computers—These devices typically measure 4 x 7 x 1 inches and weigh about a pound. They are distinguished from expandable organizers by their adherence to hardware and software compatibility standards. The operating systems are open and licensed, and application development and memory expansion are open to third-party developers and may be distributed in a standard format (such as PC Memory Card International Association, or PCMCIA). Personal digital assistants (PDAs) fall into this category, and, specifically, U.S. Robotics' Pilot products are included.

- Strong growth in the worldwide home PC market will continue across all regions of the world. The home PC market will grow slightly faster than the business PC market. The projected five-year CAGRs for these two market segments are 16.9 percent and 16.3 percent, respectively.
- Price elasticity is an important factor in the home PC market. Dataquest expects the renewed interest in the sub-$1,000 PC to boost PC ownership in non-PC households. Compaq's Presario 2200 series is a bellwether for the sub-$1,000 market segment.
- Microsoft's Windows 98 operating system (Memphis) was delayed and will miss the window of opportunity for factory-installation on Christmas PCs. Only one version will be produced rather than separate OEM and retail versions, as was done for Windows 95.
- For PC unit shipments, Asia/Pacific is the fastest-growing region, and Europe is the slowest.
- Major PC manufacturers will continue to place a strong emphasis on the branding of PCs.
- Manufacturing strategies are dictated by economies of scale with strong influence from free trade zones, the availability of components, and the quality and price of labor. For desktop PCs, the trend is toward assembling units close to the end market or at least final configuration (including CPU and main memory installation) being executed on demand close to the end market. For mobile PCs, production is largely focused in Japan and other Asian countries. A rising tide of OEM notebooks from Taiwanese vendors will continue Asia/Pacific region's growing influence on the mobile PC market.
- Motherboard production will depend more heavily on the Asia/Pacific region as suppliers continue to regain some of the market share they lost because of Intel's rapid growth in the motherboard business in 1994 and 1995.

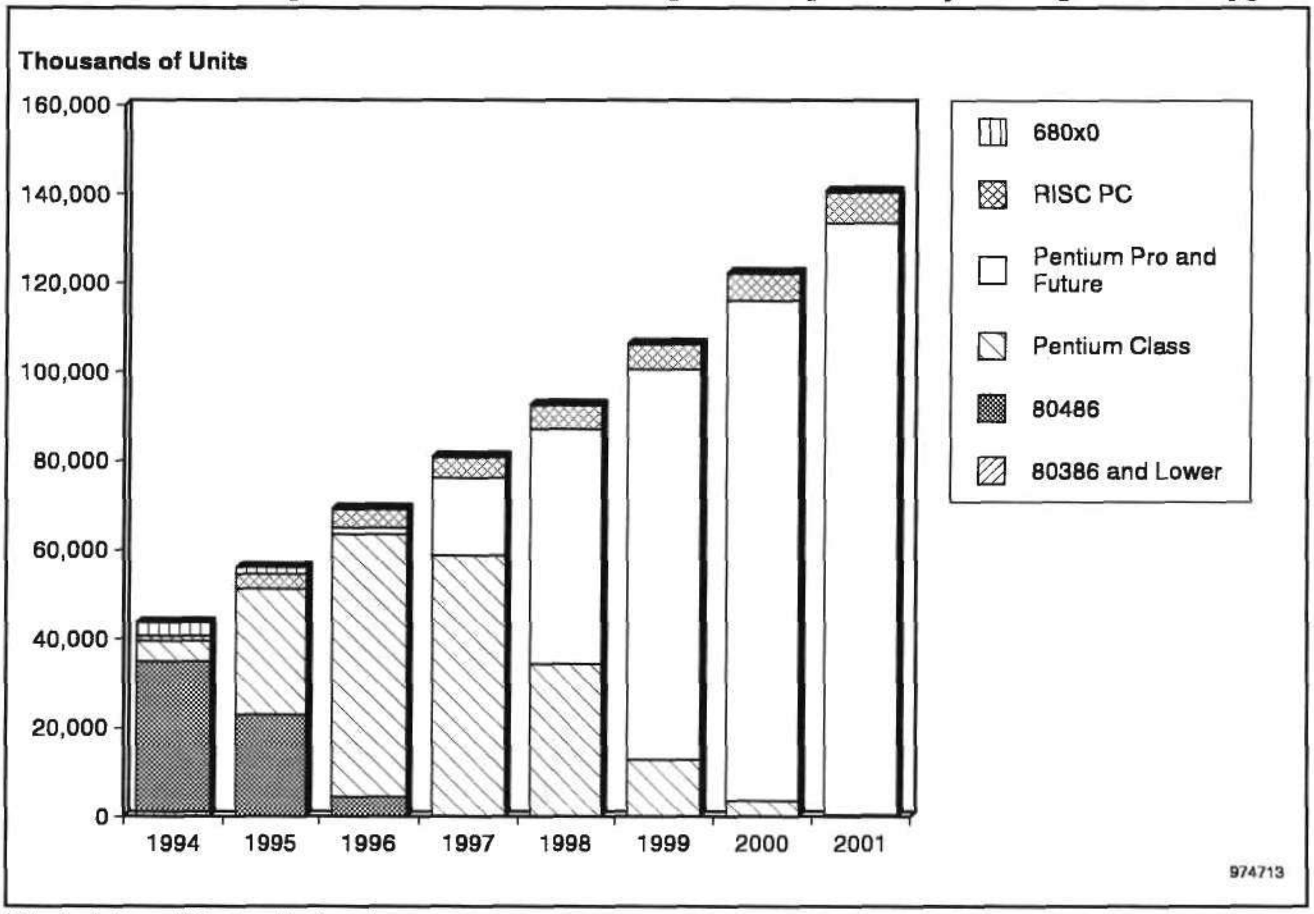
Figures 3-1 to 3-3 and Tables 3-1 to 3-7 present Dataquest's worldwide PC market forecasts. Figures 3-4 and 3-5 show the regional variation in markets and production from 1994 to 2001. Figure 3-6 illustrates the regional differences for PC and motherboard production. Table 3-8 includes the regional production data from Figure 3-6 and more.

Figure 3-1
Worldwide Personal Computer Shipments by Microprocessor Type



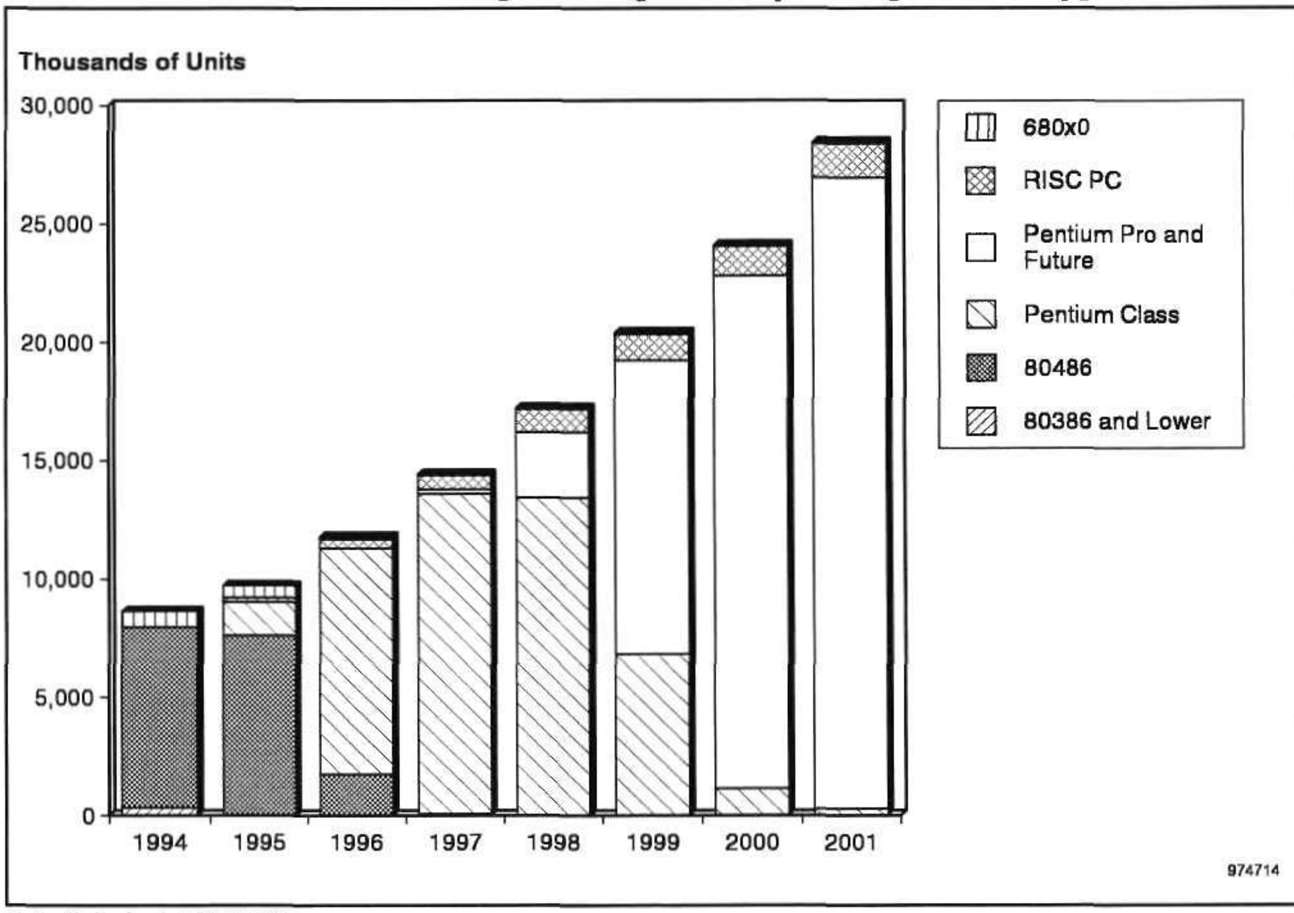
Note: Includes additional motherboards but excludes handheld PCs
Source: Dataquest (September 1997)

Figure 3-2
Worldwide Desktop/Deskside Personal Computer Shipments by Microprocessor Type



Note: Includes additional motherboards
Source: Dataquest (April 1997)

Figure 3-3
Worldwide Mobile Personal Computer Shipments by Microprocessor Type



Note: Excludes handheld PCs
Source: Dataquest (April 1997)

Table 3-1
Worldwide Personal Computer Market by Product Type

Product Type	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Desktop/Deskside									
Units (K)	39,252	50,450	59,067	69,887	81,194	93,232	107,156	123,190	15.8
ASP ($K)	1.88	1.93	1.98	2.03	2.17	2.16	2.12	2.10	1.3
Factory Revenue ($M)	73,937	97,392	116,789	141,777	175,798	201,443	227,377	259,284	17.3
Transportable/Laptop/Others									
Units (K)	166	43	55	62	63	97	135	161	24.0
ASP ($K)	6.25	5.38	4.16	3.86	3.86	4.57	4.81	4.78	2.8
Factory Revenue ($M)	1,035	230	229	238	242	443	650	770	27.5
Notebook/Tablet									
Units (K)	7,480	8,483	10,973	13,434	16,009	18,868	22,145	26,093	18.9
ASP ($K)	2.49	2.72	2.89	2.48	2.43	2.52	2.57	2.60	-2.1
Factory Revenue ($M)	18,653	23,073	31,737	33,327	38,828	47,510	56,954	67,945	16.4
Ultraportable/Notepad									
Units (K)	997	1,195	754	896	1,111	1,400	1,781	2,158	23.4
ASP ($K)	1.84	2.47	2.59	2.23	2.24	2.33	2.31	2.31	-2.3
Factory Revenue ($M)	1,832	2,948	1,957	1,995	2,488	3,255	4,122	4,979	20.5
Handheld									
Units (K)	390	244	573	803	1,144	1,723	2,396	3,830	46.2
ASP ($K)	0.82	0.98	0.53	0.42	0.41	0.40	0.39	0.39	-6.1
Factory Revenue ($M)	318	238	304	338	464	681	937	1,487	37.4
Additional Motherboards									
Units (K)	4,318	5,548	10,224	10,947	11,367	13,052	15,002	17,247	11.0
ASP ($K)	1.19	1.05	0.71	0.65	0.72	0.87	1.06	0.93	5.4
Factory Revenue ($M)	5,159	5,836	7,289	7,077	8,178	11,340	15,879	15,971	17.0

Table 3-1 (Continued)
Worldwide Personal Computer Market by Product Type

Product Type	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Total PC (Including Handheld and Additional Motherboards)									
Units (K)	52,602	65,963	81,647	96,028	110,888	128,372	148,615	172,678	16.2
ASP ($K)	1.92	1.97	1.94	1.92	2.04	2.06	2.06	2.03	0.9
Factory Revenue ($M)	100,933	129,715	158,305	184,752	225,999	264,672	305,918	350,436	17.2
Workstation									
Units (K)	735	852	871	1,020	1,342	1,779	2,290	2,595	24.4
ASP ($K)	15.06	15.74	14.61	12.78	11.31	9.83	8.51	7.77	-11.9
Factory Revenue ($M)	11,070	13,406	12,727	13,033	15,172	17,486	19,482	20,162	9.6

Note: Includes additional motherboards; excludes handheld PCs; ASP and factory revenue include standard peripherals and memory upgrades installed by the factory or PC assembler.
Source: Dataquest (April 1997)

Table 3-2
Worldwide Personal Computer Shipments by Microprocessor Type (Thousands of Units)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
386 and Lower	1,489	83	8	0	0	0	0	0	-100.0
486	41,486	30,594	6,311	256	3	0	0	0	-100.0
Pentium Class	4,596	29,655	68,483	72,174	47,821	19,647	4,799	789	-59.0
Pentium Pro and Future	0	3	1,565	17,598	55,659	100,303	134,078	159,685	152.2
RISC PC	1,151	3,571	4,524	5,184	6,260	6,698	7,342	8,373	13.1
680x0	3,489	1,812	183	13	0	0	0	0	-100.0
Others	0	0	0	0	0	0	0	0	0
Total	**52,212**	**65,719**	**81,074**	**95,225**	**109,744**	**126,649**	**146,219**	**168,848**	**15.8**

Note: Includes additional motherboards; excludes handheld PCs
Source: Dataquest (April 1997)

Table 3-3
Worldwide Desktop/Deskside Personal Computer Shipments by Microprocessor Type (Thousands of Units)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
386 and Lower	1,137	69	8	0	0	0	0	0	-100.0
486	33,862	22,970	4,546	164	0	0	0	0	-100.0
Pentium Class	4,574	28,237	58,926	58,646	34,381	12,798	3,625	490	-61.6
Pentium Pro and Future	0	3	1,565	17,413	52,872	87,901	112,433	133,018	143.2
RISC PC	1,151	3,381	4,141	4,599	5,308	5,585	6,100	6,928	10.8
680x0	2,845	1,338	106	12	0	0	0	0	-100.0
Others	0	0	0	0	0	0	0	0	NA
Total	**43,570**	**55,999**	**69,292**	**80,834**	**92,561**	**106,284**	**122,158**	**140,436**	**15.2**

Note: Includes additional motherboards
NA = Not available
Source: Dataquest (April 1997)

Table 3-4
Worldwide Mobile Personal Computer Shipments by Microprocessor Type (Thousands of Units)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
386 and Lower	352	14	0	0	0	0	0	0	-100.0
486	7,624	7,625	1,765	92	3	0	0	0	-100.0
Pentium Class	22	1,418	9,557	13,528	13,441	6,849	1,175	299	-50.0
Pentium Pro and Future	0	0	0	186	2,787	12,403	21,645	26,667	NA
RISC PC	0	190	384	585	952	1,113	1,242	1,445	30.4
680x0	644	474	77	1	0	0	0	0	-100.0
Others	0	0	0	0	0	0	0	0	NA
Total	**8,642**	**9,721**	**11,783**	**14,391**	**17,183**	**20,364**	**24,061**	**28,411**	**19.2**

Note: Excludes handheld PCs
NA = Not available
Source: Dataquest (April 1997)

Table 3-5
Worldwide Personal Computer Revenue by Microprocessor Type (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
386 and Lower	1,480	67	5	0	0	0	0	0	-100.0
486	76,725	53,695	8,592	265	3	0	0	0	-100.0
Pentium Class	13,867	65,331	136,276	134,057	94,072	36,604	9,597	797	-64.2
Pentium Pro and Future	0	14	4,744	41,948	120,676	215,953	282,732	333,802	134.1
RISC PC	2,806	7,542	8,168	8,131	10,784	11,435	12,652	14,350	11.9
680x0	5,737	2,828	217	13	0	0	0	0	-100.0
Others	0	0	0	0	0	0	0	0	NA
Total	**100,615**	**129,477**	**158,001**	**184,414**	**225,535**	**263,991**	**304,981**	**348,949**	**17.2**

Note: Includes additional motherboards; excludes handheld PCs; factory revenue includes standard peripherals and memory upgrades installed by the factory or PC assembler.
NA = Not available
Source: Dataquest (April 1997)

Table 3-6
Worldwide Desktop/Deskside Personal Computer Revenue by Microprocessor Type (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
386 and Lower	978	48	5	0	0	0	0	0	-100.0
486	57,365	34,547	5,134	139	0	0	0	0	-100.0
Pentium Class	13,679	59,763	10,6827	10,0469	62,125	22,579	6,857	452	-66.5
Pentium Pro and Future	0	14	4,744	41,346	113,116	181,118	226,328	263,507	123.3
RISC PC	2,806	7,068	7,261	6,888	8,735	9086	10,071	11,296	9.2
680x0	4,269	1,789	107	11	0	0	0	0	-100.0
Others	0	0	0	0	0	0	0	0	NA
Total	**79,096**	**103,228**	**124,078**	**148,854**	**183,976**	**212,783**	**243,255**	**275,255**	**17.3**

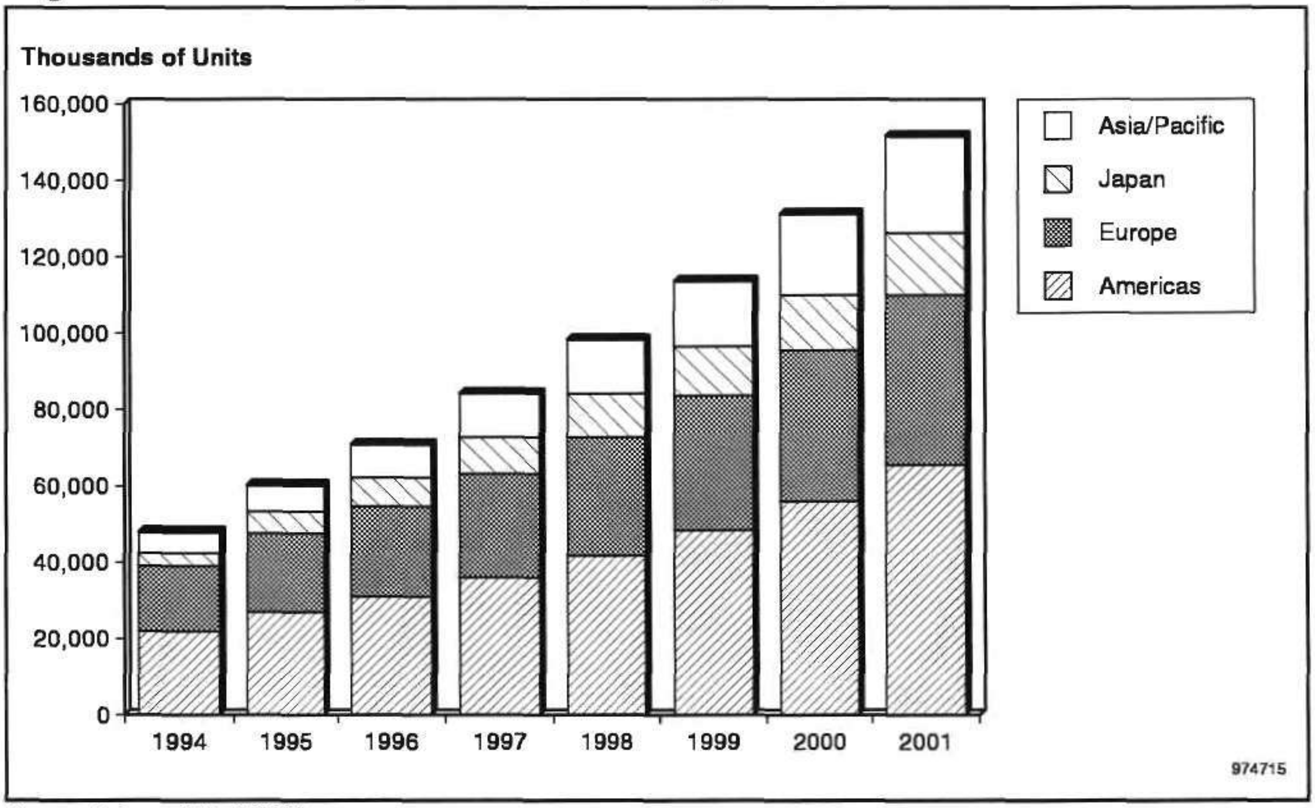
Note: Includes additional motherboards
NA = Not available
Source: Dataquest (April 1997)

Table 3-7
Worldwide Mobile Personal Computer Revenue by Microprocessor Type (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
386 and Lower	502	19	0	0	0	0	0	0	NA
486	19,360	19,148	3,458	127	3	0	0	0	-100.0
Pentium Class	189	5,569	29,448	33,587	31,948	14,025	2,740	345	-58.9
Pentium Pro and Future	0	0	0	602	7,560	34,835	56,404	70,294	1377.0
RISC PC	0	474	907	1,243	2,049	2,348	2,582	3,054	27.5
680x0	1,469	1,039	110	2	0	0	0	0	-100.0
Others	0	0	0	0	0	0	0	0	NA
Total	**21,519**	**26,248**	**33,923**	**35,560**	**41,559**	**51,208**	**61,725**	**73,693**	**16.8**

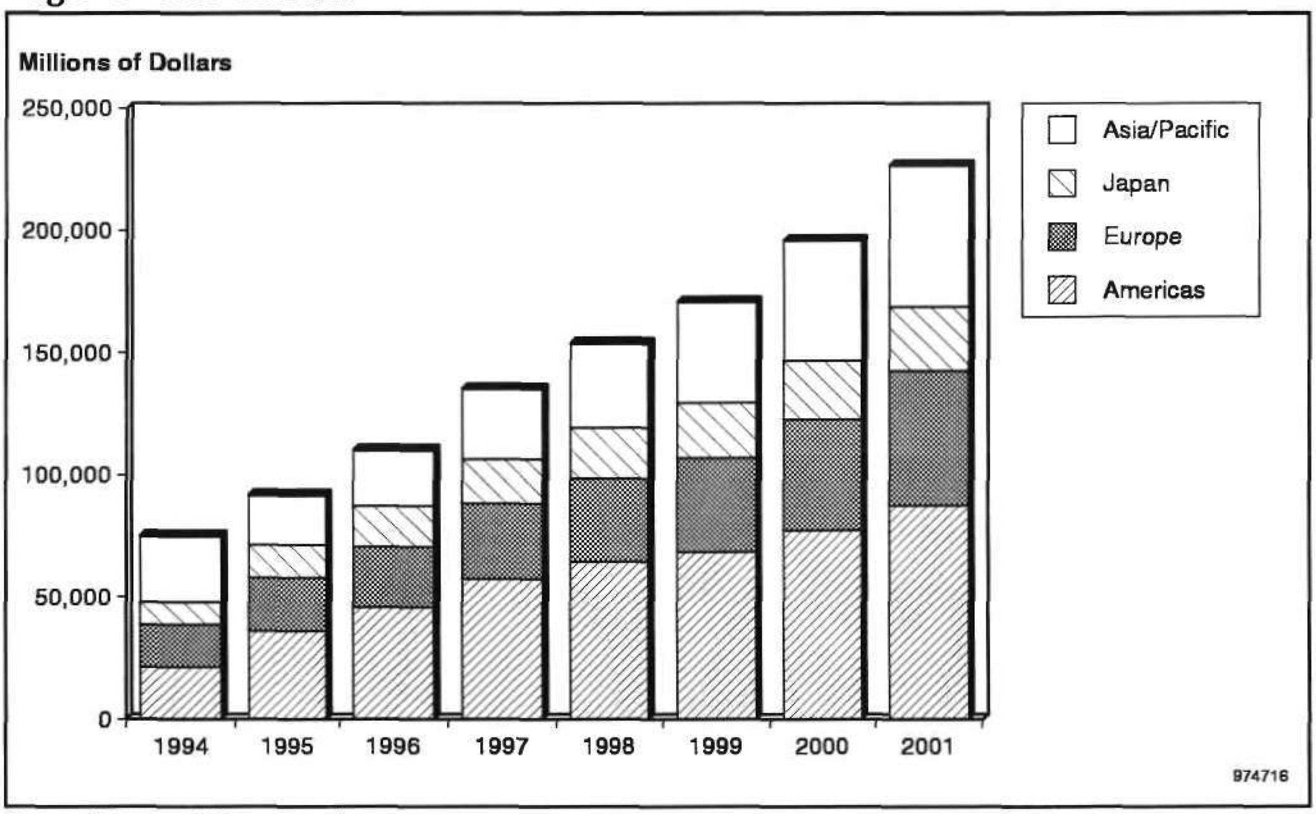
Note: Includes motherboard upgrade market; excludes handheld PCs; factory revenue includes standard peripherals and memory upgrades installed by the factory or PC assembler.
NA = Not available
Source: Dataquest (April 1997)

Figure 3-4
Regional Personal Computer Markets (Unit Shipments)



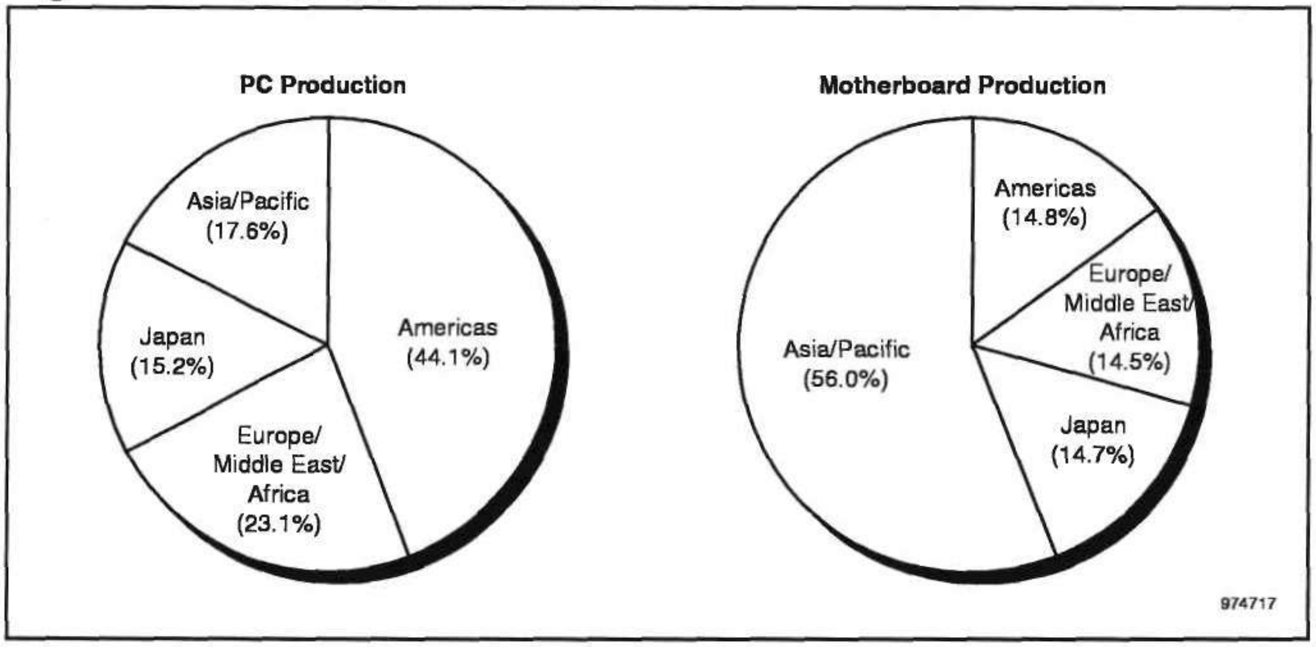
Source: Dataquest (April 1997)

Figure 3-5
Regional PC Production



Source: Dataquest (February 1997)

Figure 3-6
Regional PC and Motherboard Production for 1996



Source: Dataquest (February 1997)

Table 3-8
Regional PC and Motherboard Production (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
PC Production									
Americas	20,236	34,897	44,610	56,398	63,043	66,739	75,504	85,431	13.9
Europe/Middle East/ Africa	16,250	20,651	23,324	29,464	32,484	36,661	43,085	52,377	17.6
Japan	8,731	12,371	15,409	16,406	18,922	20,527	21,917	23,782	9.1
Asia/Pacific	23,751	16,927	17,784	22,362	27,461	33,177	39,973	47,633	21.8
Motherboard Production									
Americas	1,328	1,276	1,308	1,157	1,377	1,636	1,942	2,303	12.0
Europe/Middle East/ Africa	926	1,233	1,286	1,490	1,736	1,968	2,313	2,615	15.3
Japan	617	970	1,303	1,500	1,723	1,932	2,145	2,307	12.1
Asia/Pacific	2,991	3,319	4,952	6,253	7,072	8,027	9,081	10,116	15.4

Source: Dataquest (February 1997)

OEMs

Tables 3-9 and 3-10 list the key OEMs ranked by revenue and unit shipment market share. Compaq retained the No. 1 spot, growing its market share in both units and revenue. IBM solidified its second-place position with significant market share gains. Dell, Toshiba, and Hewlett-Packard posted strong growth, too, though Apple Computer and the NEC/Packard Bell team each lost significant market share.

Table 3-9
Personal Computers Worldwide Revenue Market Share (Percent)

Rank		1995	1996
1	Compaq Computer Corp.	10.2	10.74
2	IBM	8.0	9.52
3	NEC	5.5	4.97
4	Dell Computer Corp.	3.6	4.79
5	Apple Computer	7.7	4.71
6	Toshiba	3.4	4.64
7	Hewlett-Packard	3.6	4.12
8	Packard Bell	4.5	3.71
9	Fujitsu	2.0	3.50
10	Gateway 2000	2.7	3.25
	Others (28)	48.75	46.05
	Total	**100.00**	**100.00**

Note: Does not include motherboard upgrade revenue
Source: Dataquest (May 1997)

Table 3-10
Personal Computers Worldwide Unit Market Share (Percent)

Rank		1995	1996
1	Compaq Computer Corp.	10.0	10.06
2	IBM	7.9	8.63
3	Apple Computer	7.8	5.27
4	NEC	4.8	4.45
5	Packard Bell	5.3	4.30
6	Hewlett-Packard	3.7	4.15
7	Dell Computer Corp.	3.0	3.99
8	Toshiba	2.5	3.64
9	Fujitsu	1.8	3.31
10	Acer	3.1	3.21
	Others	50.0	49.0
	Total	**100.0**	**100.00**

Note: Does not include additional motherboards or handheld PC
Source: Dataquest (May 1997)

Systems Technology and Architecture Trends

The technology road maps of PCs and workstations are principally driven by the twin factors of economy and improved end-user features. PC makers typically try to give buyers more features with each new product generation while maintaining price points. Workstation makers are known more for emphasizing performance and other features, although the low end of the workstation market is forced to compete directly with the high end of the PC market. Some specific trends are listed in the following sections.

Personal Computers

Trends in PC market are as follows:

- Demand for increased computing power will come from servicing graphical user interface (GUI) and WYSIWYG-oriented applications, including processing (compressing and decompressing) both store-forward-and-read multimedia (object linking and embedding, or OLE-enabled) and real-time multimedia such as desktop videoconferencing. Networking support increasingly will require faster servicing as transfer rates climb (for example, toward 100 Mbps over Ethernet) and the size and frequency of transferred files and e-mail increase, as well.
- Pentium-class microprocessors will dominate for one more year as multimedia features and higher clock frequencies give these processors a midlife boost in performance. Next-generation MPUs such as Pentium II will grow in importance and are expected to match unit shipments of Pentium-class MPUs for 1998.
- The Power PC alliance suffered a devastating blow when Microsoft announced it would stop supporting Windows NT on the Power PC microprocessors.
- PCI and Industry Standard Architecture (ISA) combinations are the overwhelming standard for backplane buses. PCI will be enhanced with accelerated graphics port (AGP) in late 1997. ISA will continue to exist for a few years for compatibility with the vast bulk of legacy add-in cards but will face extinction in 2000 or 2001.
- Plug-and-play PCs, with support from major players such as Microsoft, Intel, Compaq, AMD, and others, continues to be a significant feature in the drive to make PCs more user-friendly. Universal serial bus (USB) and 1394 will be the standards for external plug-and-play devices, with USB gaining rapid acceptance through 1997. 1394 is gaining ground but is still two years away from widespread adoption.
- The "green" PC, as stimulated by the Energy Star program a few years ago and similar requirements coming out of Europe, has been recycled with new emphasis on desktop PC power management. Advanced configuration power interface (ACPI) and Microsoft's OnNow are critical elements of the renewed efforts to make desktop PCs more energy efficient.
- EIDE will remain the dominant interface to mass storage, with parallel SCSI the choice for connecting external mass storage devices for the next several years. Parallel SCSI will face increasing pressure from serial SCSI standards (predominately 1394, with fiber channel arbitrated loop making inroads in the workstation market).

- Serial and parallel I/O have remained constant, but technologies such as 1394 and USB are vying to displace those trusted standbys.
- USB ports are rapidly becoming a standard feature for new PCs. This local bus for the PC will provide a common standard for communicating among PCs, modems, scanners, joysticks, keyboards, mice, monitors, and printers. Peripheral manufacturers are rolling out USB peripherals slowly and steadily.
- Desktop management interface (DMI) will enhance the remote monitoring capabilities of networked computers, allowing system administrators to check a variety of operational and environmental parameters over a network.
- Mobile computers will be enhanced with 32-bit CardBus slots rather than the standard 16-bit PCMCIA slots, but the average number of slots per mobile PC may decline as modems and network controllers become standard equipment on more notebook designs.
- Other key trends in mobile computing will include commercialized low-power components, standardization of operating voltage for circuits and components at 3V/3.3V, continued increases in sophistication of battery management, improved battery technology, and effective handwriting/voice recognition.

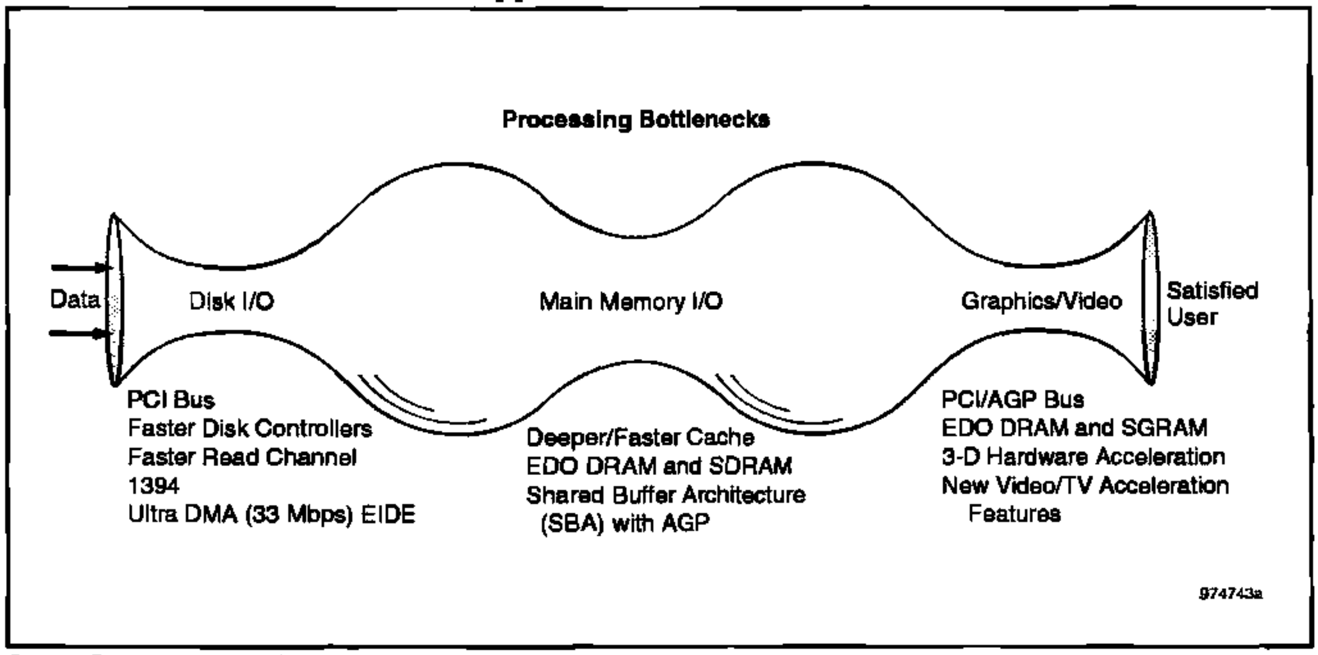
Table 3-11 highlights projected trends in PC technology. Figure 3-7 shows areas that offer opportunities for enhancement. Tables 3-12 through 3-16 provide forecasts for key PC and workstation technologies.

Table 3-11
The Evolving PC

	1994	1996	1998	2000	Trend
Main Memory (Factory Installed)	8-10MB FPM DRAM	14-16MB EDO DRAM	36-40MB SDRAM	110-115MB ADRAM*	Toward synchronous types of DRAM
CPU	486 DX2/DX4	Pentium 100-133 MHz	200-MHz Pentium w/ MMX; 266-MHz Pentium II	600-MHz Pentium II	Rapid adoption of MMX; shift from Pentium to Pentium II
Cache (KB) (Factory Installed)	128	0/256	256/512	512/1024	Secondary cache included in Pentium II module
Peripheral Buses	VL/ISA	PCI/ISA	PCI/AGP/ISA	PCI/AGP	Rise of AGP for graphics; ISA will fade by 2000
Graphics and Video	32-bit, 2-D Accel, 1MB buffer	64-bit, 2-D and Video Accel, 2MB buffer	64-bit, 2-D, 3-D, and Video Accel, 4MB buffer	128-bit, 2-D, 3-D, and Video Accel, 6MB buffer	Rapid growth of 3-D as graphics vendors strive to continue to add value
Storage	EIDE (5 MB/sec)/SCSI	EIDE (13 MB/sec)/ SCSI-2	EIDE(33 MB/sec)/ SCSI-2/3/1394	EIDE (33 MB/sec)/ SCSI-2/3/1394	EIDE likely to remain in-box interface; rise of 1394
Local I/O	RS-232/422	RS-232/422, beginning of shift to USB	USB, RS-232/422	USB/1394	USB will become primary interface; RS-232/422 will fade by 2000

*ADRAM, or advanced DRAM, includes future types of SDRAM such as DDR as well as Rambus DRAM.
Source: Dataquest (September 1997)

Figure 3-7
PC Performance Enhancement Opportunities



Source: Dataquest (September 1997)

Table 3-12
Worldwide PC Bus Requirements (Percentage of Total or Category)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
VL/ISA	66.9	49.2	15.6	0.6	0	0	0	0	-100.0
PCI/ISA	16.6	44.0	81.4	88.1	49.7	5.0	0	0	-100.0
PCI/AGP/ISA	0	0	0	10.0	50.0	95.0	100.0	100.0	NA
Others	16.5	6.8	3.0	1.3	0.3	0	0	0	-100.0

NA = Not available
Source: Dataquest (September 1997)

Table 3-13
Worldwide Penetration of PCMCIA/PC Card Slot Forecast (Thousands of Slots)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
With One or More Type II Slots	10,389	13,175	14,411	11,529	6,917	2,767	0	-100.0
With One or More Type III Slots	4,040	4,831	5,139	5,115	4,804	4,408	5,000	0.7
With One or More CardBus Slots	0	0	2,522	3,153	3,783	4,540	5,448	NA

NA = Not available
Source: Dataquest (September 1997)

Table 3-14
Worldwide PC (Host) Storage Interface Requirement (Percentage of Category)

	1994	1995	1996	1997	1998	1999	2000	2001
All PCs								
EIDE/ATA	85	86	88	86	83	49	10	0
EIDE/ATA/1394	-	-	-	1	5	40	80	90
SCSI (I/II/III)	15	14	12	12	11	10	9	8
Others	-	-	-	1	1	1	1	2
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

NA = Not applicable
Source: Dataquest (September 1997)

Table 3-15
Worldwide PC Graphics Standard Penetration (Motherboard-Based or Add-In)

	1994	1995	1996	1997	1998	1999	2000	2001
2-D Accel	0	0	0	0	0	0	0	0
2-D Accel with Video Accel	97	76	25	4	0	0	0	0
2-D, 3-D and Video Accel	3	24	73	76	55	37	36	39
2-D, 3-D, Video, and TV Accel	0	0	2	20	45	63	64	61

Source: Dataquest (September 1997)

Table 3-16
Worldwide Embedded Communications and Multimedia in PCs (Percentage of Total)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Overall PC									
Analog Modem	1.5	1.6	2.9	6.2	9.9	11.9	14.0	15.1	39.1
LAN	0.9	1.7	8.7	22.7	24.2	25.0	25.8	26.7	25.1
USB	0	0	8.8	47.7	97.7	100.0	100.0	100.0	62.5
Sound I/O	3.5	22.4	28.6	37.6	41.9	45.5	49.9	54.3	13.6
Graphics	44.9	57.4	57.3	61.8	62.0	62.2	62.4	62.6	1.8
MPEG Decoder	0	0.6	1.1	2.0	2.0	2.0	2.0	2.0	11.8
General-Purpose DSP	0.1	0.5	1.0	1.7	2.3	3.0	3.7	3.7	30.3
Desktop/Deskside PC									
Analog Modem	1.4	1.5	1.7	2.0	2.4	2.7	3.0	3.0	12.0
LAN	1.0	2.0	10.0	25.0	25.0	25.0	25.0	25.0	20.1
USB	0	0	10.0	50.0	100.0	100.0	100.0	100.0	58.5
Sound I/O	1.2	21.4	25.0	30.0	33.0	36.0	40.0	45.0	12.5
Graphics	34.0	50.0	50.0	55.0	55.0	55.0	55.0	55.0	1.9
MPEG Decoder	0	0.5	1.0	2.0	2.0	2.0	2.0	2.0	14.9
General-Purpose DSP	0.1	0.4	0.8	1.6	2.3	3.2	4.0	4.0	38.0
Mobile PC (Excluding Handhelds)									
Analog Modem	2.0	2.0	10.0	30.0	50.0	60.0	70.0	75.0	49.6
LAN	0.1	0.1	1.0	10.0	20.0	25.0	30.0	35.0	103.6
USB	0	0	2.0	35.0	85.0	100.0	100.0	100.0	118.7
Sound I/O	15.0	28.3	50.0	80.0	90.0	95.0	100.0	100.0	14.9
Graphics	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0
MPEG Decoder	0	1.0	2.0	2.0	2.0	2.0	2.0	2.0	0
General-Purpose DSP	0	1.0	2.0	2.0	2.0	2.0	2.0	2.0	0

Source: Dataquest (September 1997)

Chapter 4

Semiconductor Market Trends for PCs and Workstations

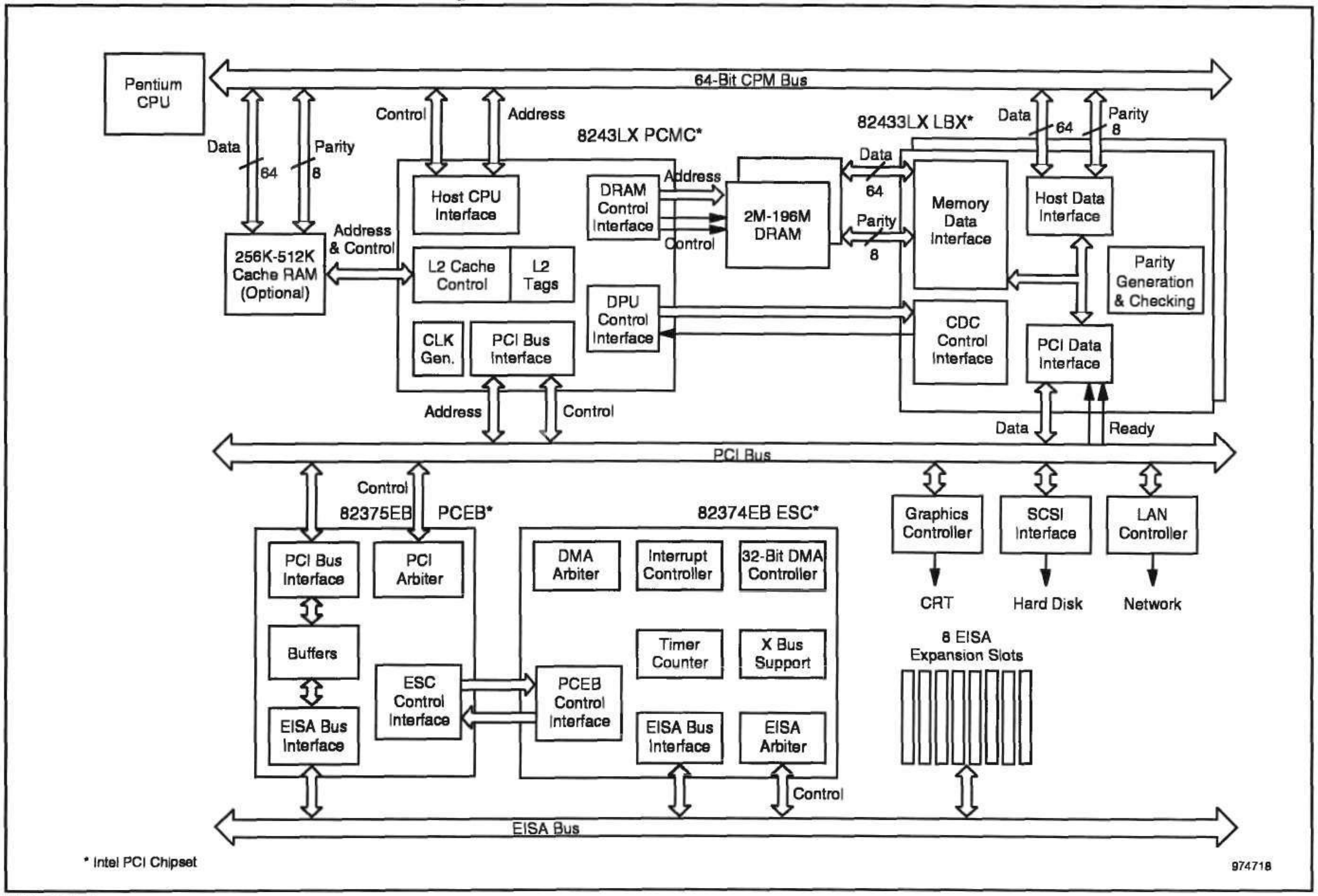
Semiconductor Market Opportunities and Technology Trends

Semiconductor market opportunities and technology trends are as follows:

- New generations of Pentium, Pentium Pro, PowerPC, Alpha, PA-RISC, SPARC, and MIPS processors will drive future PCs, workstations, and servers. Future trends include internal frequencies climbing past the current 266-MHz offerings for PCs and 500-MHz for workstations. Multiprocessing features will also be available in many workstations and high-end PCs using Pentium Pro and Pentium II microprocessors.
- Proprietary processors such as ARM will continue to be used in palmtop devices and other communications-centric applications.
- PC main memory size will double from 1996 to 1998, reaching 38MB for the average factory-installed memory size in 1998.
- SDRAM will replace EDO for main memory applications with the crossover in late 1997.
- SGRAM will replace EDO for graphics memory applications with the crossover in the first half of 1998.
- Bursting, MPU-specific SRAM will be used for cache design. SRAM modules are popular for PCs with Socket 7 microprocessors. The list of Socket 7 microprocessors includes Pentium, Pentium with MMX Technology, AMD K6, and Cyrix M2 products.
- New chipsets to support MPUs and the new buses (USB and the AGP enhancement to PCI) will continue to emerge. Watch for third-party core logic vendors to add AGP to their Pentium-bus products for use with K6 and M2 microprocessors.
- 3-D acceleration should be considered a standard feature for new graphics chips. Competition will be fierce through 1997 and early 1998 with emphasis on performance as measured by the new Ziff Davis 3-D benchmark. TV features and MPEG-2 motion compensation engines are the next value-added features for desktop PC graphics controllers. Integrated memory and 3-D acceleration are the biggest value-added features for mobile graphics controllers.
- Mixed-signal I/O chips will support high-speed storage and peripherals communications (EIDE, SCSI, and 1394).

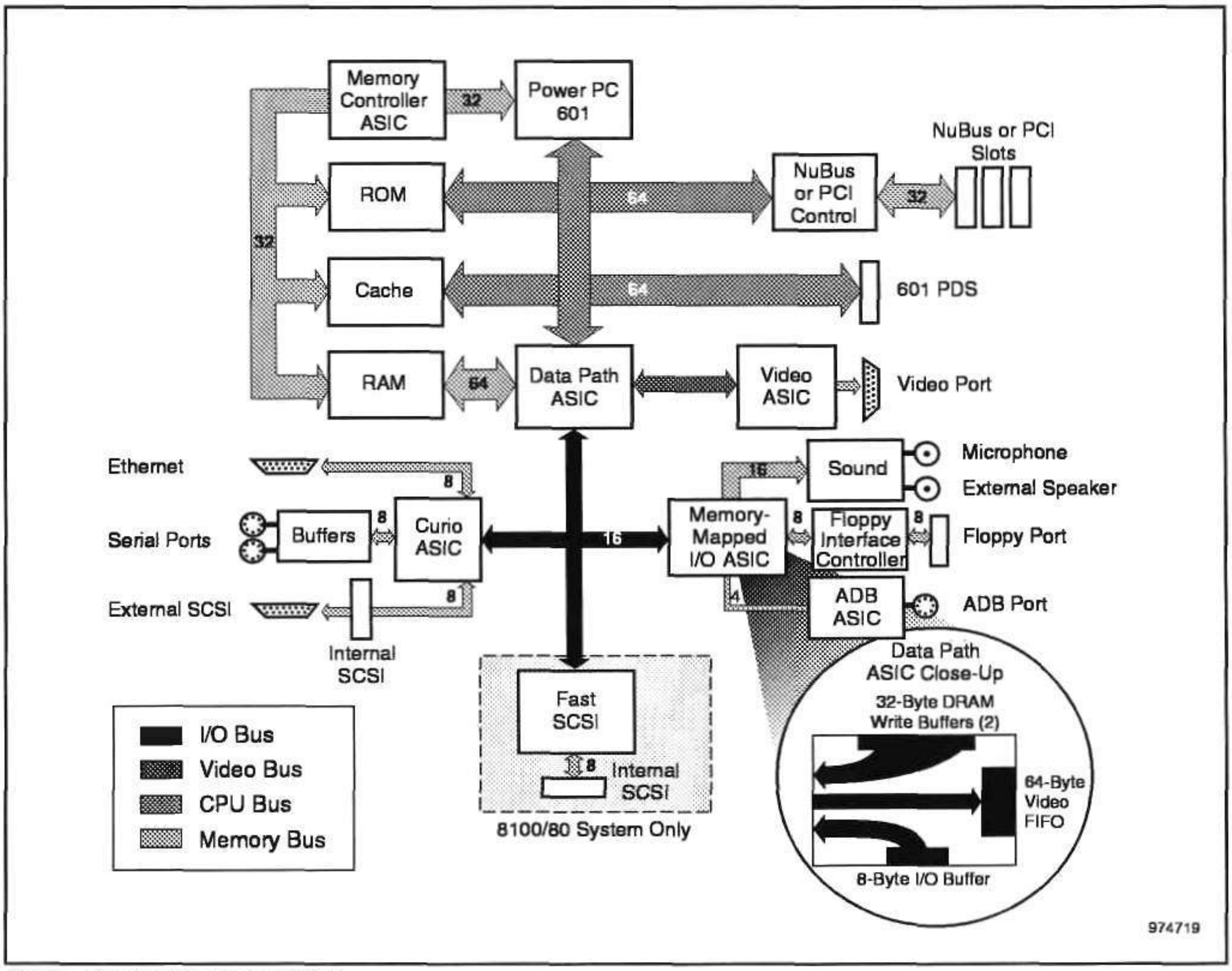
Figures 4-1 to 4-4 provide block diagrams for generic Pentium desktop, Power Macintosh, generic notebook, and Apple Newton systems.

Figure 4-1
Generic Pentium-Based Desktop PC Using PCI Bus



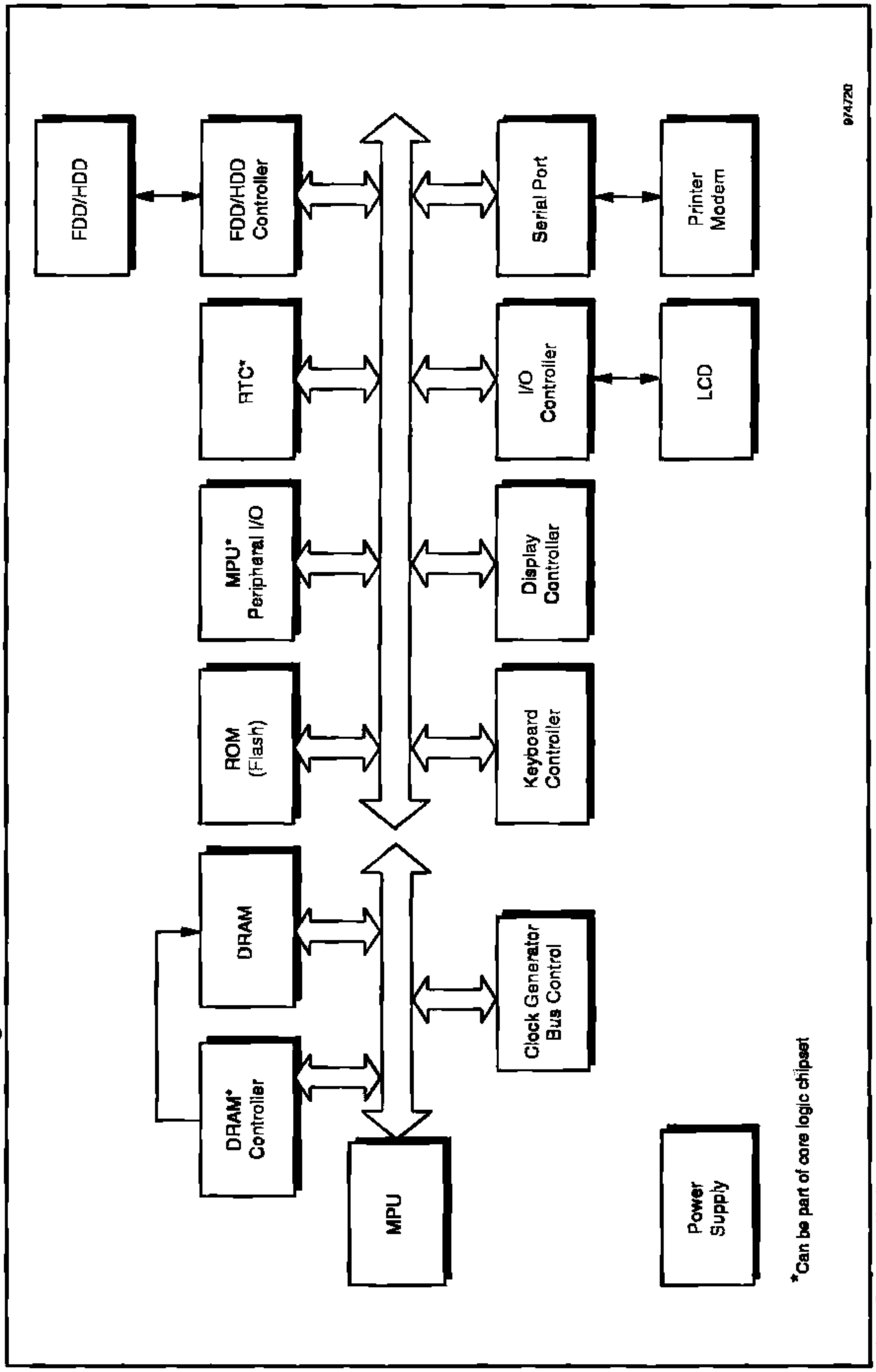
Source: Intel

Figure 4-2
Power Macintosh Hardware Architecture



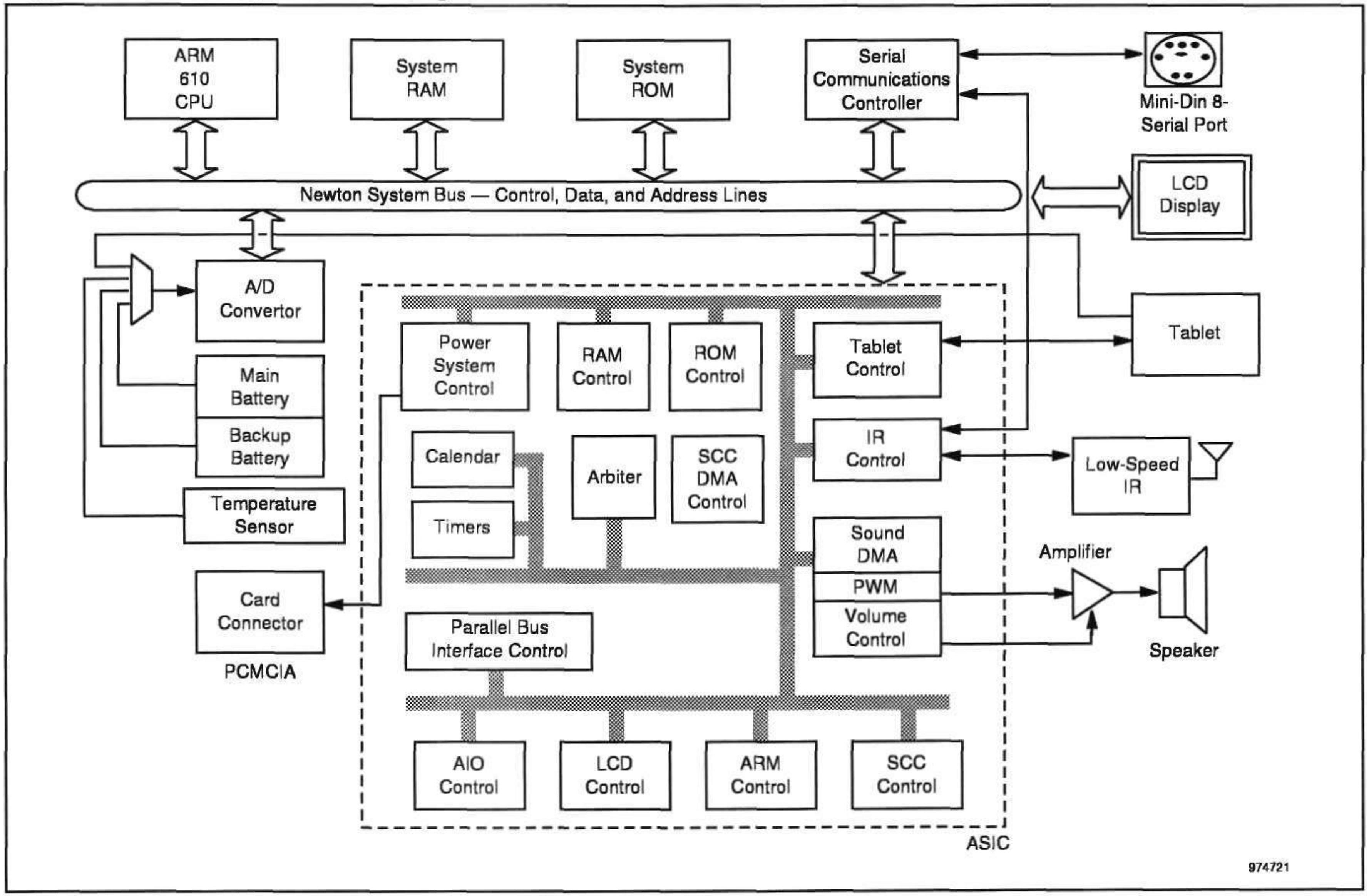
Source: Dataquest (September 1997)

Figure 4-3
Generic Notebook Block Diagram



Source: Dataquest (April 1997)

Figure 4-4
Apple Newton MessagePad Block Diagram

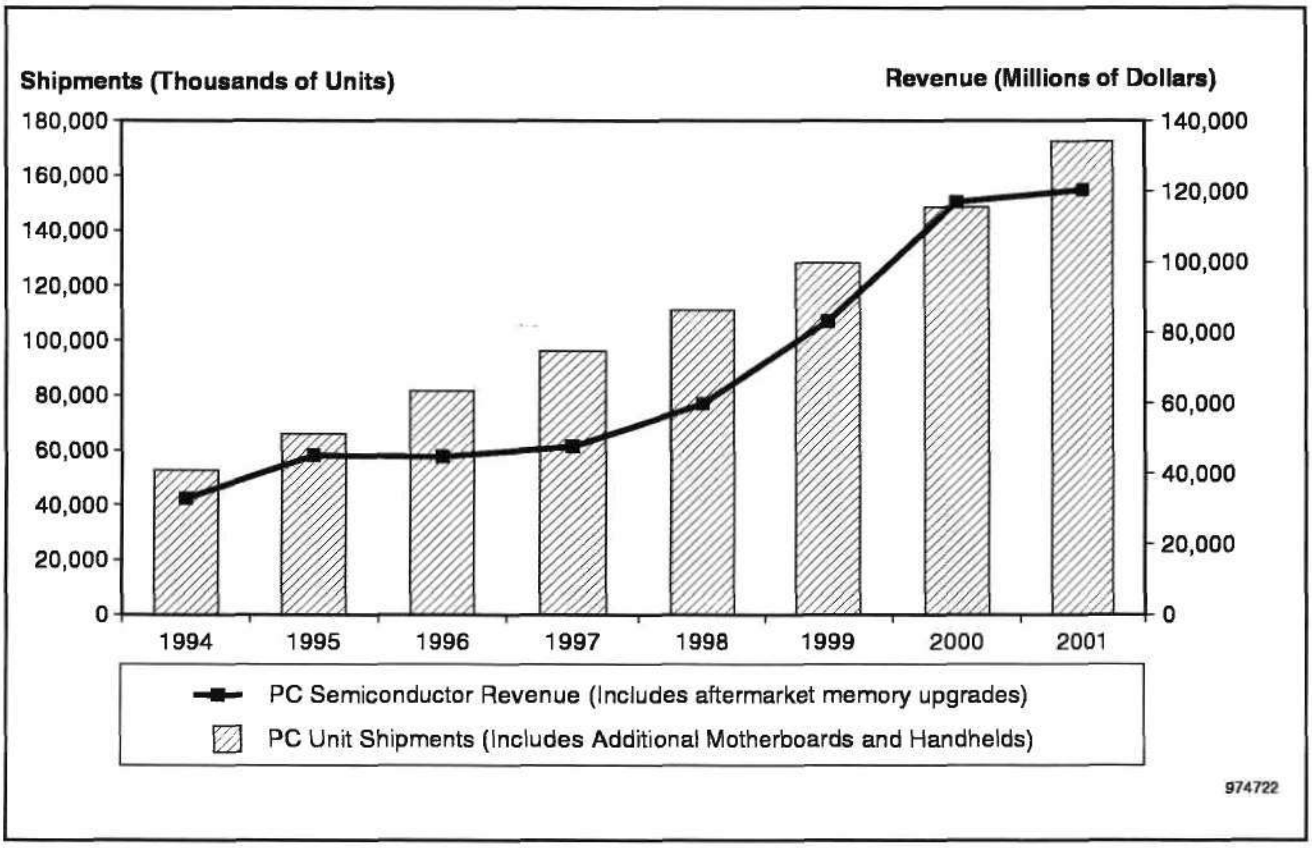


Source: Apple, *PC Week*

Chapter 5
Market Size and Forecast for PC and Workstation Semiconductors

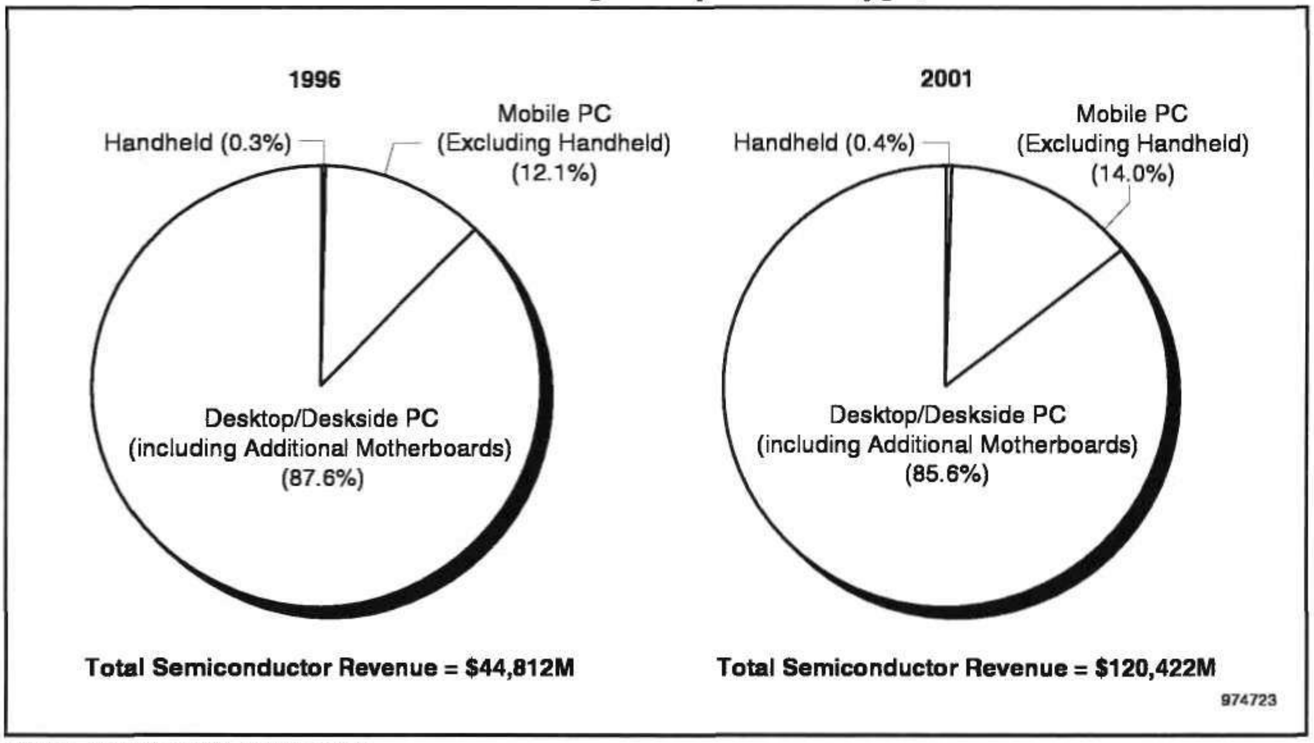
Figures 5-1 and 5-2 and Table 5-1 provide forecasts and illustrations of semiconductor opportunities in the PC and workstation markets, including a focus on opportunities by region, system type, and semiconductor device type.

Figure 5-1
Worldwide PC and PC Semiconductor Market



Source: Dataquest (September 1997)

Figure 5-2
Worldwide PC Semiconductor Consumption by Product Type, 1996 and 2001



Source: Dataquest (September 1997)

Table 5-1
Worldwide PC and PC Semiconductor Markets (Includes Handheld PCs and Aftermarket Memory)

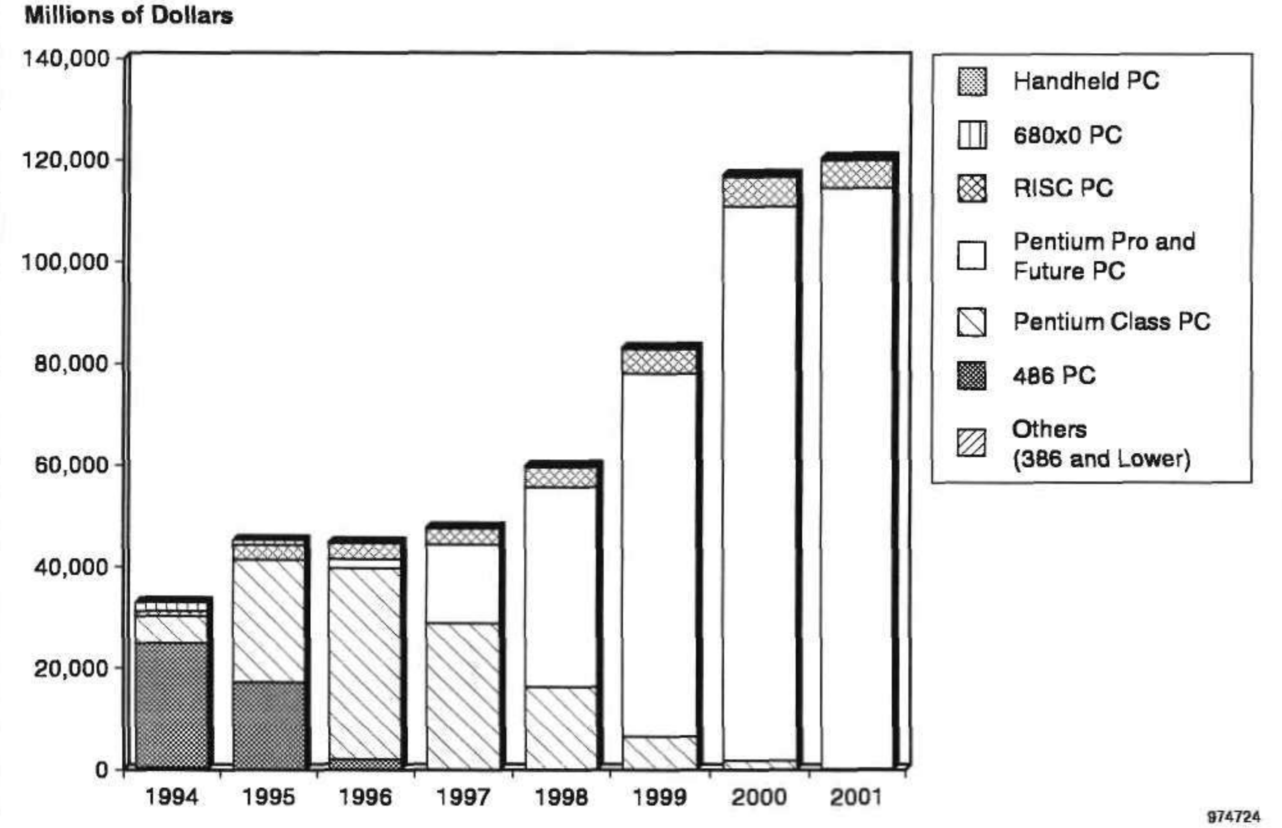
	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Complete PC Systems									
Units (K)	48,284	60,415	71,423	85,081	99,521	115,319	133,613	155,431	17.2
Factory ASP ($K)	1.98	2.05	2.11	2.09	2.19	2.20	2.17	2.15	1.1
Factory Revenue ($M)	95,775	123,878	151,016	177,675	217,821	253,332	290,039	334,465	18.5
Semiconductor Content per System ($)	623	682	546	494	535	643	783	693	2.8
Semiconductor TAM ($M)	30,097	41,183	39,020	42,020	53,242	74,197	104,629	107,754	20.5
Desktop/Deskside PC Systems									
Units (K)	39,252	50,450	59,068	69,887	81,194	93,232	107,156	123,190	16.3
Factory ASP ($K)	1.88	1.93	1.98	2.03	2.17	2.16	2.12	2.10	1.9
Factory Revenue ($M)	73,937	97,392	116,789	141,777	175,798	201,443	227,377	259,284	18.5
Semiconductor Content per System ($)	674	723	567	522	576	683	827	735	2.7
Semiconductor TAM ($M)	26,450	36,488	33,463	36,512	46,807	63,693	88,580	90,490	19.4
Mobile PC Systems									
Units (K)	9,032	9,965	12,356	15,194	18,327	22,087	26,457	32,241	21.6
Factory ASP ($K)	2.42	2.66	2.77	2.36	2.29	2.35	2.37	2.33	-2.3
Factory Revenue ($M)	21,838	26,486	34,227	35,898	42,023	51,889	62,663	75,181	18.8
Semiconductor Content per System ($)	404	471	450	363	351	476	607	535	5.2
Semiconductor TAM ($M)	3,647	4,695	5,556	5,509	6,435	10,504	16,049	17,264	27.9
Additional Motherboards									
Units (K)	4,318	5,548	10,224	10,947	11,367	13,052	15,002	17,247	22.0
Factory ASP ($K)	1.19	1.05	0.73	0.61	0.68	0.81	0.98	0.87	-1.4
Factory Revenue ($M)	5,159	5,836	7,436	6,719	7,752	10,540	14,734	15,076	20.3
Semiconductor Content per System ($)	674	723	567	522	576	683	827	735	2.7
Semiconductor TAM ($M)	2,909	4,013	5,792	5,719	6,553	8,917	12,401	12,669	25.3
Total PC Production									
Units (K)	52,602	65,963	81,647	96,028	110,888	128,372	148,615	172,678	17.6
Factory ASP ($K)	1.92	1.97	1.94	1.92	2.03	2.06	2.05	2.02	0.8
Factory Revenue ($M)	100,933	129,715	158,452	184,394	225,573	263,872	304,773	349,541	18.6
Semiconductor Content per System ($)	627	685	549	497	539	647	787	697	2.8
Semiconductor TAM ($M)	33,007	45,196	44,812	47,739	59,795	83,114	117,030	120,422	21.0
Workstation									
Units (K)	735	852	871	1,020	1,342	1,779	2,290	2,595	24.4
Factory ASP ($K)	15.06	15.74	14.61	12.78	11.31	9.83	8.51	7.77	-11.9
Factory Revenue ($M)	11,070	13,406	12,727	13,033	15,172	17,486	19,482	20,162	9.6
Semiconductor Content per System ($)	2,015	2,338	1,971	1,562	1,594	1,721	1,844	1,696	-3.0
Semiconductor TAM ($M)	1,481	1,992	1,717	1,593	2,138	3,062	4,222	4,401	20.7

Note: Includes handheld PCs, graphics, serial/parallel I/O, storage adapters, and memory SIMMs installed up to point of sale
Source: Dataquest (September 1997)

Semiconductor Opportunities by System

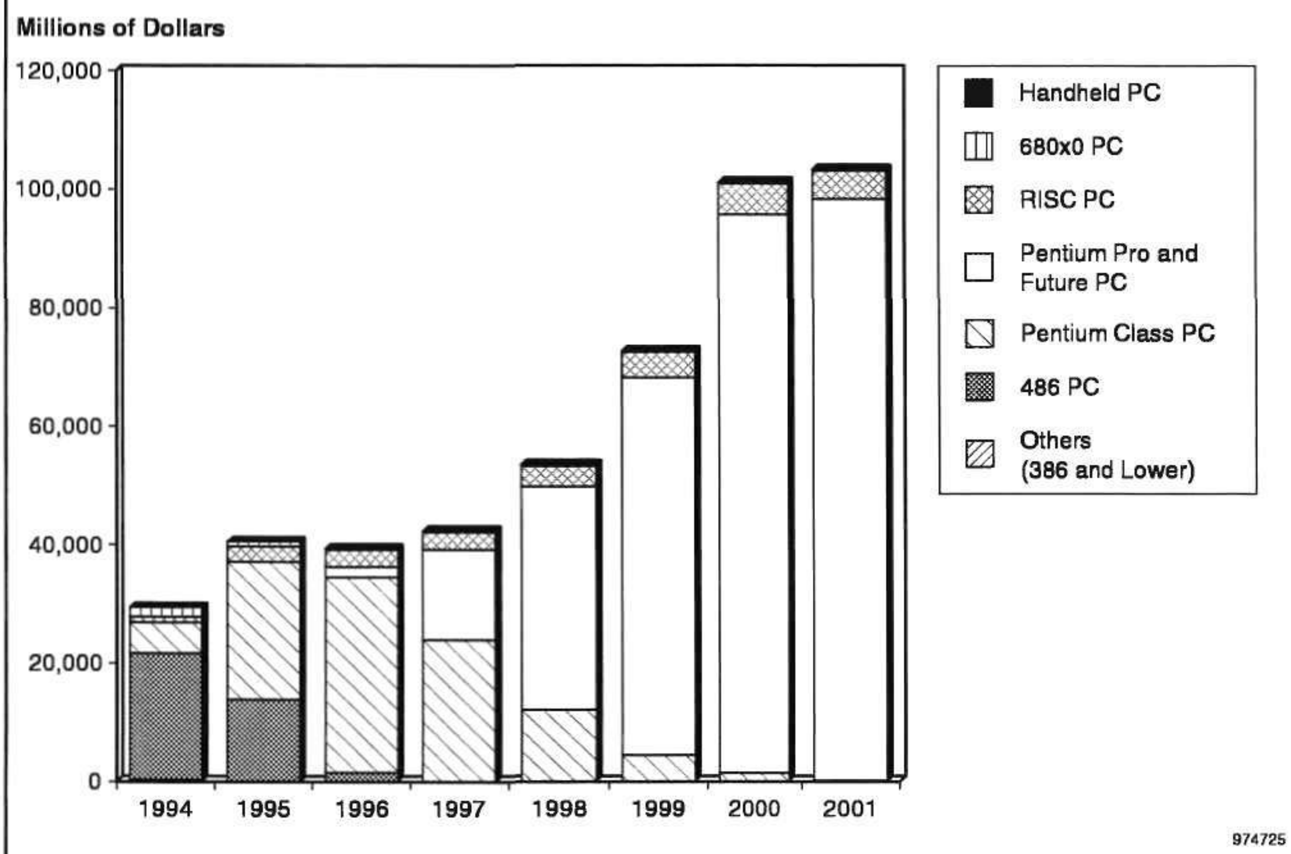
Figures 5-3 through 5-13 and Tables 5-2 through 5-4 detail semiconductor opportunities by system.

Figure 5-3
Worldwide PC Semiconductor Market Revenue by Microprocessor Type



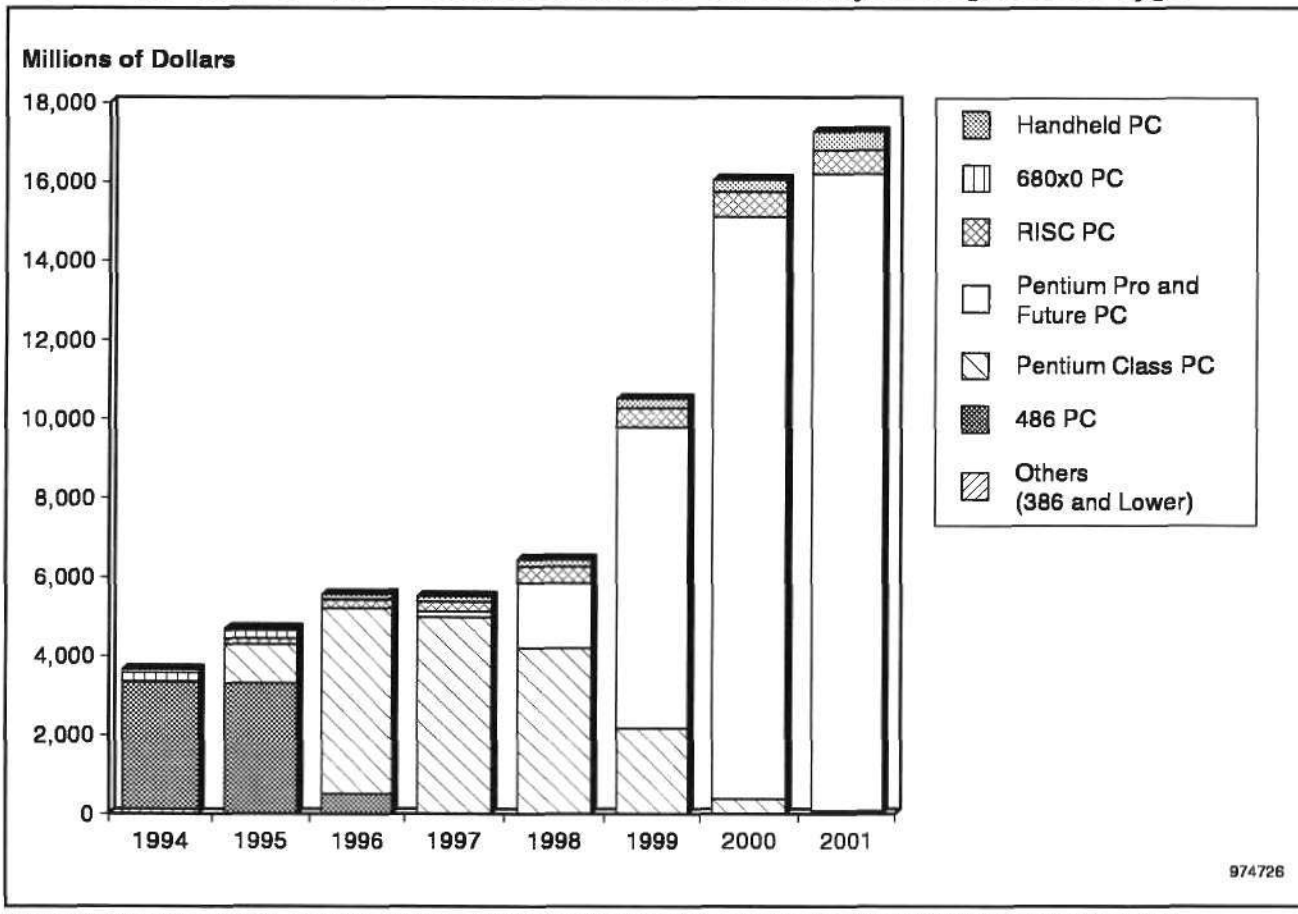
Note: Includes motherboard, graphics, storage, serial/parallel I/O adapters, and add-on memory installed up to point of sale
Source: Dataquest (September 1997)

Figure 5-4
Worldwide Desktop/Deskside PC and Additional Motherboard Semiconductor Market Revenue by Microprocessor Type



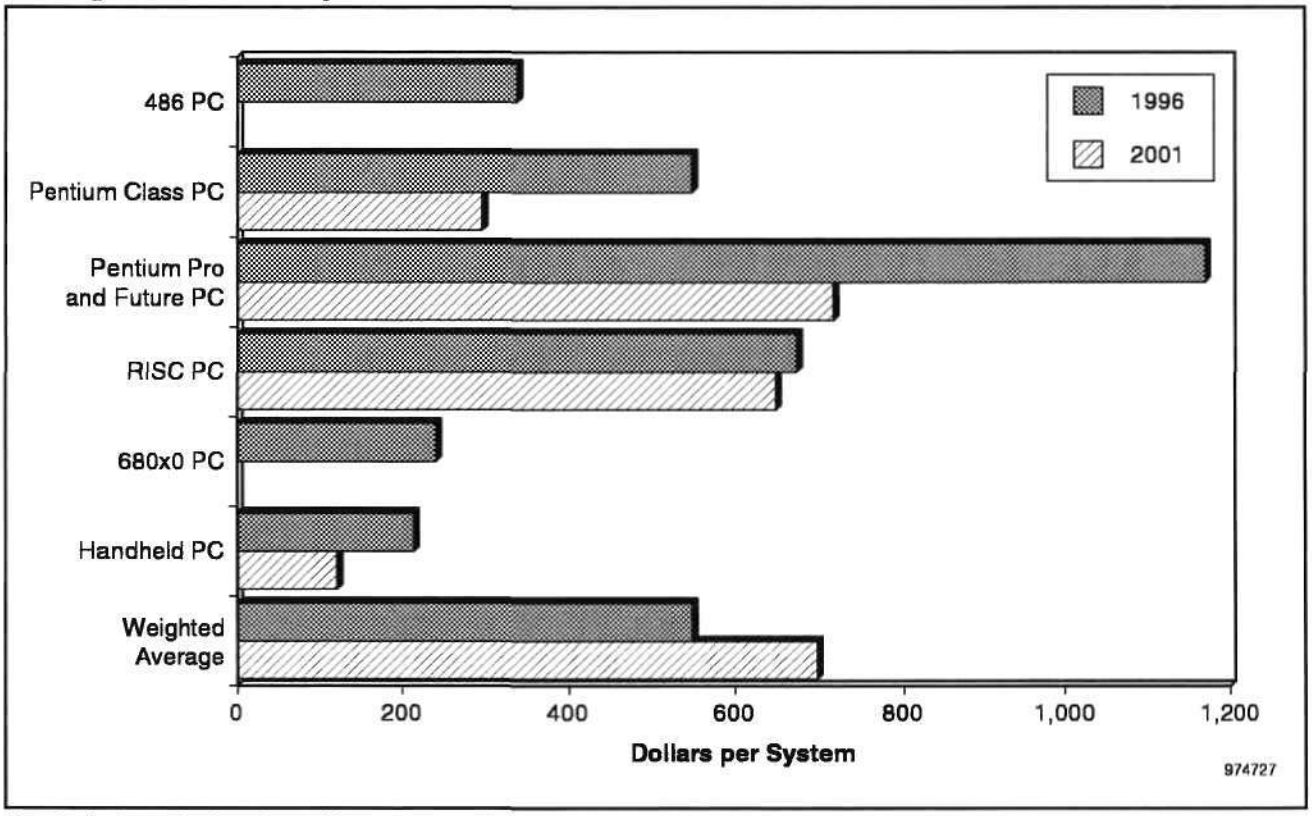
Note: Includes motherboard, graphics, storage, serial/parallel I/O adapters, and add-on memory installed up to point of sale
Source: Dataquest (September 1997)

Figure 5-5
Worldwide Mobile PC Semiconductor Market Revenue by Microprocessor Type



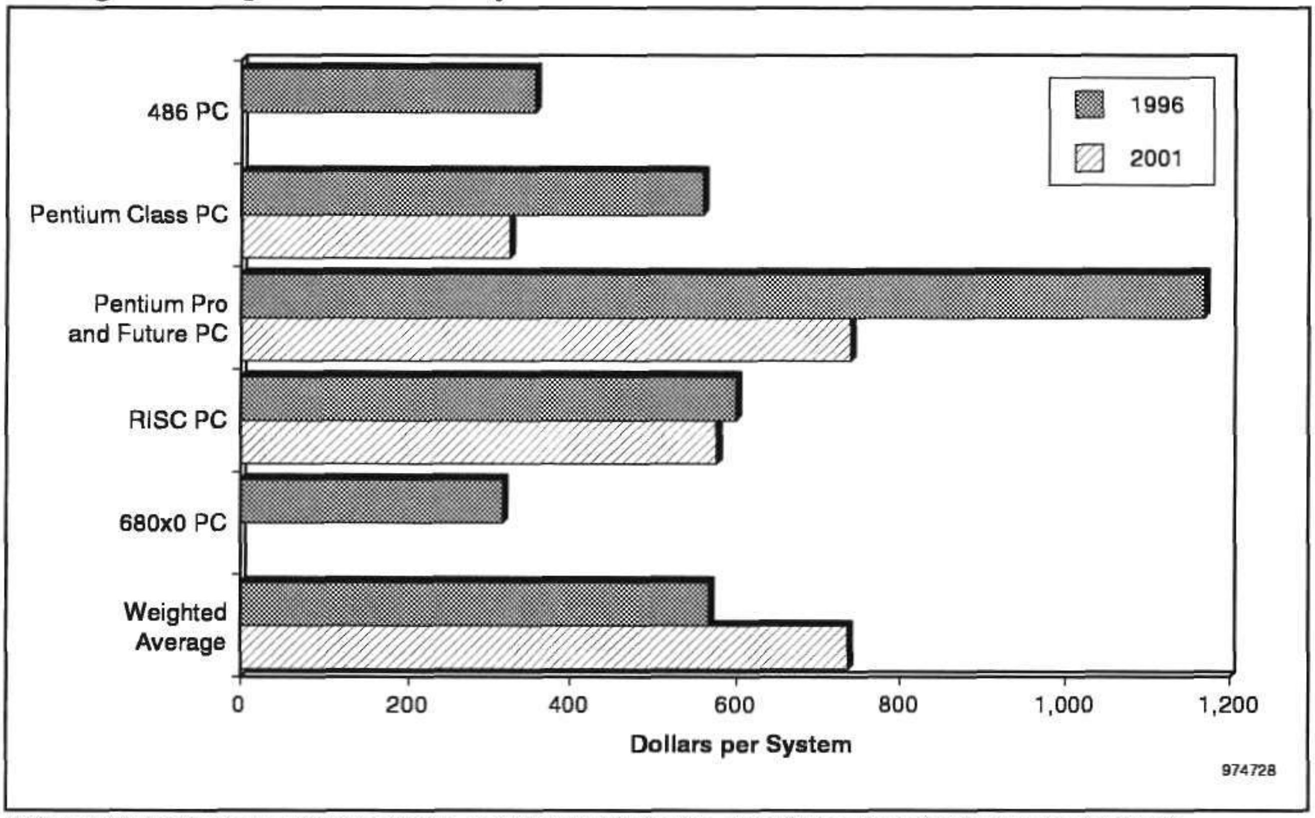
Note: Includes motherboard, graphics, storage, serial/parallel I/O adapters, and add-on memory installed up to point of sale
Source: Dataquest (September 1997)

Figure 5-6
Average Overall PC System Semiconductor Content



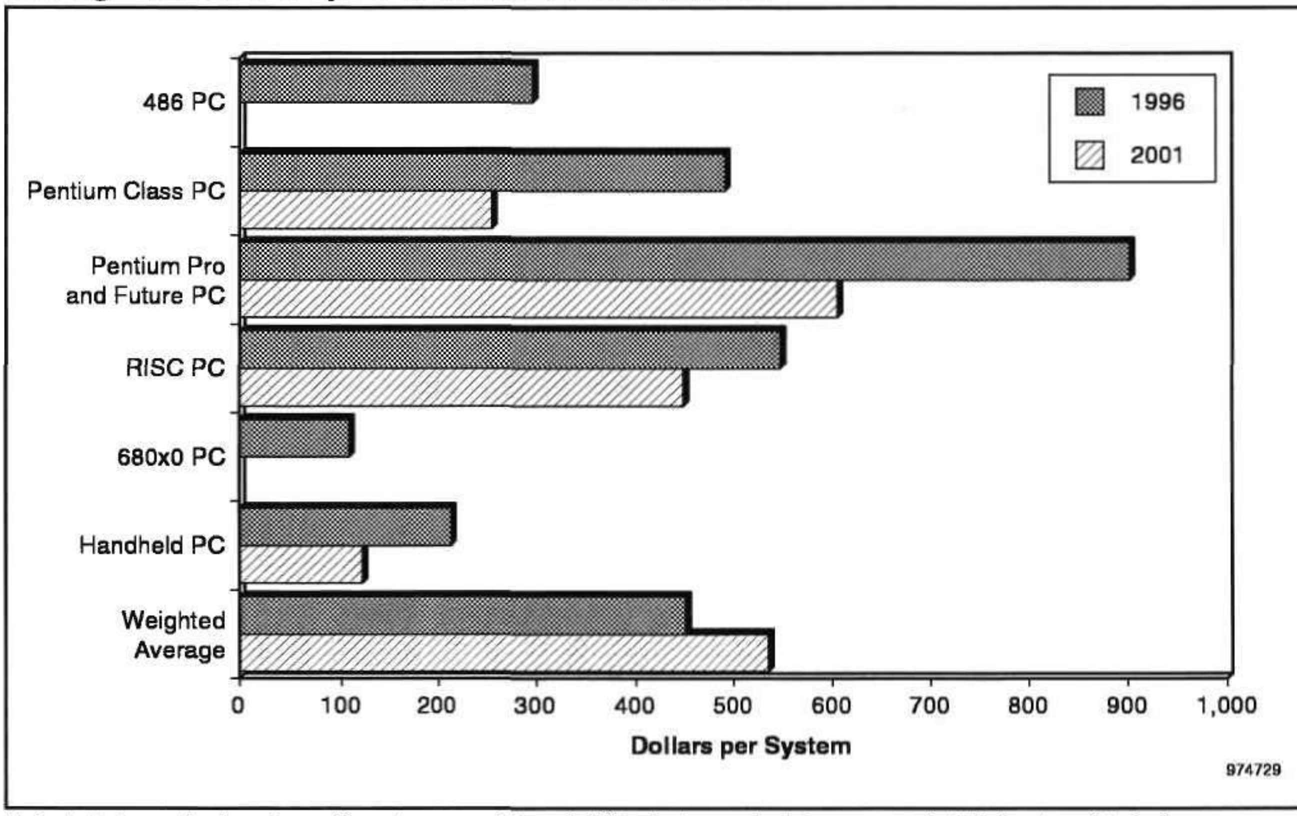
Note: Includes motherboard, graphics, storage, serial/parallel I/0 adapters, and add-on memory installed up to point of sale
Source: Dataquest (September 1997)

Figure 5-7
Average Desktop/Deskside PC System Semiconductor Content



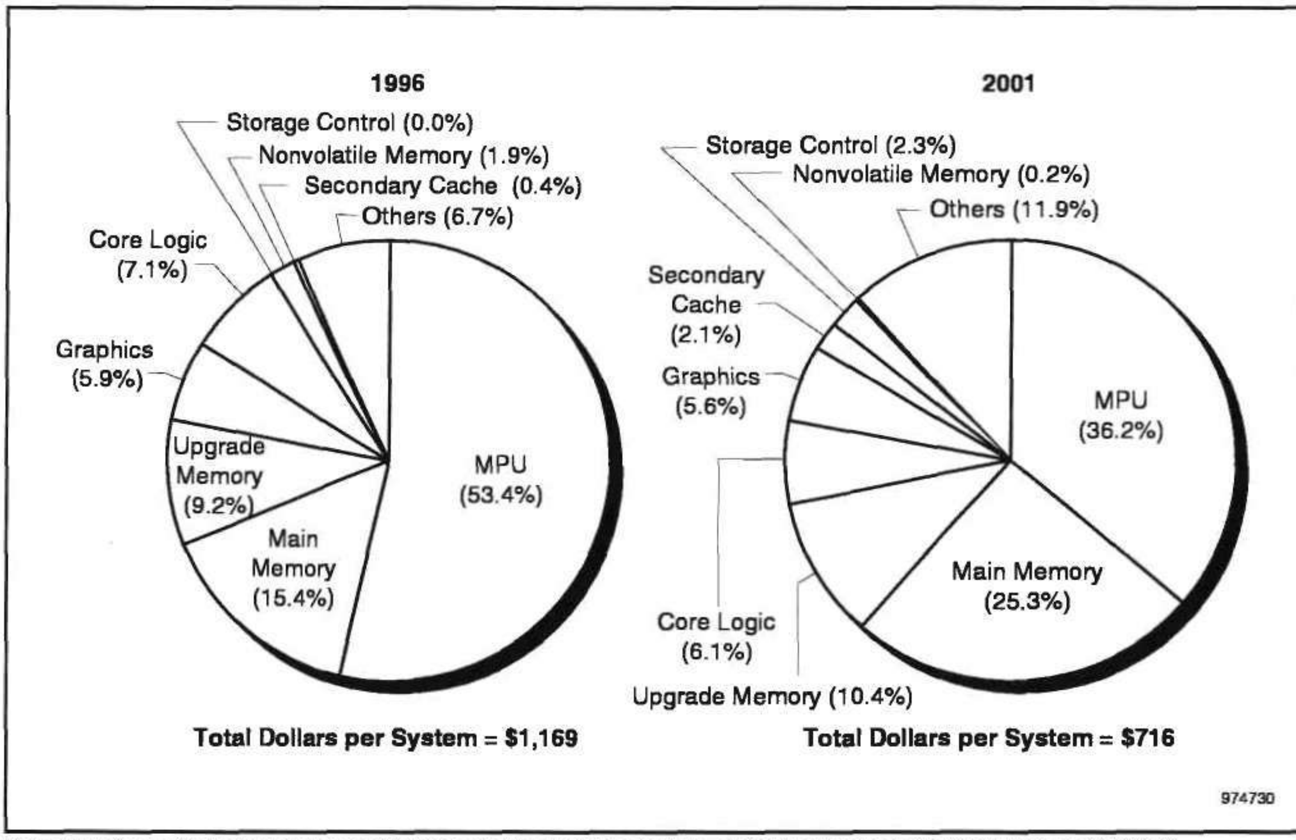
Note: Includes motherboard, graphics, storage, serial/parallel I/O adapters, and add-on memory installed up to point of sale
Source: Dataquest (September 1997)

Figure 5-8
Average Mobile PC System Semiconductor Content



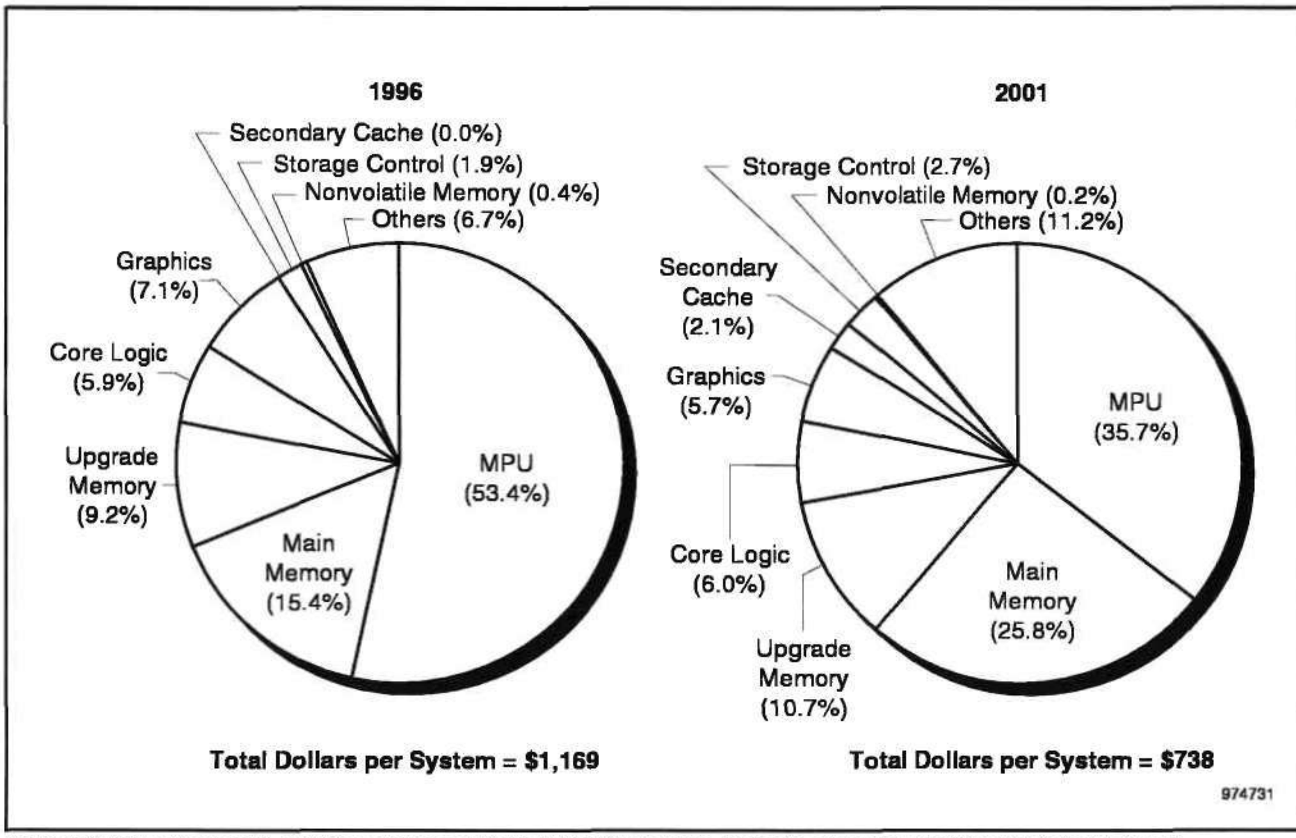
Note: Includes motherboard, graphics, storage, serial/parallel I/0 adapters, and add-on memory installed up to point of sale
Source: Dataquest (September 1997)

Figure 5-9
Overall Pentium Pro and Future PC Semiconductor Content Trend, 1996 and 2001



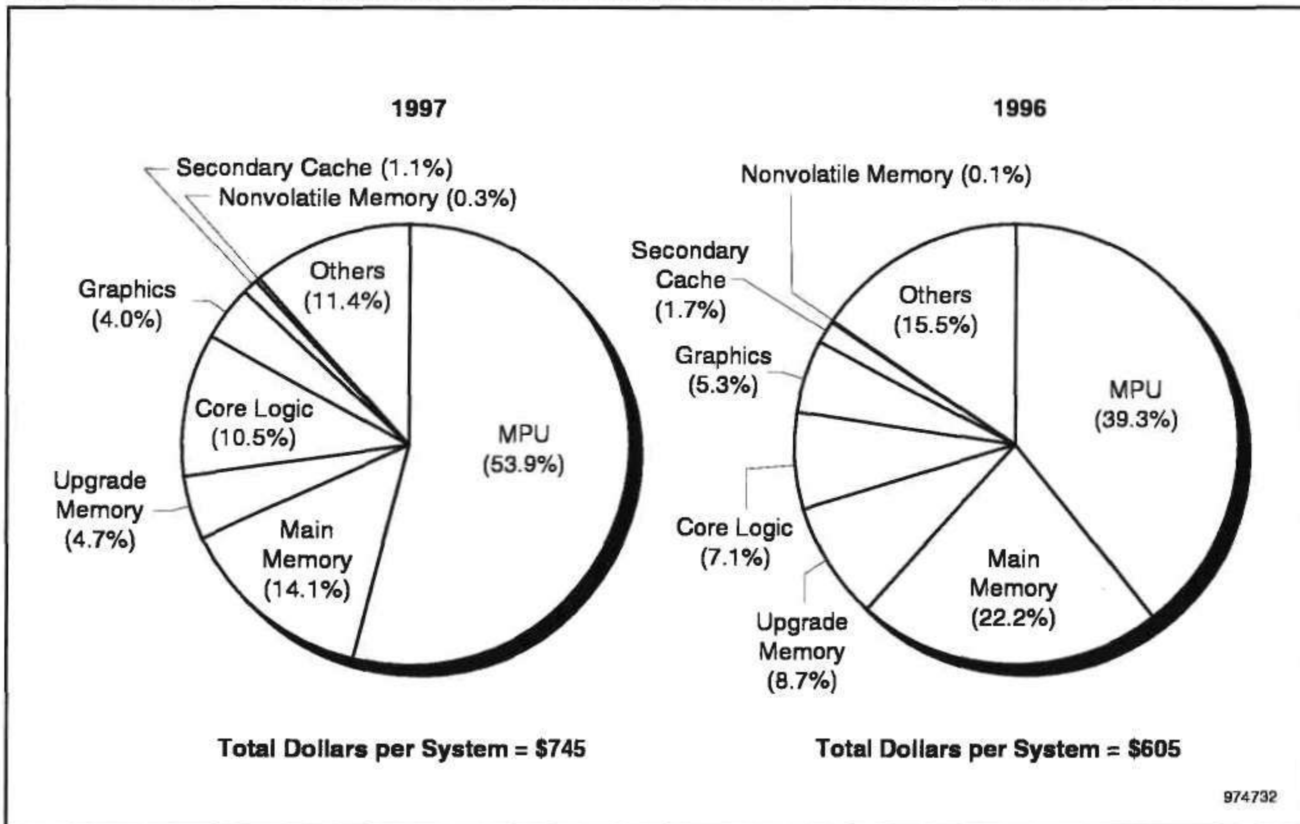
Note: Includes motherboard, graphics, storage, serial/parallel I/O adapters, and add-on memory installed up to point of sale
Source: Dataquest (September 1997)

Figure 5-10
Desktop/Deskside Pentium Pro and Future PC Semiconductor Content Trend, 1996 and 2001



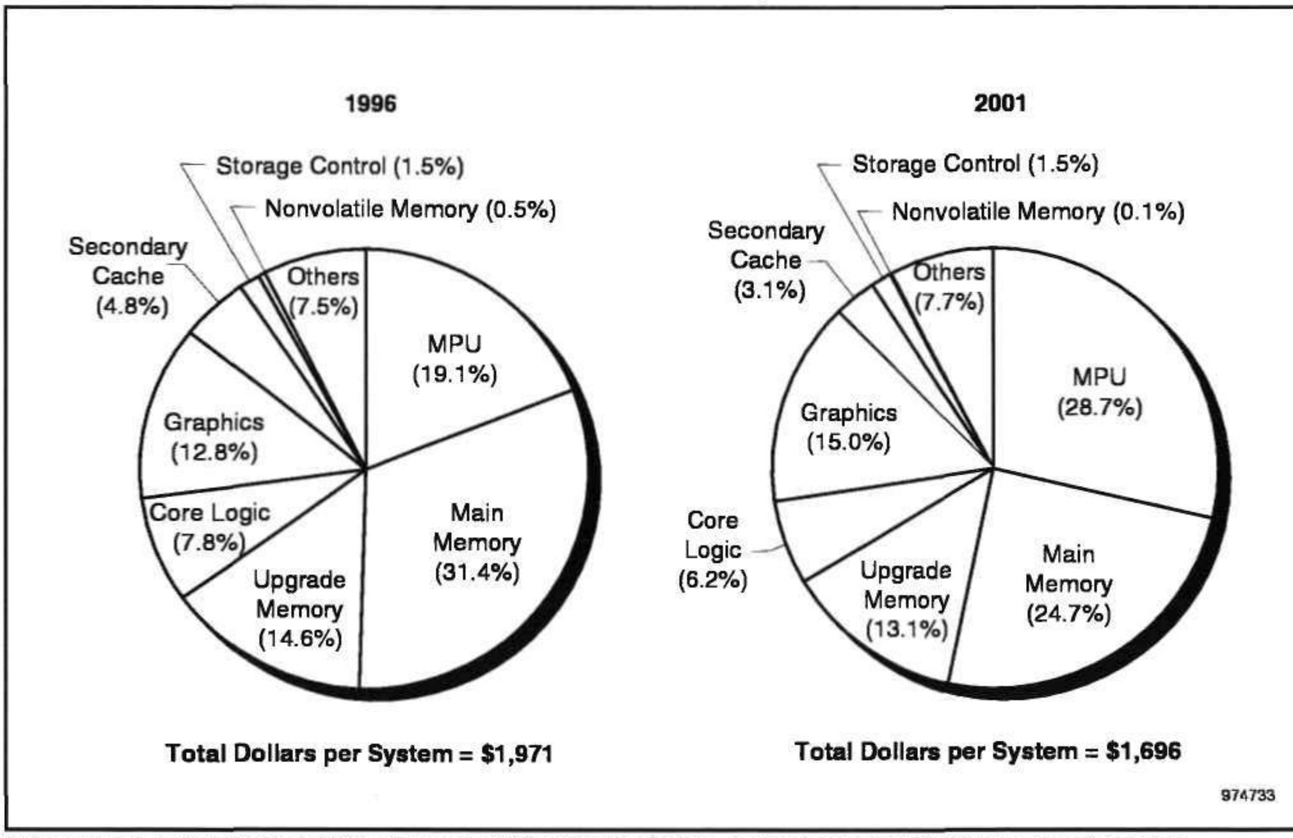
Note: Includes motherboard, graphics, storage, serial/parallel I/0 adapters, and add-on memory installed up to point of sale
Source: Dataquest (September 1997)

Figure 5-11
Mobile Pentium Pro and Future PC Semiconductor Content Trend, 1996 and 2001



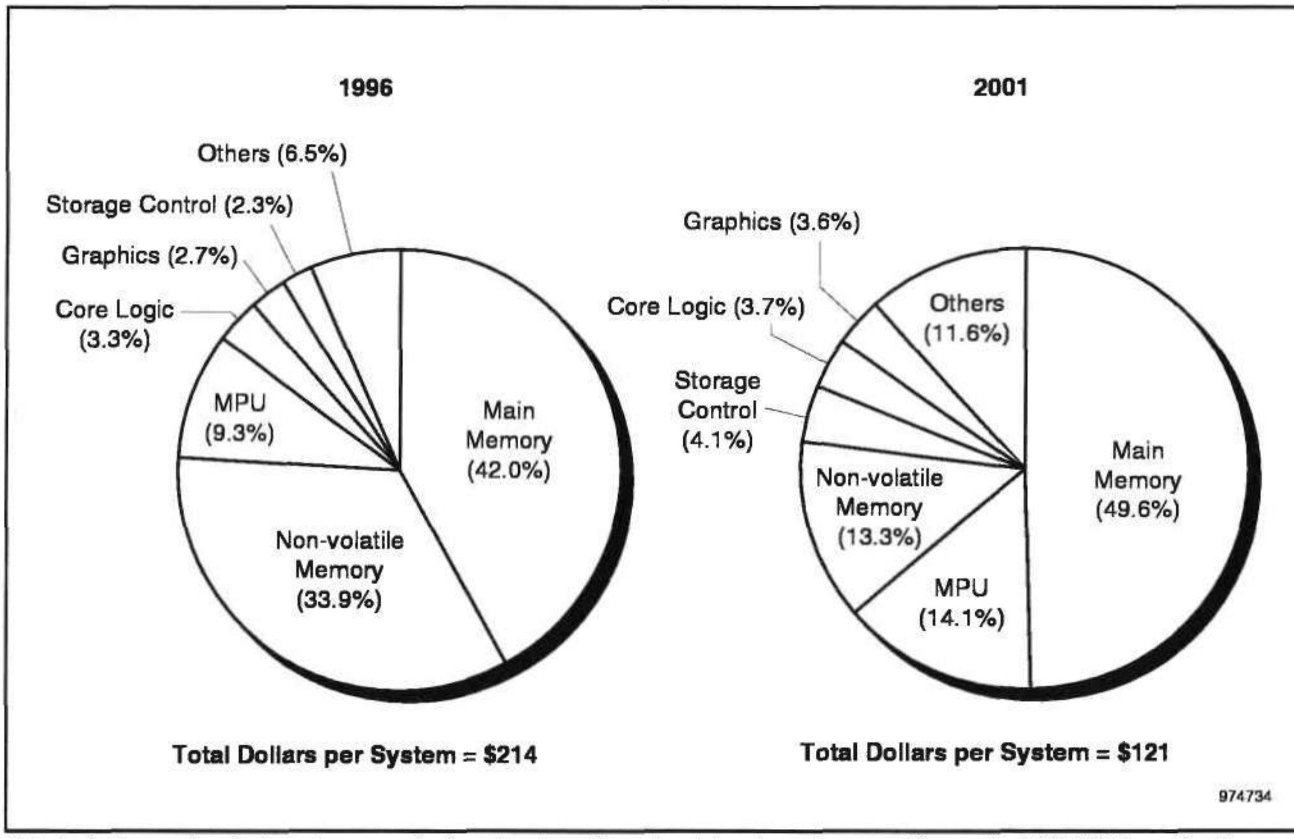
Note: Includes motherboard, graphics, storage, serial/parallel I/O adapters, and add-on memory installed up to point of sale
Source: Dataquest (September 1997)

Figure 5-12
Overall Workstation Semiconductor Content Trend, 1996 and 2001



Note: Includes motherboard, graphics, storage, serial/parallel I/0 adapters, and add-on memory installed up to point of sale
Source: Dataquest (September 1997)

Figure 5-13
Handheld PC Semiconductor Content Trend, 1996 and 2001



Note: Includes semiconductor value on motherboard and card-based peripherals such as graphics, audio, LAN, WAN, and the like; excludes semiconductor value on mass storage peripherals.
Source: Dataquest (September 1997)

Table 5-2
Worldwide PC Semiconductor Market by System (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Others (386 and Lower)	525	27	0	0	0	0	0	0	-
486 PC	24,512	17,248	2,140	56	0	0	0	0	-100.0
Pentium-Class PC	5,199	24,177	37,629	28,906	16,400	6,626	1,853	234	-63.8
Pentium Pro and Future PC	0	6	1,830	15,464	39,264	71,422	108,993	114,293	128.6
RISC PC	1,041	2,814	3,046	3,181	3,965	4,841	5,886	5,432	12.3
680x0 PC	1,656	877	44	5	0	0	0	0	-100.0
Handheld PC	74	48	123	126	166	225	298	463	30.4
Total	**33,007**	**45,196**	**44,812**	**47,739**	**59,795**	**83,114**	**117,030**	**120,422**	**21.9**
Year-to-Year Growth	**-**	**36.9**	**-0.8**	**6.5**	**25.3**	**39.0**	**40.8**	**2.9**	**-**

Note: Includes motherboard, graphics, storage, serial/parallel I/O adapters, and add-on memory installed up to point of sale; also includes motherboard upgrade market
Source: Dataquest (September 1997)

Table 5-3
Worldwide Desktop/Deskside PC Semiconductor Market by System* (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Others (386 and Lower)	396	22	0	0	0	0	0	0	-
486 PC	21,299	13,942	1,616	36	0	0	0	0	-100.0
Pentium-Class PC	5,177	23,180	32,933	23,934	12,194	4,454	1,469	158	-65.6
Pentium Pro and Future PC	0	6	1,830	15,325	37,619	63,808	94,261	98,156	121.8
RISC PC	1,041	2,672	2,836	2,930	3,547	4,348	5,251	4,844	11.3
680x0 PC	1,447	678	40	5	0	0	0	0	-100.0
Total	**29,360**	**40,501**	**39,255**	**42,231**	**53,360**	**72,610**	**100,981**	**103,158**	**21.3**
Year-to-Year Growth	-	37.9	-3.1	7.6	26.4	36.1	39.1	2.2	-193.1

NA = Not available
Note: Includes motherboard, graphics, storage, serial/parallel I/O adapters, and add-on memory installed up to point of sale; also includes motherboard upgrade market
Source: Dataquest (September 1997)

Table 5-4
Worldwide Mobile PC Semiconductor Market by System (Millions of Dollars)

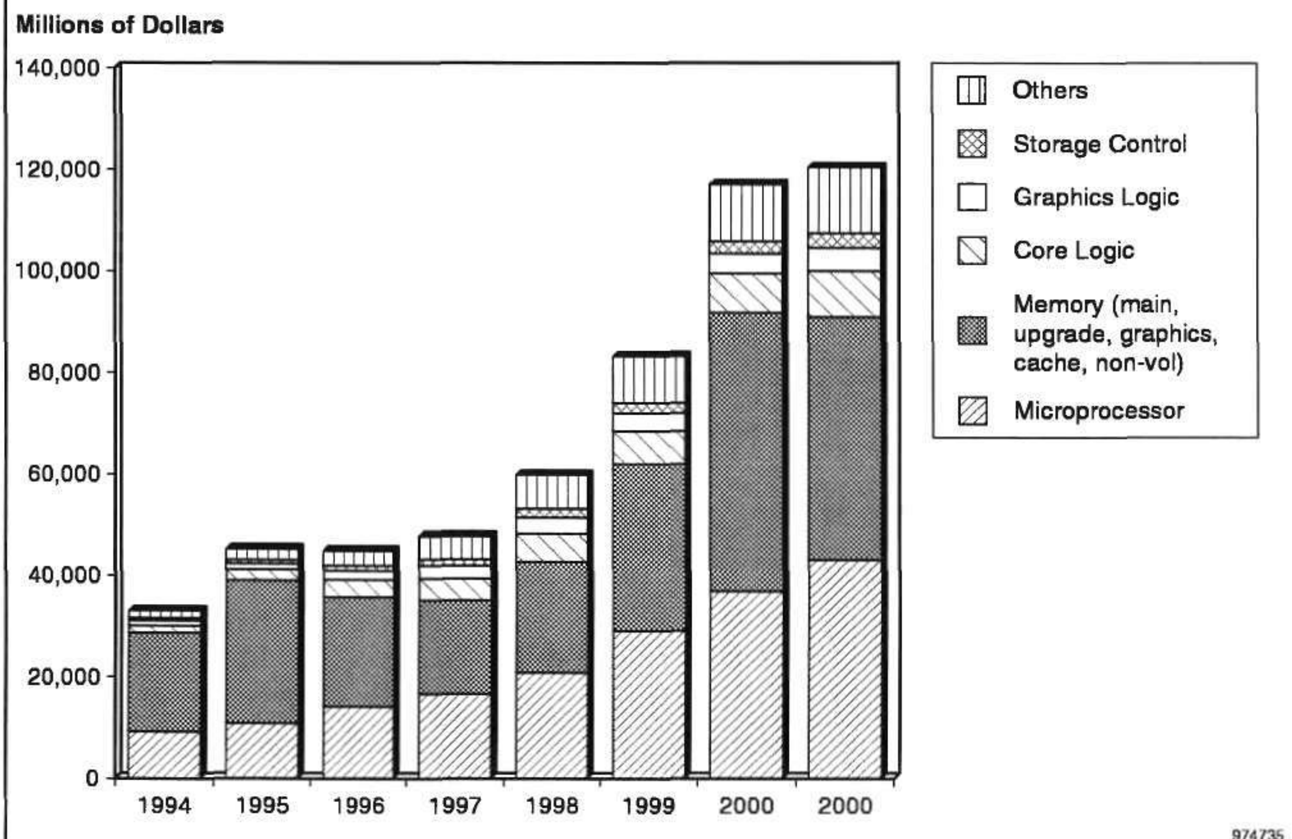
	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Others (386 and Lower)	129	4	0	0	0	0	0	0	-
486 PC	3,213	3,306	525	20	0	0	0	0	-100.0
Pentium-Class PC	23	997	4,695	4,972	4,206	2,171	384	76	-56.1
Pentium Pro and Future PC	0	0	0	138	1,645	7,614	14,732	16,137	-
RISC PC	0	142	210	251	418	493	635	587	22.8
680x0 PC	209	198	4	0	0	0	0	0	-100.0
Handheld PC	74	48	123	126	166	225	298	463	30.4
Total	**3,647**	**4,695**	**5,556**	**5,509**	**6,435**	**10,504**	**16,049**	**17,264**	**25.5**
Year-to-Year Growth	**-**	**28.7**	**18.3**	**-0.9**	**16.8**	**63.2**	**52.8**	**7.6**	**-**

NA = Not available
Note: Includes motherboard, graphics, storage, serial/parallel I/O adapters, and add-on memory installed up to point of sale; also includes motherboard upgrade market
Source: Dataquest (September 1997)

Semiconductor Opportunities by Device Type

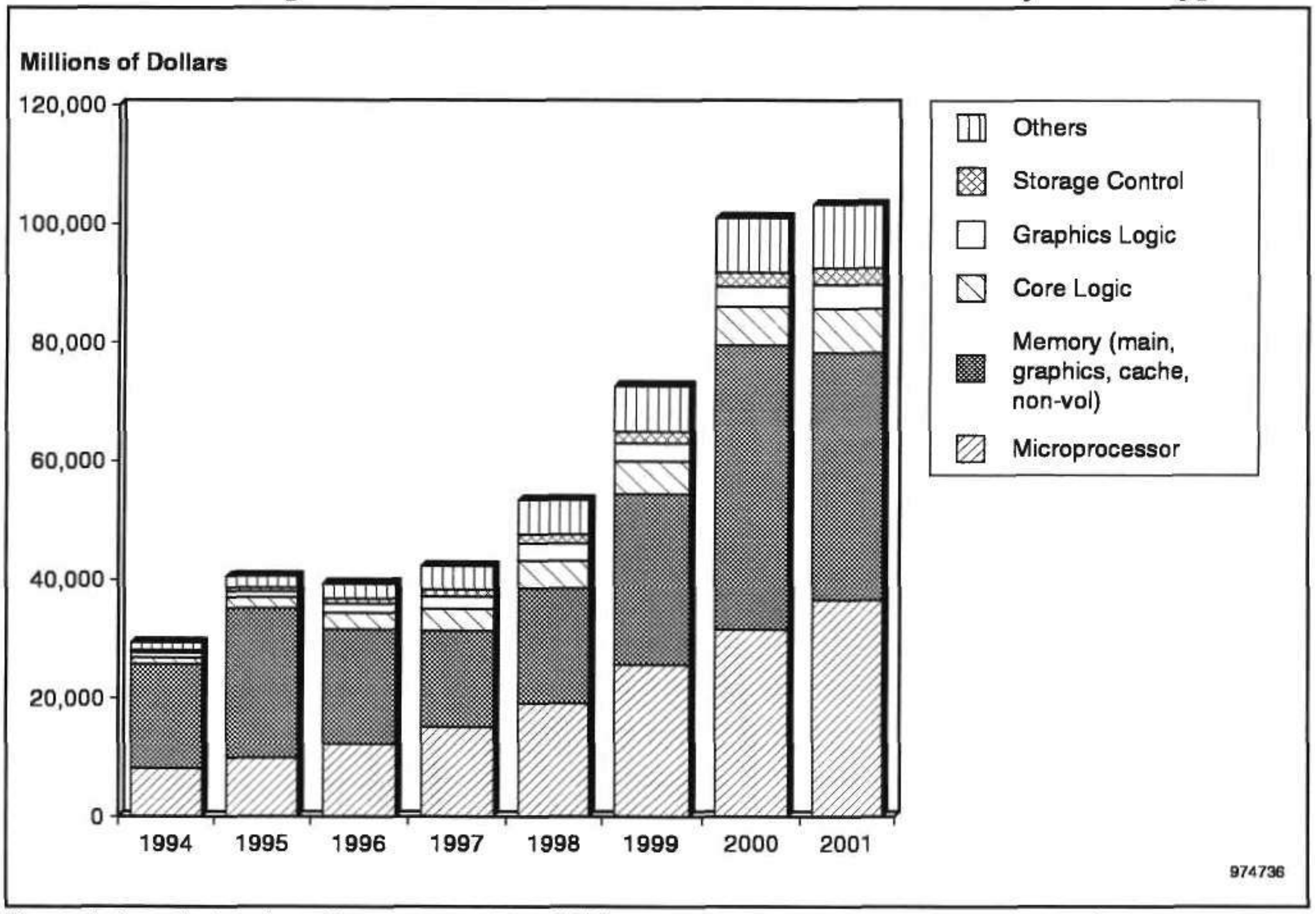
Figures 5-14 through 5-22 and Tables 5-5 through 5-19 detail semiconductor opportunities by device type.

Figure 5-14
Worldwide Total PC Semiconductor Market Revenue by Device Type



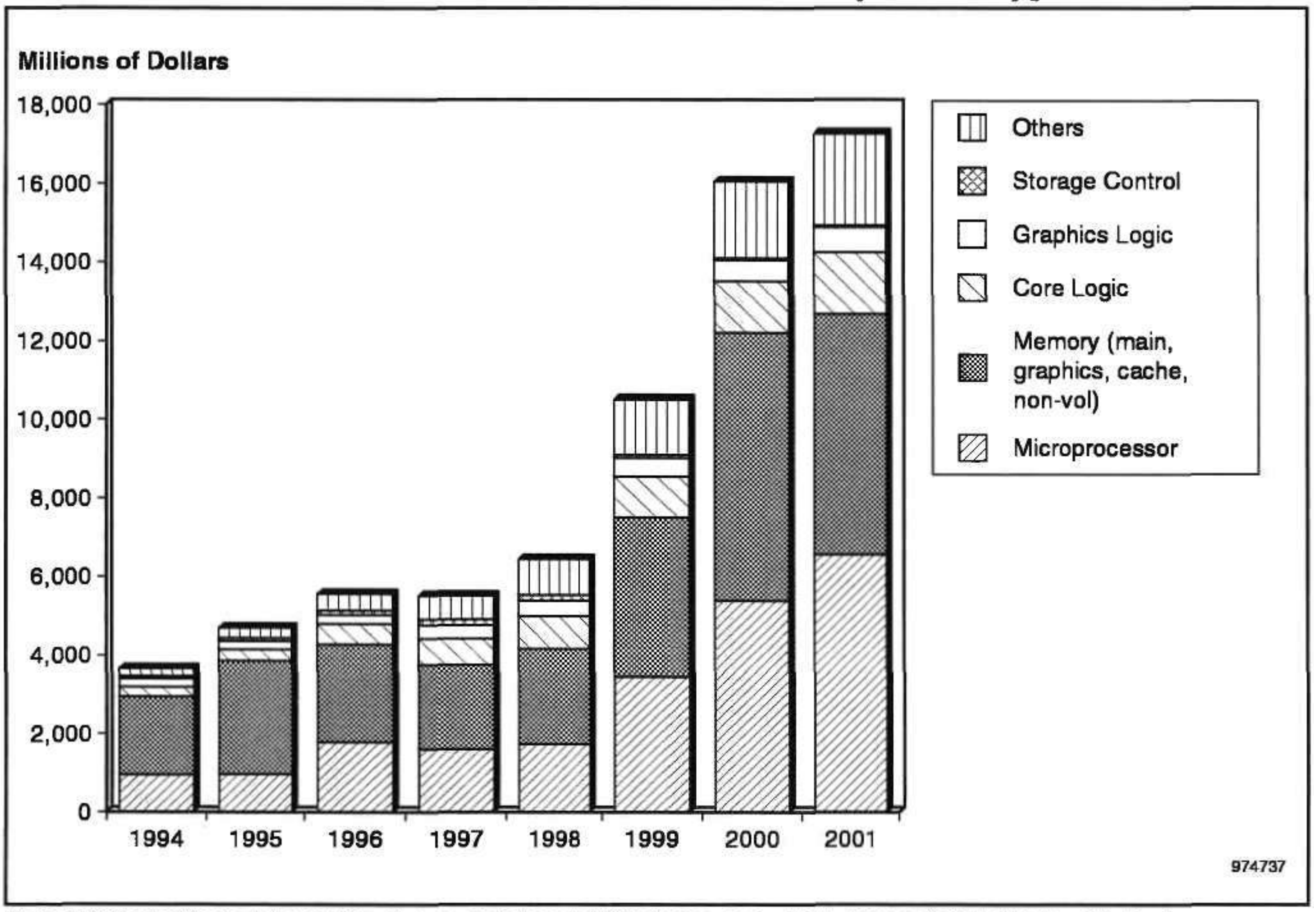
Note: Includes motherboard, graphics, storage, serial/parallel I/O adapters, and add-on memory installed up to point of sale
Source: Dataquest (September 1997)

Figure 5-15
Worldwide Desktop/Deskside PC Semiconductor Market Revenue by Device Type



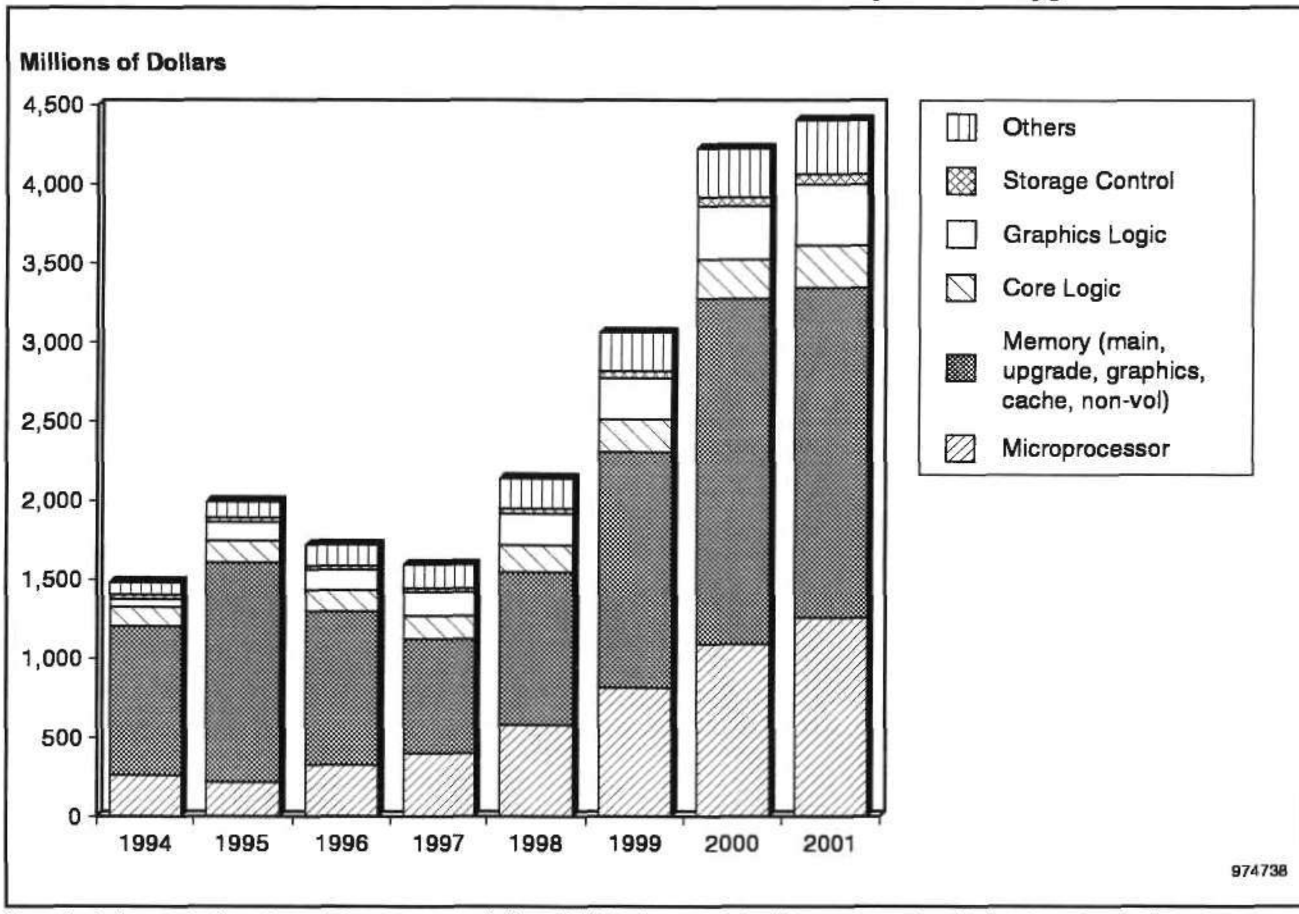
Note: Includes motherboard, graphics, storage, serial/parallel I/O adapters, and add-on memory installed up to point of sale
Source: Dataquest (September 1997)

Figure 5-16
Worldwide Mobile PC Semiconductor Market Revenue by Device Type



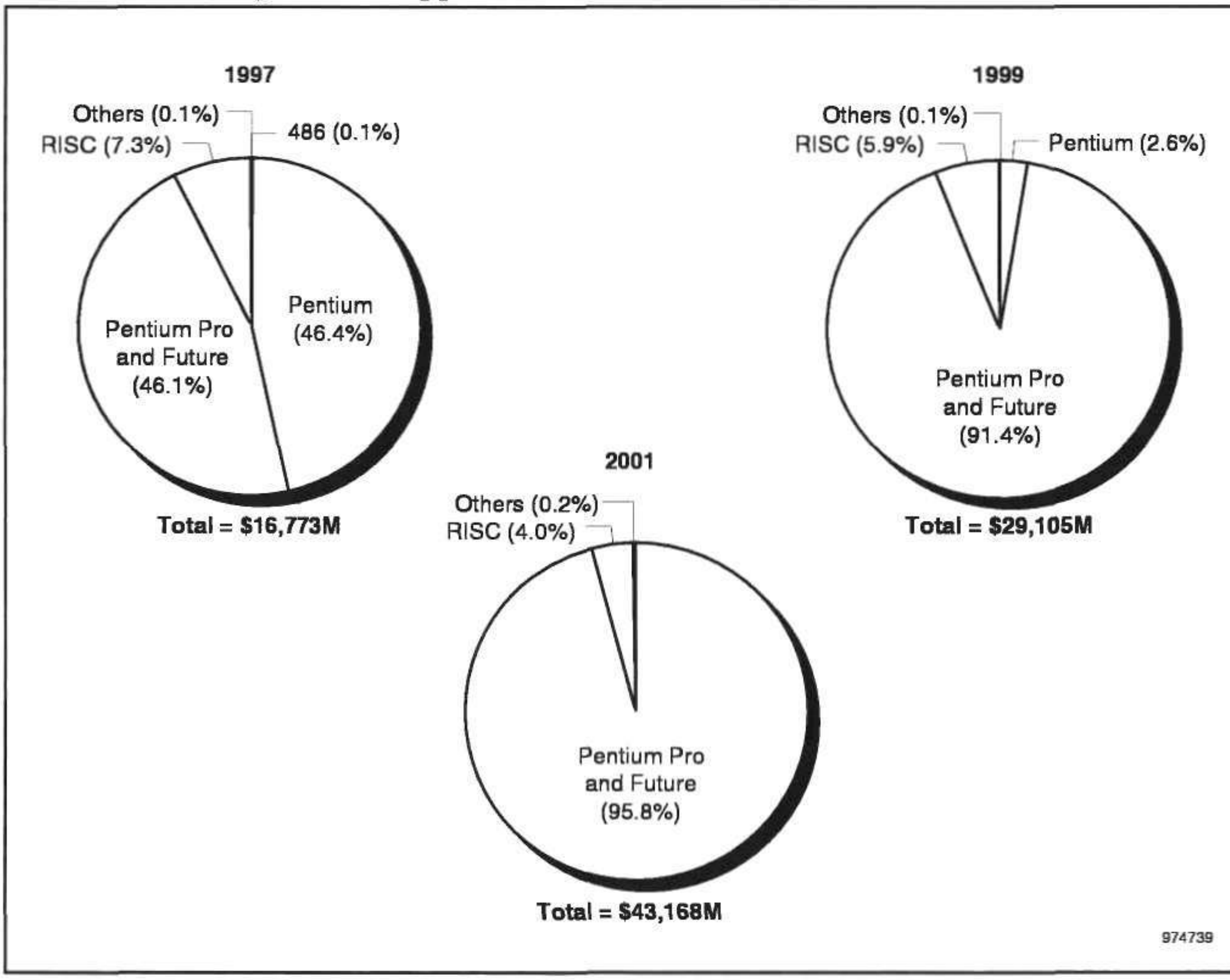
Note: Includes motherboard, graphics, storage, serial/parallel I/0 adapters, and add-on memory installed up to point of sale
Source: Dataquest (September 1997)

Figure 5-17
Worldwide Workstation Semiconductor Market Revenue by Device Type



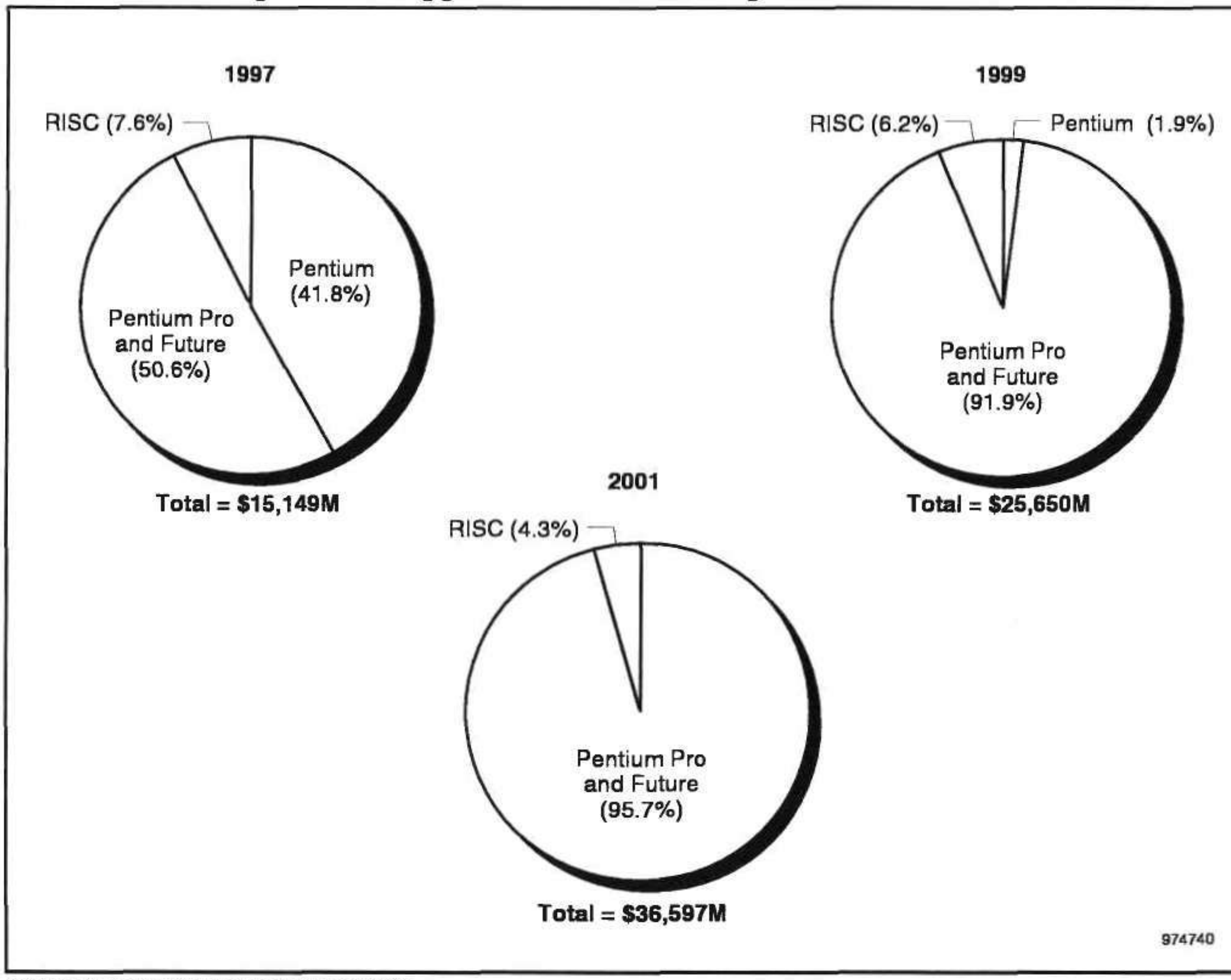
Note: Includes motherboard, graphics, storage, serial/parallel I/0 adapters, and add-on memory installed up to point of sale; percentages may not total 100% because of rounding.
Source: Dataquest (September 1997)

Figure 5-18
Worldwide Microprocessor Opportunities in PCs



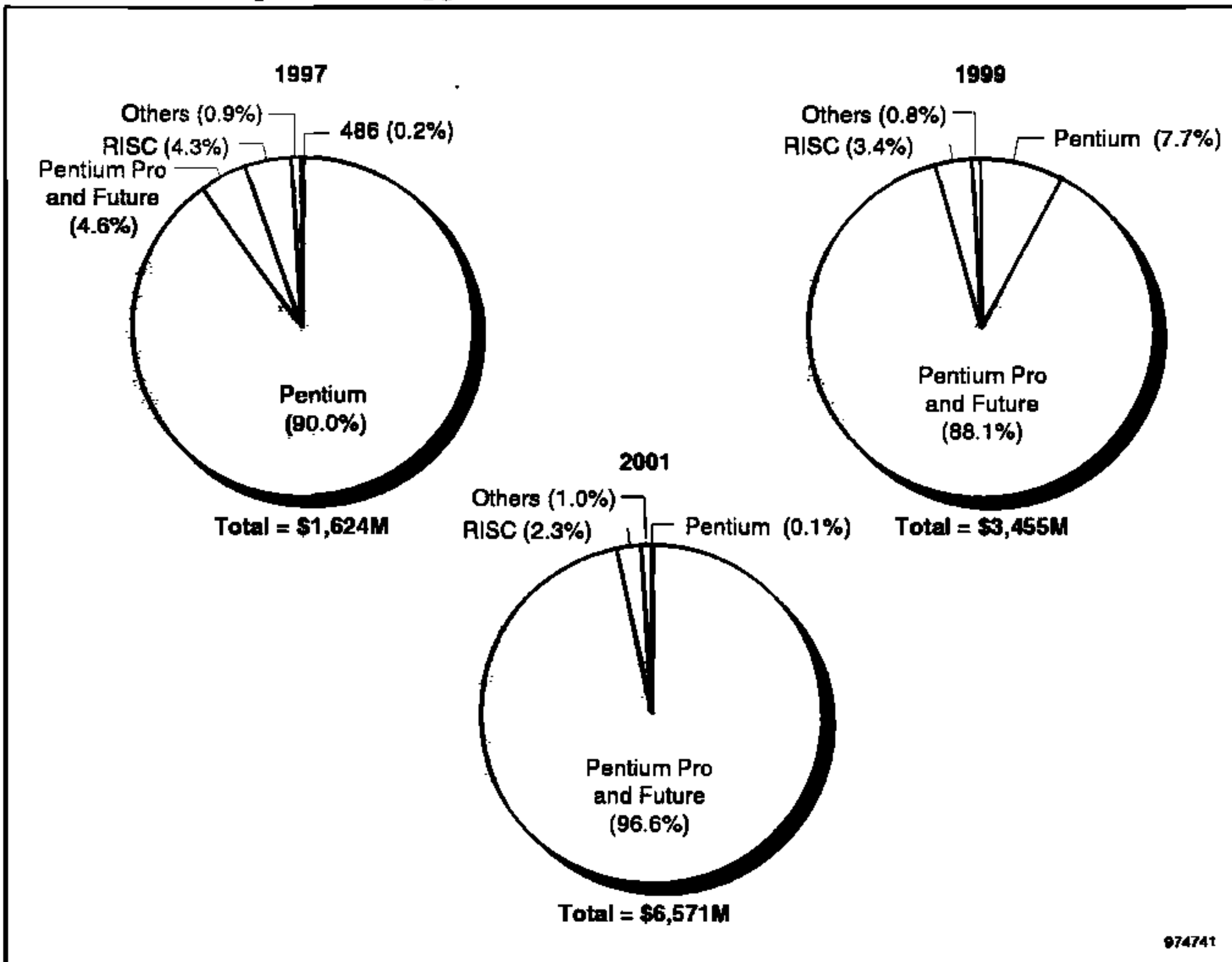
Source: Dataquest (September 1997)

Figure 5-19
Worldwide Microprocessor Opportunities in Desktop/Deskside PCs



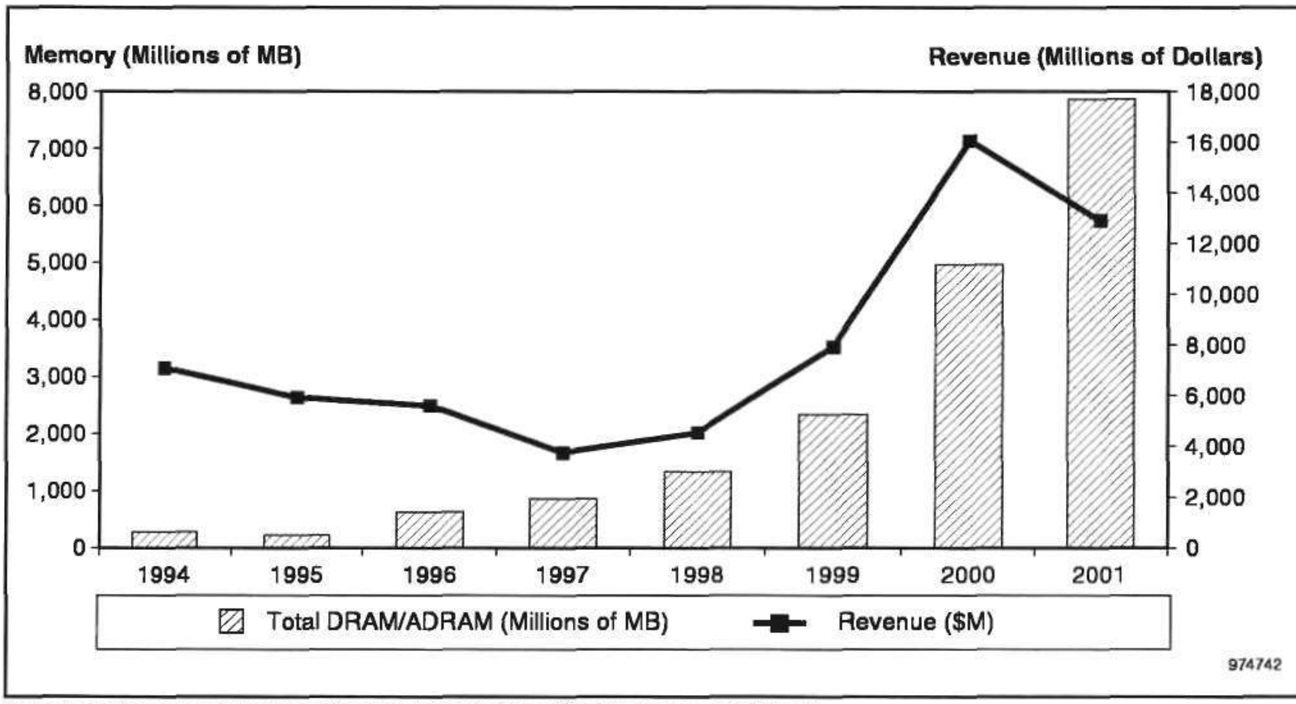
Note: Includes motherboard upgrade market
Source: Dataquest (September 1997)

Figure 5-20
Worldwide Microprocessor Opportunities in Mobile PCs



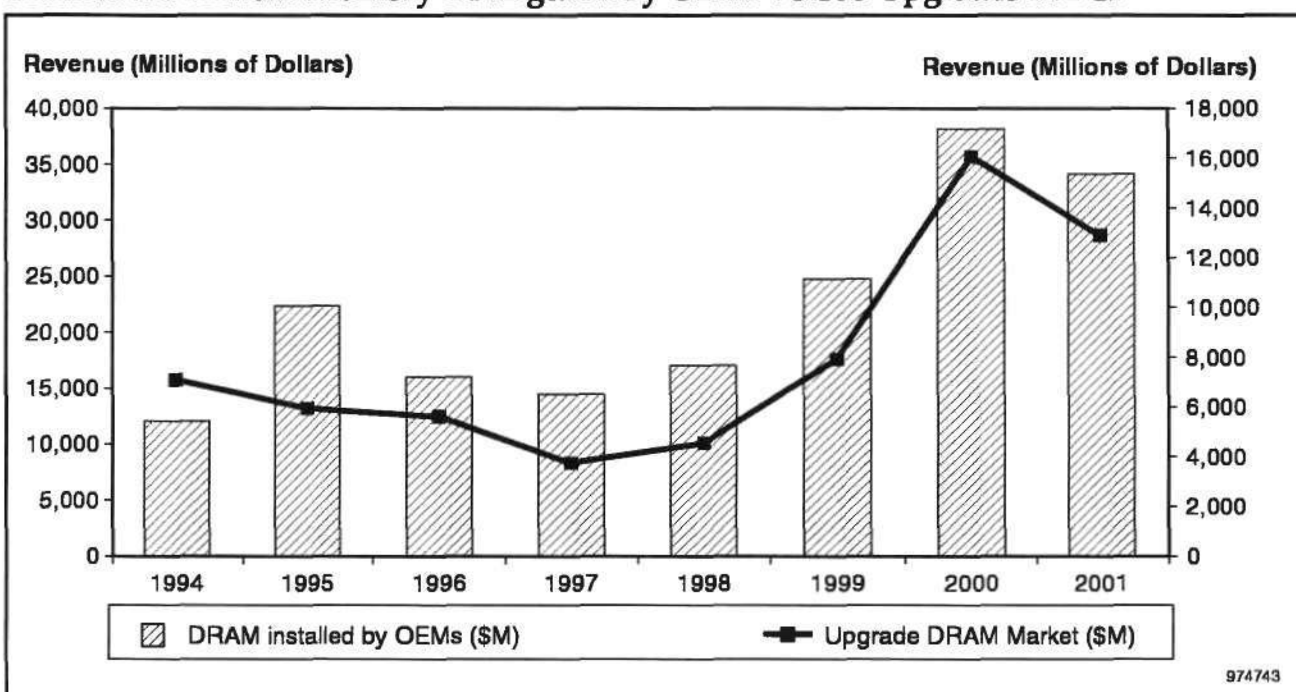
Source: Dataquest (September 1997)

Figure 5-21
Worldwide Aftermarket DRAM Demand in PCs



Note: Includes memory purchased for installation in PCs after PC system point of sale
Source: Dataquest (September 1997)

Figure 5-22
Breakdown of Main Memory Configured by OEMs versus Upgrades in PCs



Source: Dataquest (September 1997)

Table 5-5
Worldwide Total PC Semiconductor Market by Device Type (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Microprocessor	9,253	10,958	14,161	16,773	20,939	29,105	36,982	43,168	25.0
Memory (Main, Graphics, Cache, Nonvolatile)	19,436	28,092	21,715	18,400	21,821	32,928	54,848	47,838	17.1
Core Logic	1,388	2,155	3,361	4,334	5,500	6,532	7,787	9,032	21.9
Graphics Logic	1,043	1,211	1,730	2,461	3,257	3,450	3,855	4,610	21.7
Storage Control	510	747	1,047	1,312	1,741	2,128	2,469	2,862	22.3
Others	1,377	2,032	2,799	4,459	6,537	8,970	11,090	12,911	35.8
Total Semiconductor	**33,007**	**45,196**	**44,812**	**47,739**	**59,795**	**83,114**	**117,030**	**120,422**	**21.9**
Growth Year-to-Year	**-**	**36.9**	**-0.8**	**6.5**	**25.3**	**39.0**	**40.8**	**2.9**	**-**

Note: Includes motherboard, graphics, storage, serial/parallel I/O adapters, and upgrade memory
Source: Dataquest (September 1997)

Table 5-6
Worldwide Desktop/Deskside PC Semiconductor Market by Device Type (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Microprocessor	8,290	9,980	12,367	15,149	19,187	25,650	31,588	36,597	24.2
Memory (Main, Graphics, Cache, Nonvolatile)	17,445	25,211	19,226	16,261	19,406	28,867	48,015	41,713	16.8
Core Logic	1,135	1,852	2,837	3,659	4,664	5,486	6,480	7,471	21.4
Graphics Logic	843	996	1,493	2,129	2,863	2,989	3,316	3,971	21.6
Storage Control	448	678	934	1,163	1,587	2,034	2,426	2,819	24.7
Others	1,199	1,783	2,399	3,869	5,654	7,583	9,155	10,587	34.6
Total Semiconductor	**29,359**	**40,501**	**39,255**	**42,231**	**53,360**	**72,610**	**100,981**	**103,158**	**21.3**
Growth Year-to-Year	**-**	**37.9**	**-3.1**	**7.6**	**26.4**	**36.1**	**39.1**	**2.2**	**-**

Note: Includes motherboard, graphics, storage, serial/parallel I/O adapters, and upgrade memory; also includes semiconductor content of additional motherboards
Source: Dataquest (September 1997)

Table 5-7
Worldwide Mobile PC Semiconductor Market by Device Type (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Microprocessor	962	978	1,794	1,624	1,752	3,455	5,394	6,571	29.6
Memory (Main, Graphics, Cache, Nonvolatile)	1,990	2,881	2,489	2,139	2,415	4,061	6,833	6,124	19.7
Core Logic	253	303	523	675	835	1,047	1,306	1,561	24.4
Graphics Logic	200	215	237	332	395	461	539	639	21.9
Storage Control	63	69	113	148	154	94	42	44	-17.3
Others	179	249	400	590	883	1,386	1,935	2,325	42.2
Total Semiconductor	**3,647**	**4,695**	**5,556**	**5,509**	**6,435**	**10,504**	**16,049**	**17,264**	**25.5**
Growth Year-to-Year	**-**	**28.7**	**18.3**	**-0.9**	**16.8**	**63.2**	**52.8**	**7.6**	**-**

Note: Includes motherboard, graphics, storage, serial/parallel I/O adapters, and upgrade memory
Source: Dataquest (September 1997)

Table 5-8
Wordwide Workstation Semiconductor Market by Device Type

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Microprocessor	265	221	328	402	580	816	1,093	1,261	30.9
Memory (main, graphics, cache, non-vol)	941	1,387	972	723	969	1,491	2,183	2,084	16.5
Core Logic	121	140	134	146	171	206	247	271	15.2
Graphics Logic	50	116	128	150	197	262	337	382	24.4
Storage Control	29	30	26	25	34	44	57	65	19.9
Others	74	98	129	146	187	243	306	338	21.2
Total Semiconductor	**1,481**	**1,992**	**1,717**	**1,593**	**2,138**	**3,062**	**4,222**	**4,401**	**20.7**
Growth Year-to-Year	**-**	**34.5**	**-13.8**	**-7.2**	**34.3**	**43.2**	**37.9**	**4.2**	**-**

Note: Includes motherboard, graphics, storage, serial/parallel I/O adapters, and upgrade memory
Source: Dataquest (September 1997)

Table 5-9
Worldwide Semiconductor Memory Demand in PCs and Workstations by Device (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
DRAM/VRAM	19,162	28,310	21,615	18,211	21,595	32,685	54,214	47,039	16.8
SRAM	872	777	772	672	950	1,476	2,553	2,601	27.5
EPROM/OTP/ROM	137	59	15	5	5	5	5	6	-17.7
Flash	206	333	285	235	240	253	258	276	-0.6
Total	**20,377**	**29,479**	**22,687**	**19,123**	**22,790**	**34,419**	**57,030**	**49,922**	**17.1**

Note: Includes memory installed in factory and upgrade memory
Source: Dataquest (September 1997)

Table 5-10
Worldwide Semiconductor Memory Demand in Desktop/Deskside PCs and Motherboard Upgrades by Device (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
DRAM/VRAM	16,408	24,250	18,393	15,517	18,417	27,448	45,683	39,353	16.4
SRAM	809	653	636	575	811	1,231	2,144	2,170	27.8
EPROM/OTP/ROM	91	46	10	3	4	4	4	4	-17.3
Flash	137	262	187	166	175	184	185	186	-0.1
Total	**17,445**	**25,211**	**19,226**	**16,261**	**19,406**	**28,867**	**48,015**	**41,713**	**16.8**

Note: Includes memory installed in factory and upgrade memory
Source: Dataquest (September 1997)

Table 5-11
Worldwide Semiconductor Memory Demand in Mobile PCs by Device (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
DRAM/VRAM	1,869	2,768	2,341	2,034	2,291	3,848	6,480	5,741	19.7
SRAM	18	38	53	40	61	147	283	296	41.0
EPROM/OTP/ROM	41	11	5	1	1	1	1	2	-18.1
Flash	62	63	90	65	61	64	68	85	-1.0
Total	**1,990**	**2,881**	**2,489**	**2,139**	**2,415**	**4,061**	**6,833**	**6,124**	**19.7**

Note: Includes memory installed in factory and upgrade memory
Source: Dataquest (September 1997)

Table 5-12
Worldwide Semiconductor Memory Demand in Workstations by Device (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
DRAM/VRAM	886	1,292	882	661	886	1,389	2,051	1,944	17.1
SRAM	44	86	82	58	78	98	127	135	10.4
EPROM/OTP/ROM	5	1	0	0	0	0	0	0	-25.1
Flash	7	8	8	5	4	4	5	5	-9.5
Total	**941**	**1,387**	**972**	**723**	**969**	**1,491**	**2,183**	**2,084**	**16.5**

Note: Includes memory installed in factory and upgrade memory
Source: Dataquest (September 1997)

Table 5-13
Worldwide Aftermarket DRAM/VRAM Memory Demand in PCs and Workstations

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Total DRAM/ ADRAM (Millions of MB)	277	224	623	857	1,337	2,330	4,967	7,871	66.1
Revenue ($M)	7,087	5,940	5,611	3,749	4,546	7,923	16,055	12,903	18.1

Note: Includes memory purchased for installation in PCs after PC system point of sale
Source: Dataquest (September 1997)

Table 5-14
Worldwide Semiconductor Memory Demand by Total PC System (Market Value by Function; Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
486 PC									
Main OEM	6,738	7,490	877	20	0	0	0	0	-100.0
Upgrade Memory	6,293	3,798	195	4	0	0	0	0	-100.0
Display Buffer	1,062	956	216	5	0	0	0	0	-100.0
Cache	629	388	65	0	0	0	0	0	-100.0
Nonvolatile	194	167	29	1	0	0	0	0	-100.0
Total	**14,916**	**12,800**	**1,382**	**29**	**0**	**0**	**0**	**0**	**-100.0**
Pentium-Class PC									
Main OEM	1,765	10,013	10,922	8,604	5,487	2,666	784	82	-62.4
Upgrade Memory	254	1,569	4,673	2,407	1,209	488	257	22	-65.7
Display Buffer	118	781	2,005	1,329	803	342	114	15	-62.6
Cache	135	207	543	419	156	20	2	0	-76.4
Nonvolatile	36	162	197	126	57	16	3	1	-69.0
Total	**2,308**	**12,731**	**18,340**	**12,885**	**7,712**	**3,532**	**1,160**	**120**	**-63.4**

Table 5-14 (Continued)
Worldwide Semiconductor Memory Demand by Total PC System (Market Value by Function; Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Pentium Pro and Future PC									
Main OEM	0	1	282	2,762	8,193	17,825	30,814	28,879	152.4
Upgrade Memory	0	1	169	921	2,810	6,652	14,624	11,865	134.0
Display Buffer	0	0	48	344	828	1,471	2,803	1,979	110.8
Cache	0	0	0	147	621	1,271	2,334	2,378	-
Nonvolatile	0	0	7	63	139	189	202	207	96.3
Total	**0**	**3**	**505**	**4,237**	**12,591**	**27,409**	**50,777**	**45,308**	**145.8**
RISC PC									
Main OEM	383	1,114	726	655	862	1,222	1,921	1,397	14.0
Upgrade Memory	140	478	319	257	272	372	537	437	6.5
Display Buffer	47	188	228	187	163	147	162	184	-4.1
Cache	35	80	80	48	95	88	90	88	1.8
Nonvolatile	9	16	17	13	11	8	8	8	-13.2
Total	**614**	**1,875**	**1,370**	**1,159**	**1,402**	**1,838**	**2,718**	**2,115**	**9.1**
Workstation									
Main OEM	808	1,195	539	412	520	823	1,214	1,089	15.1
Upgrade Memory	0	0	251	161	255	411	637	579	18.2
Display Buffer	77	97	92	88	111	155	200	277	24.7
Cache	44	86	82	58	78	98	127	135	10.4
Nonvolatile	12	9	8	5	4	5	5	5	-10.1
Total	**941**	**1,387**	**972**	**723**	**969**	**1,491**	**2,183**	**2,084**	**16.5**
Others									
Main OEM	840	449	63	56	80	107	144	230	29.5
Upgrade Memory	400	93	4	0	0	0	0	0	-100.4
Display Buffer	236	86	7	1	2	3	4	3	-15.5
Cache	29	15	1	0	0	0	0	0	-99.7
Nonvolatile	92	39	43	32	34	40	45	62	7.7
Total	**1,597**	**682**	**118**	**90**	**116**	**150**	**192**	**295**	**20.1**
Total PC and Workstation									
Main OEM	10,535	20,262	13,409	12,508	15,142	22,643	34,876	31,677	18.8
Upgrade Memory	7,087	5,940	5,611	3,749	4,546	7,923	16,055	12,903	18.1
Display Buffer	1,541	2,108	2,596	1,954	1,907	2,118	3,283	2,458	-1.1
Cache	872	777	772	672	950	1,476	2,553	2,601	27.5
Nonvolatile	343	392	300	240	245	258	263	282	-1.2
Total	**20,377**	**29,479**	**22,687**	**19,123**	**22,790**	**34,419**	**57,030**	**49,922**	**17.1**

NA = Not available
Source: Dataquest (September 1997)

Table 5-15
Worldwide Semiconductor Memory Demand for Desktop/Deskside PC Systems (Market Value by Function; Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
486 PC									
Main OEM	5,585	6,078	655	13	0	0	0	0	-100.0
Upgrade Memory	5,958	3,282	164	3	0	0	0	0	-100.0
Display Buffer	867	756	172	3	0	0	0	0	-100.0
Cache	612	370	63	0	0	0	0	0	-100.0
Nonvolatile	134	125	21	0	0	0	0	0	-100.0
Total	**13,155**	**10,611**	**1,073**	**19**	**0**	**0**	**0**	**0**	**-100.0**
Pentium-Class PC									
Main OEM	1,760	9,713	9,546	7,183	4,208	1,828	609	55	-64.4
Upgrade Memory	251	1,494	4,243	2,052	935	348	234	19	-66.0
Display Buffer	117	743	1,919	1,252	712	284	103	13	-63.1
Cache	134	191	502	391	130	8	0	0	-100.0
Nonvolatile	36	154	153	94	34	8	2	0	-71.4
Total	**2,300**	**12,295**	**16,363**	**10,973**	**6,019**	**2,476**	**948**	**87**	**-64.9**
Pentium Pro and Future PC									
Main OEM	0	1	282	2,742	7,909	16,139	26,896	25,294	145.8
Upgrade Memory	0	1	169	914	2,696	5,977	13,084	10,467	128.2
Display Buffer	0	0	48	343	809	1,345	2,453	1,717	104.9
Cache	0	0	0	145	600	1,150	2,069	2,097	-
Nonvolatile	0	0	7	63	135	173	180	183	91.5
Total	**0**	**3**	**505**	**4,207**	**12,149**	**24,783**	**44,682**	**39,758**	**139.4**
RISC PC									
Main OEM	383	1,074	671	604	758	1,063	1,696	1,227	12.8
Upgrade Memory	140	447	298	241	253	342	473	409	6.5
Display Buffer	47	178	208	166	138	123	134	152	-6.1
Cache	35	76	71	38	80	73	75	73	0.6
Nonvolatile	9	15	15	12	9	7	7	7	-14.3
Total	**383**	**1,074**	**671**	**604**	**758**	**1,063**	**1,696**	**1,227**	**12.8**
Others									
Main OEM	708	326	11	1	0	0	0	0	-99.8
Upgrade Memory	400	93	4	0	0	0	0	0	-100.2
Display Buffer	191	63	4	0	0	0	0	0	-99.8
Cache	28	15	1	0	0	0	0	0	-100.0
Nonvolatile	49	15	1	0	0	0	0	0	-100.2
Total	**1,376**	**513**	**21**	**1**	**0**	**0**	**0**	**0**	**-99.7**

Table 5-15 (Continued)
Worldwide Semiconductor Memory Demand for Desktop/Deskside PC Systems (Market Value by Function; Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Total Desktop/Deskside PC									
Main OEM	8,437	17,192	11,165	10,543	12,874	19,030	29,201	26,575	18.9
Upgrade Memory	6,749	5,318	4,878	3,211	3,884	6,667	13,792	10,895	17.4
Display Buffer	1,222	1,741	2,351	1,764	1,659	1,752	2,690	1,883	-4.3
Cache	809	653	636	575	811	1,231	2,144	2,170	27.8
Nonvolatile	229	308	197	169	178	188	189	190	-0.7
Total	**17,445**	**25,211**	**19,226**	**16,261**	**19,406**	**28,867**	**48,015**	**41,713**	**16.8**

NA = Not available
Source: Dataquest (September 1997)

Table 5-16
Worldwide Semiconductor Memory Demand for Mobile PC Systems (Market Value by Function; Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
486 PC									
Main OEM	1,153	1,412	222	7	0	0	0	0	-100.0
Upgrade Memory	335	516	32	1	0	0	0	0	-100.0
Display Buffer	195	201	44	2	0	0	0	0	-100.0
Cache	17	18	3	0	0	0	0	0	-100.0
Nonvolatile	60	42	8	0	0	0	0	0	-100.0
Total	**1,761**	**2,189**	**309**	**10**	**0**	**0**	**0**	**0**	**-100.0**
Pentium-Class PC									
Main OEM	5	300	1,376	1,420	1,279	838	175	27	-54.3
Upgrade Memory	2	75	430	355	274	140	23	3	-63.1
Display Buffer	1	38	86	77	91	58	11	1	-55.7
Cache	1	16	41	28	25	11	2	0	-60.5
Nonvolatile	0	8	43	32	22	9	1	0	-63.8
Total	**9**	**436**	**1,976**	**1,912**	**1,693**	**1,056**	**212**	**33**	**-56.0**
Pentium Pro and Future PC									
Main OEM	0	0	0	19	284	1,687	3,918	3,585	-
Upgrade Memory	0	0	0	6	114	675	1,539	1,399	-
Display Buffer	0	0	0	2	19	127	350	262	-
Cache	0	0	0	2	21	122	265	280	-
Nonvolatile	0	0	0	0	5	16	23	24	-
Total	**0**	**0**	**0**	**30**	**443**	**2,626**	**6,095**	**5,550**	**-**

Table 5-16 (Continued)
Worldwide Semiconductor Memory Demand for Mobile PC Systems (Market Value by Function; Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
RISC PC									
Main OEM	0	40	55	51	104	159	225	171	25.3
Upgrade Memory	0	30	21	15	19	30	64	28	6.5
Display Buffer	0	10	19	21	25	24	27	32	10.5
Cache	0	4	10	10	14	15	15	15	9.2
Nonvolatile	0	1	2	1	2	1	1	1	-5.8
Total	**0**	**86**	**107**	**99**	**164**	**230**	**333**	**247**	**18.3**
Handhelds									
Main OEM	23	16	52	56	80	107	144	230	34.8
Upgrade Memory	0	0	0	0	0	0	0	0	-
Display Buffer	0	0	1	1	2	3	4	3	19.5
Cache	0	0	0	0	0	0	0	0	-
Nonvolatile	31	19	42	32	34	40	45	62	8.2
Total	**54**	**35**	**94**	**89**	**116**	**150**	**192**	**295**	**25.6**
Others									
Main OEM	110	107	0	0	0	0	0	0	-231.1
Upgrade Memory	0	0	0	0	0	0	0	0	32.7
Display Buffer	46	22	2	0	0	0	0	0	-99.8
Cache	1	0	0	0	0	0	0	0	4.3
Nonvolatile	12	5	0	0	0	0	0	0	-19.9
Total	**167**	**135**	**2**	**0**	**0**	**0**	**0**	**0**	**-99.7**
Total Mobile PC									
Main OEM	1,290	1,876	1,705	1,554	1,747	2,791	4,461	4,012	18.7
Upgrade Memory	338	622	483	378	407	845	1,626	1,430	24.3
Display Buffer	241	270	153	102	137	212	392	299	14.3
Cache	18	38	53	40	61	147	283	296	41.0
Nonvolatile	103	74	95	66	63	66	70	87	-1.6
Total	**1,990**	**2,881**	**2,489**	**2,139**	**2,415**	**4,061**	**6,833**	**6,124**	**19.7**

NA = Not available
Source: Dataquest (September 1997)

Table 5-17
Average Memory Configuration Assumptions for PCs and Workstations by System (Megabytes per System)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
486 PC									
Main OEM	5.53	8.19	13.72	16.00	0	0	0	0	-100.0
Upgrade Memory	5.16	4.15	3.06	2.92	0	0	0	0	-100.0
Display Buffer	1.00	1.19	1.36	1.32	0	0	0	0	-100.0
Cache	131.99	144.44	155.64	4.69	0	0	0	0	-100.0
Nonvolatile	0.15	0.25	0.25	0.25	0	0	0	0	-100.0
Pentium-Class PC									
Main OEM	13.07	11.29	15.75	24.22	30.00	35.47	44.92	56.40	29.1
Upgrade Memory	1.88	1.77	6.74	6.78	6.61	6.49	14.73	15.27	17.8
Display Buffer	1.00	1.00	2.08	2.28	2.58	2.83	3.76	4.24	15.4
Cache	256.00	79.25	119.07	178.41	110.01	38.99	15.66	24.26	-27.3
Nonvolatile	0.25	0.25	0.16	0.18	0.18	0.16	0.17	0.20	4.7
Pentium Pro and Future PC									
Main OEM	0	14.16	17.78	31.89	38.49	46.46	63.19	98.06	40.7
Upgrade Memory	-	14.16	10.67	10.63	13.20	17.34	29.99	40.29	30.4
Display Buffer	-	2.00	3.00	3.98	3.90	3.88	5.84	6.83	17.9
Cache	-	0	0	256.00	377.59	496.17	726.67	725.25	-
Nonvolatile	-	0.25	0.25	0.38	0.38	0.37	0.36	0.36	7.7
RISC PC									
Main OEM	11.33	10.43	15.85	25.66	35.98	47.71	71.93	90.48	41.7
Upgrade Memory	4.14	4.47	6.96	10.06	11.36	14.52	20.13	28.32	32.4
Display Buffer	1.50	2.00	2.46	3.39	3.77	4.67	5.83	6.83	22.7
Cache	262.14	256.00	266.85	284.89	512.00	512.00	512.00	512.00	13.9
Nonvolatile	0.25	0.20	0.21	0.27	0.26	0.25	0.27	0.28	6.1
Workstation									
Main OEM	40.00	53.00	68.70	92.30	114.00	136.00	164.00	256.00	30.1
Upgrade Memory	0	0	32.00	36.00	55.93	68.00	86.00	136.00	33.6
Display Buffer	2.50	3.00	6.00	8.00	9.00	10.00	11.00	16.00	21.7
Cache	512.00	752.00	926.00	1,127.00	1,285.00	1,402.00	1,508.00	1,650.00	12.2
Nonvolatile	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0

Note: Includes memory added through system point of sale; excludes graphics BIOS typically using a 32Kx8 EPROM/OTP
NA = Not available
Source: Dataquest (September 1997)

Table 5-18
Average Memory Configuration Assumptions for Desktop/Deskside PC Systems (Megabytes per System)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
486 PC									
Main OEM	6.00	10.00	16.00	18.00	20.00	24.00	32.00	0	-100.0
Upgrade Memory	6.40	5.40	4.00	4.00	4.00	4.00	4.00	0	-100.0
Display Buffer	1.00	1.25	1.50	1.50	1.50	1.50	1.50	0	-100.0
Cache	157.29	183.50	207.67	0	0	0	0	0	-100.0
Nonvolatile	0.13	0.25	0.25	0.25	0	0	0	0	-100.0
Pentium-Class PC									
Main OEM	14.00	13.00	18.00	28.00	36.00	42.00	52.00	68.00	30.5
Upgrade Memory	2.00	2.00	8.00	8.00	8.00	8.00	20.00	24.00	24.6
Display Buffer	117.09	743.20	1,919.36	1,252.24	711.73	283.88	102.56	13.19	-63.1
Cache	256.00	76.80	128.00	204.80	128.00	25.60	0	0	-100.0
Nonvolatile	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0
Pentium Pro and Future PC									
Main OEM	0	16.00	20.00	36.00	44.00	54.00	74.00	116.00	42.1
Upgrade Memory	0	16.00	12.00	12.00	15.00	20.00	36.00	48.00	32.0
Display Buffer	0	2.00	3.00	4.00	4.00	4.00	6.00	7.00	18.5
Cache	0	0	0	256.00	384.00	512.00	768.00	768.00	-
Nonvolatile	0	0.25	0.25	0.38	0.38	0.38	0.38	0.38	9.0
RISC PC									
Main OEM	12.00	12.00	18.00	30.00	42.00	56.00	86.00	108.00	43.1
Upgrade Memory	4.14	5.00	8.00	12.00	14.00	18.00	24.00	36.00	35.1
Display Buffer	1.50	2.00	2.50	3.50	4.00	5.00	6.00	7.00	22.9
Cache	256.00	256.00	256.00	256.00	512.00	512.00	512.00	512.00	14.9
Nonvolatile	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0

Note: Includes memory added through system point of sale; excludes graphics BIOS typically using a 32Kx8 EPROM/OTP
NA = Not available
Source: Dataquest (September 1997)

Table 5-19
Average Memory Configuration Assumptions for Mobile PC Systems (Megabytes per System)

	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
486 PC									
Main OEM	5.50	7.00	14.00	18.00	0	0	0	0	-100.0
Upgrade Memory	1.60	2.56	2.00	2.00	0	0	0	0	-100.0
Display Buffer	1.00	1.00	1.00	1.00	0	0	0	0	-100.0
Cache	19.66	26.76	21.63	13.07	0	0	0	0	-100.0
Nonvolatile	0.25	0.25	0.25	0.25	0	0	0	0	-100.0
Pentium-Class PC									
Main OEM	8.00	8.00	16.00	24.00	28.00	36.00	46.00	56.00	28.5
Upgrade Memory	4.00	2.00	5.00	6.00	6.00	6.00	6.00	6.00	3.7
Display Buffer	1.00	1.00	1.00	1.30	2.00	2.50	3.00	3.00	24.6
Cache	256.00	128.00	64.00	64.00	64.00	64.00	64.00	64.00	0.0
Nonvolatile	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.0
Pentium Pro and Future PC									
Main OEM	0	0	16.00	24.00	30.00	40.00	56.00	82.00	38.7
Upgrade Memory	0	0	10.00	8.00	12.00	16.00	22.00	32.00	26.2
Display Buffer	0	0	2.00	2.00	2.00	3.00	5.00	6.00	24.6
Cache	0	0	0	256.00	256.00	384.00	512.00	512.00	-
Nonvolatile	0	0	0	0.25	0.25	0.25	0.25	0.25	-
RISC PC									
Main OEM	6.00	8.00	16.00	20.00	32.00	42.00	56.00	72.00	35.1
Upgrade Memory	0	6.00	6.00	6.00	6.00	8.00	16.00	12.00	14.9
Display Buffer	1.00	2.00	2.00	2.50	2.50	3.00	5.00	6.00	24.6
Cache	256.00	256.00	384.00	512.00	512.00	512.00	512.00	512.00	5.9
Nonvolatile	0	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.0
Handhelds									
Main OEM	1.25	1.60	2.50	3.25	4.00	4.00	4.00	4.00	9.9
Upgrade Memory	0	0	0	0	0	0	0	0	-
Display Buffer	0	0	0.25	0.25	0.50	0.50	0.50	0.50	14.9
Cache	0	0	0	0	0	0	0	0	-
Nonvolatile	2.50	3.50	4.00	4.25	4.50	4.50	4.50	4.50	2.4

Note: Includes memory added through system point of sale; excludes graphics BIOS typically using a 32Kx8 EPROM/OTP
NM = Not meaningful
Source: Dataquest (September 1997)

Chapter 6

Input/Output and Dedicated Systems

Tables 6-1 through 6-6 detail system and semiconductor market data on selected computer I/O systems and high-volume dedicated systems such as copiers and expandable organizers. Data for sound boards, graphics boards, and digital video cards is one year old because newer data was not available at time of publication. These tables will be republished in the third quarter of 1997 to reflect finalized 1996 market sizes as well as updated forecasts.

Key Trends

Sound Boards

Key trends in sound boards are as follows:

- The sound board market faces increasing competition from integrated designs with sound chips on the motherboard or on custom daughter-card modules. Integrated sound chips are primarily used for mobile and consumer PCs, although a few business desktops have integrated sound capability.
- Microsoft has adopted DSP Group's TrueSpeech technology as a compression standard. Several vendors already support ADPCM for compression.
- Movement to 16 bit is nearly complete. Wave-table synthesis is gaining market share.
- Key chip functions include FM and wave-table synthesis (512KB to 4MB ROM-based), ASSP/ASICs (mixed-signal and digital CMOS), audio amplifiers, and mixers. SCSI host adapters have declined in popularity compared to EIDE or proprietary variants of EIDE.

Graphics Boards

Key trends in graphics boards are as follows:

- This market will get a boost from the move to 3-D acceleration this year.
- Boards are moving to greater than 1Kx1K-pixel resolutions, accelerated BitBLT-based, 64-bit data paths, and RAMDAC technology moving from 85 MHz to 135 MHz. Also, digital video, 3-D, and sound capability are appearing in the high-end boards.
- EDO DRAM will be the dominant memory for 1997, but will be replaced with SGRAM late this year or early in 1998. Minimal buffers start at 2MB and move to 4MB with optional SIMMs. Most high-end add-in boards have traditionally had a separate RAMDAC but many new products feature integrated DACs with speeds up to 270 MHz.

Digital Video Boards

Key trends in digital video boards are as follows:

- There will be continued penetration into the multimedia content creator market (software title development, market communications, and training). Playback board growth will be limited to full-screen 15- to 30-fps acceleration. Other opportunities exist for TV tuner, capture pass-through, and integrated multimedia acceleration boards.
- MPEG-1 hardware has disappeared for mainstream application as software MPEG-1 has improved in quality and benefited from faster microprocessors with multimedia enhancements.
- Key semiconductor opportunities include compression decoders for MPEG-2 and JPEG, among others (and encoders for real-time algorithms), PAL/NTSC to CCIR decoders and encoders, ASICs (CMOS), digital video processors (scaling, among others), and ADRAM pixel buffers.

Leading digital video board OEMs worldwide include ATI, Creative Technologies, Diamond Multimedia, FutureTel, IBM, Intel, Matrox, Optibase, Optivision, Orchid, STB Systems, and Video Logic.

Monitors

Key trends in monitors are as follows:

- Color will grow to 98 percent of the market in 1999.
- 15-inch tubes will be the predominant size in 1997; 17-inches tubes will be predominant in 1998.
- There will be a chip content of about $15 for primarily video amplifier (moving to 220 MHz) and CRT controls.

Keyboards

The trend in keyboards is commodity items moving toward ergonomic and wireless versions.

Leading keyboard OEMs worldwide are Keytronic, Silitek, and MaxiSwitch.

Table 6-1
Worldwide Sound Board Application Market

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Board Units (M)	13.7	11.5	12.1	12.7	13.4	14.0	14.7	5.0
Board ASP ($)	64.6	66.25	66.25	66.25	66.25	66.25	66.25	0
Board Factory Revenue ($M)	883.1	765.0	803.2	843.4	885.6	929.8	976.3	5.0
16-Bit and Higher Penetration	97.0	98.2	100.0	100.0	100.0	100.0	100.0	0.4
Semiconductor Content ($)	16.1	17	17.5	18	18	18	18	1.1
Semiconductor Market ($M)	220.8	196.3	212.2	229.1	240.6	252.6	265.3	6.2
ASSP/ASIC ($M)	94.9	82.1	86.2	90.6	95.1	99.8	104.8	5.0
Synthesis ($M)	81.7	70.7	74.2	78.0	81.9	85.9	90.2	5.0
Analog/Discrete	33.1	28.6	30.1	31.6	33.2	34.8	36.6	5.0
Memory/Others ($M)	11	14.8	21.6	29.1	30.5	32.0	33.6	17.8

Source: Dataquest (September 1997)

Table 6-2
Worldwide Sound Board OEMs (1995 Unit Share)

OEM	Unit Share
Creative	61.1
Aztech	36.5
Diamond	0.5
Turtle Beach	0.3
Others	1.6

Source: Dataquest (September 1997)

Table 6-3
Worldwide Graphic Board Application Market

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Board Units (K)	12,634.5	16,677.5	20,013.0	23,815.5	27,673.6	31,741.7	35,836.3	16.5
Board ASP ($)	160.0	152.0	160.0	152.0	149.0	146.0	143.1	-1.2
Board Factory Revenue ($M)	2,021.5	2,535.0	3,202.1	3,620.0	4,122.3	4,633.7	5,126.8	15.1
Semiconductor Content ($)	57.0	55.0	58.0	60.0	59.0	58.0	57.0	0.7
Semiconductor Market ($M)	720.2	917.3	1,160.8	1,428.9	1,632.7	1,841.0	2,042.7	17.4

Source: Dataquest (September 1997)

Table 6-4
Worldwide Digital Video Board Application Market

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Board Units (K)	605.0	1,080.3	1,188.3	1,307.1	1,437.8	1,581.6	1,739.8	10.0
With Hardware Compression and/or Decompression	169.0	351.5	369.0	387.5	406.8	427.2	448.5	5.0
With TV Tuner	100.0	189.0	236.3	295.3	369.1	461.4	576.8	25.0
Board ASP	310.0	228.0	216.6	205.7	195.5	185.7	176.4	-5.0
Board Factory Revenue ($M)	187.6	246.3	257.4	268.9	281.0	293.7	306.9	4.5
Semiconductor Content ($)	87.8	79.8	78.2	76.6	75.1	73.6	72.1	-2.0
Semiconductor Market ($M)	53.1	86.2	92.9	100.2	108.0	116.4	125.5	7.8
TV Signal Processing ($M)	1.5	3.8	4.7	5.9	7.4	9.2	11.5	25.0
Video Scaling/Processing ($M)	20.0	27.0	28.4	29.8	31.3	32.8	34.5	5.0
Compression/ Decompression($M)	5.9	17.6	18.5	19.4	20.3	21.4	22.4	5.0
Memory (DRAM/VRAM) ($M)	22.7	27.0	28.4	29.8	31.3	32.8	34.5	5.0
Others ($M)	3.0	10.8	13.0	15.3	17.7	20.2	22.6	15.8

Source: Dataquest (September 1997)

Table 6-5
Worldwide Monitor Application Market

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
System Units (K)	41,227.0	54,419.6	65,303.6	77,711.2	90,300.5	103,574.6	116,935.8	16.5
System ASP ($)	352.0	316.8	285.1	256.6	230.9	207.9	187.1	-10.0
System Factory Revenue ($M)	14,494.0	17,240.1	18,619.4	19,941.3	20,854.6	21,528.2	21,874.8	4.9
Semiconductor Content ($)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	0
Semiconductor Market ($M)	188.0	272.1	326.5	388.6	451.5	517.9	584.7	16.5

Source: Dataquest (September 1997)

Table 6-6
Worldwide Keyboard Application Market

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1996-2001
System Units (K)	55,961.6	73,869.3	88,643.2	105,485.4	122,574.0	140,592.4	158,728.8	16.5
Semiconductor Content ($)	2.45	2.50	2.50	2.50	2.50	2.50	2.50	0
Semiconductor Market ($M)	137.1	184.7	221.6	263.7	306.4	351.5	396.8	16.5

Source: Dataquest (September 1997)

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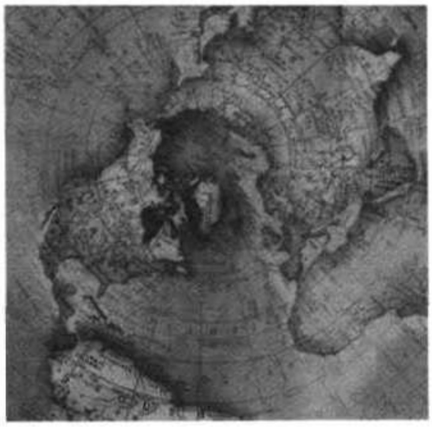

Dataquest

1997 Trends in Computational Microprocessors and Core Logic

Market Trends

Program: Personal Computer Semiconductors and Applications Worldwide
Product Code: PSAM-WW-MT-9702
Publication Date: September 22, 1997
Filing: Market Trends

1997 Trends in Computational Microprocessors and Core Logic

Market Trends

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Chapter 1
Executive Summary

At the start of 1996, Dataquest asked "Can any vendor compete with Intel in 1996?" By the end of the year, it became obvious that none could—at least not for that year. Using the narrowest of market definitions, Intel laid claim to 96 cents out of every dollar spent on x86 microprocessors used in computational applications, leaving just four cents for other x86 vendors to fight over. Alternative x86 vendors struggled first to release and then to find customers for their products. AMD completed its K5 development, but woefully lagged behind Intel's Pentium with regard to operating frequency and performance. AMD was forced to discount the already low prices it charged for its products and watched its average selling prices erode dramatically. Cyrix finally squeezed its design onto a die it could manufacture at reasonable cost, only to encounter a variety of subtle thermal problems that restricted its operating frequencies. Both vendors watched as red ink gushed from their books, and both hoped to staunch their losses with new products in 1997.

The news from the RISC camp was no more encouraging. Microsoft pulled the plug on future support of the PowerPC in Windows NT, leaving the PowerPC's ultimate fate in computational applications resting solely on the long-term success of the Macintosh platform, a precarious position at best. Vendors of RISC-based workstations and servers began to feel the heat from the combination of Intel's Pentium Pro microprocessor and Microsoft's Windows NT 4.0 release. NetPower and NEC converted their MIPS-based Windows NT products to Pentium Pro, leading Microsoft to discontinue support for that platform as well. By the end of the year, the architecturally neutral Windows NT environment supported only two architectures—Intel and Alpha.

Dataquest anticipates that the market for computational microprocessors will grow at a compound annual growth rate (CAGR) of 17 percent from 83.3 million units in 1996 to almost twice that number, 173 million, in the year 2001. Revenue for the segment will grow even more rapidly at 21 percent, from $17 billion in 1996 to $40.6 billion in the year 2001. Dataquest forecasts that the market for x86 microprocessors used in personal computers, workstations, and servers will grow from 77.6 million units in 1996 to 163 million units in the year 2001. The revenue associated with these processors will grow from $15.4 billion to $37.1 billion over the same period.

Dataquest projects that following a dismal showing in 1996, when non-Intel x86 processors captured only 5 percent of x86 revenue and 16 percent of unit shipments, these products will rebound and account for 13 percent of all revenue ($2.5 billion) and 21 percent of all shipments (18.9 million units) in 1997. By the year 2000, the non-Intel component of this market will capture 18 percent of the total market revenue ($5.5 billion) and 29 percent of total unit shipments (41 million units). We anticipate that Intel will only grudgingly cede this market share, and Intel's competitors will be forced to sell their wares at a steep discount to the prices offered by Intel. The most likely scenario sees Intel abandoning the sub-$100 processor market to its competitors, who can then drive their own growth based on the increasing market for sub-$1,000 personal computers.

A popular rumor holds that following Intel's serious entry into the core logic market in 1993, all other participants abandoned that market and left it all to Intel. According to Dataquest, in 1996 Intel increased its share of the core logic market from 32 to 66 percent measured in dollars, and from 22 to 56 percent measured in units. Some vendors threw in the towel, and abandoned the market. Those that based their business on this market battened down the hatches and prepared to ride out the storm. Many see a glimmer of hope on the horizon, as Intel begins to emphasize its Pentium II designs and leaves the socket 7 arena to x86 clone vendors and alternative chipset suppliers.

Dataquest anticipates that the market for personal computer core logic will grow from $1.6 billion in 1996 to $2.6 billion in the year 2001. Sales of Socket 7-oriented logic peaked in 1996, at about $1.2 billion, and will slowly decline to $460 million by the year 2001.

Project Analyst: Nathan Brookwood

Chapter 2
Review of Computational Microprocessor Market

1996 Market Overview

Intel garnered 96 cents from every 1996 dollar spent on x86 microprocessors used in computational applications. Of course, it started in a strong position, having claimed 90 cents out of every dollar the prior year. When viewed from this perspective, Andy Grove's 1996 compensation works out to just more than $1 million per point of market share—a good deal for all involved. Even with the broadest of market definitions, microprocessor units sold into all computational applications, Intel still garnered 77 percent of all units, up from 71 percent in 1995. It's a good thing Mr. Grove did not peg his compensation to this broader measure.

Other vendors fared less well. Alternative x86 vendors struggled first to release their products and then to find customers for them. AMD completed its K5 development, but K5 fell short of Pentium's operating frequency and performance and had to be sold at drastically lower prices. Meanwhile, AMD's engineers raced to complete the NexGen-derived K6 design on which the company had pinned its hopes for a rebound. Cyrix finally squeezed its design onto a die it could manufacture at reasonable cost, only to encounter a variety of subtle thermal problems that restricted its operating frequencies. Neither vendor fared too well in 1996, and both looked to 1997 as the year to stop the bleeding.

The news from the RISC camp was no more encouraging. The Apple/IBM/Motorola PowerPC alliance began the year with the expectation that the Common Hardware Reference Platform (CHRP) would smooth the way for platforms that could support both the Mac OS and Windows NT. By year's end, Microsoft had pulled the plug on future support of the PowerPC in Windows NT, leaving the PowerPC's ultimate fate in computational applications resting solely on the long-term success of the Macintosh platform. The ongoing turmoil at Apple, with regard to management, organization and product strategy, did little to reassure prospective buyers that they could count on that platform's long-term success.

As the year progressed, vendors of RISC-based workstations and servers began to feel the heat from the combination of Intel's Pentium Pro microprocessor and Microsoft's Windows NT 4.0 release. Unit growth, anemic to begin with, slowed as Compaq, Hewlett-Packard, and IBM all introduced workstation-class products with Intel inside. NetPower and NEC converted their MIPS-based Windows NT products to Pentium Pro, leading Microsoft to discontinue support for that platform as well. By the end of the year, the architecturally neutral Windows NT environment supported only two architectures—Intel and Alpha.

Statistical Review of the 1996 Computational Microprocessor Market

Tables 2-1 and 2-2 summarize the computational microprocessor market in terms of revenue and unit shipments over the past two years. Figures 2-1, 2-2, 2-3, and 2-4 present this information graphically. The market grew 34 percent in revenue but only 17 percent in unit shipments. Much of the revenue growth came from higher average selling prices, as personal computer buyers repeatedly spent a little more money to buy a lot more performance in their new systems. There was no need for an instant replay to determine last year's winner, and most participants (other than Intel) would most likely prefer not to watch a replay of this most difficult year.

In the tables that follow, a few anomalies complicate the interpretation of the data. In 1995, Digital Equipment Corporation failed to provide revenue related to its Alpha microprocessor shipments, leaving Dataquest with an empty entry in its database. This makes it impossible to measure Digital's growth in this market.

Hewlett-Packard's sales of PA-RISC devices are not captured in Dataquest's revenue database, because the chips are not generally available for purchase on the open market. Dataquest is reporting its estimates of HP's unit shipments because the company plays a major role in workstation and server markets, and its exclusion from these tallies would greatly distort the results.

Table 2-1
Computational Microprocessor Vendors by Revenue (Millions of Dollars)

1995 Rank	1996 Rank	Company	1995 Revenue ($M)	1996 Revenue ($M)	1995-1996 Growth (%)	1995 Market Share (%)	1996 Market Share (%)
1	1	Intel	10,365	14,675	42	83	88
3	2	IBM	592	613	4	5	4
2	3	Advanced Micro Devices	743	300	-60	6	2
11	4	Digital	0	235	NA	0	1
6	5	Texas Instruments	196	213	9	2	1
4	6	Motorola	221	209	-5	2	1
12	7	Sun Microsystems	0	170	NA	0	1
5	8	Cyrix	205	160	-22	2	1
8	9	NEC	39	40	3	0	0
9	10	Toshiba	32	32	0	0	0
15	11	SGS-Thomson	0	8	NA	0	0
13	12	Integrated Device Technology	0	3	NA	0	0
7	13	Fujitsu	51	0	-100	0	0
10	14	United Microelectronics	15	0	NA	0	0
14	15	Hewlett-Packard	0	0	NA	0	0
		Total Market	**12,459**	**16,658**	**34**	**10**	**100**

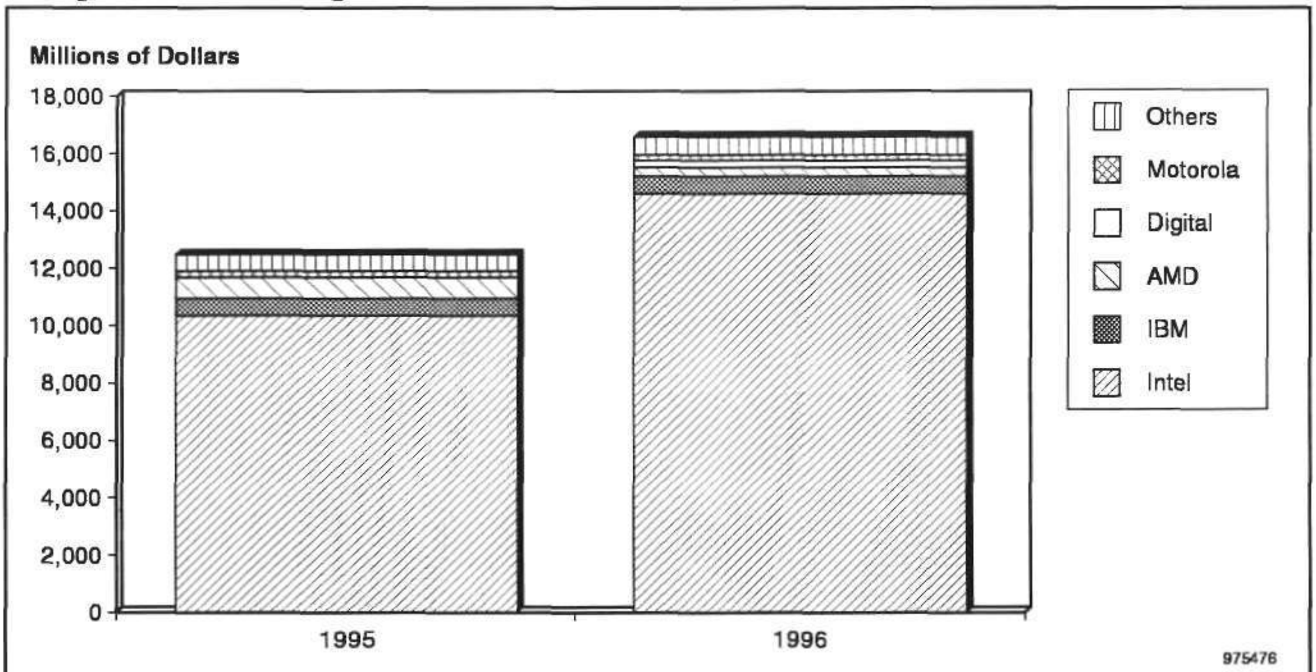
NA = Not available
Source: Dataquest (August 1997)

Table 2-2
Computational Microprocessor Vendors by Unit Shipments (Thousands of Units)

1995 Rank	1996 Rank	Company	1995 Units (K)	1996 Units (K)	1995-1996 Growth (%)	1995 Market Share (%)	1996 Market Share (%)
1	1	Intel	50,806	65,000	28	71	77
2	2	Advanced Micro Devices	9,482	8,802	-7	13	10
3	3	IBM	3,806	4,231	11	5	5
4	4	Cyrix	3,404	1,920	-44	5	2
5	5	Motorola	2,363	1,507	-36	3	2
6	6	Texas Instruments	561	1,099	96	1	1
14	7	Sun Microsystems	0	525	NA	0	1
9	8	Hewlett-Packard	225	300	33	0	0
10	9	Digital	165	300	82	0	0
8	10	NEC	268	100	-63	0	0
15	11	SGS-Thomson	0	75	NA	0	0
12	12	Toshiba	105	40	-62	0	0
11	13	Integrated Device Technology	125	10	-92	0	0
7	14	Fujitsu	270	0	-100	0	0
13	15	United Microelectronics	10	0	-100	0	0
		Total Market	**71,590**	**83,909**	**17**	**100**	**100**

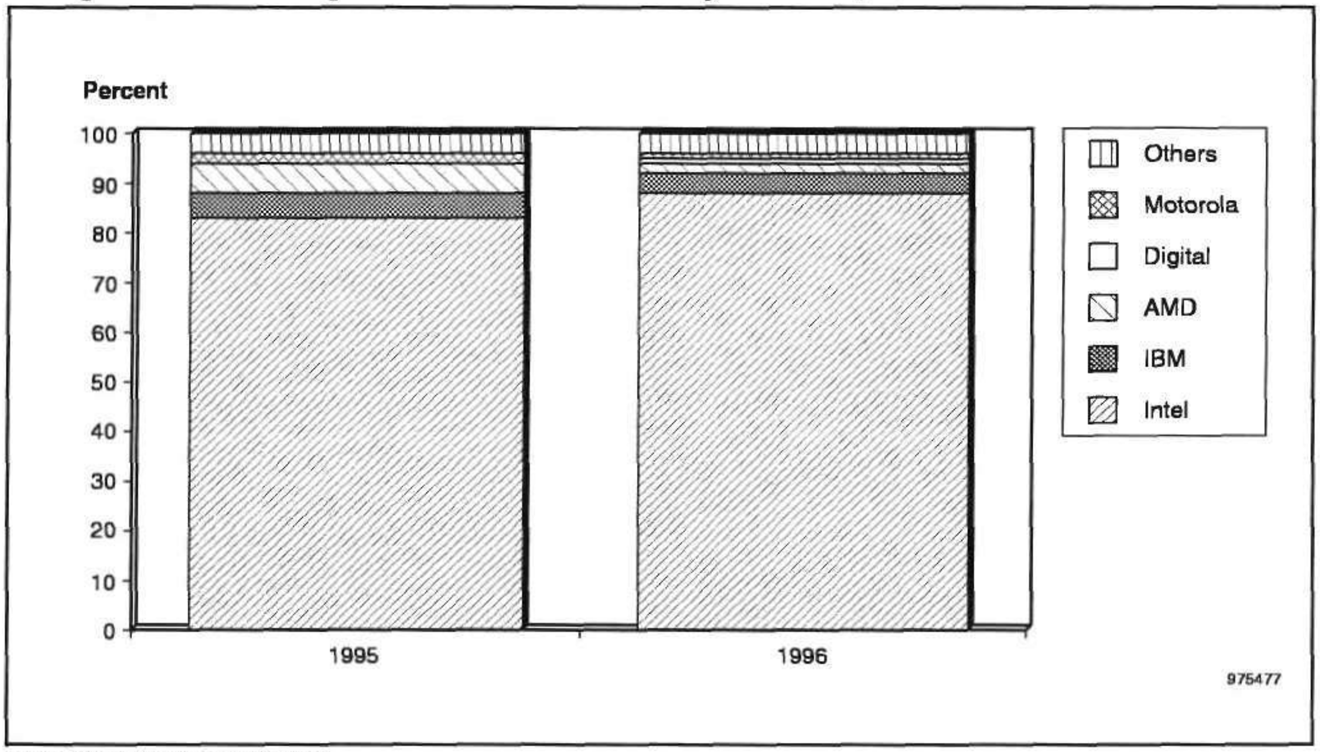
NA = Not available
Source: Dataquest (August 1997)

Figure 2-1
Computational Microprocessor Vendor Revenue, 1995-1996



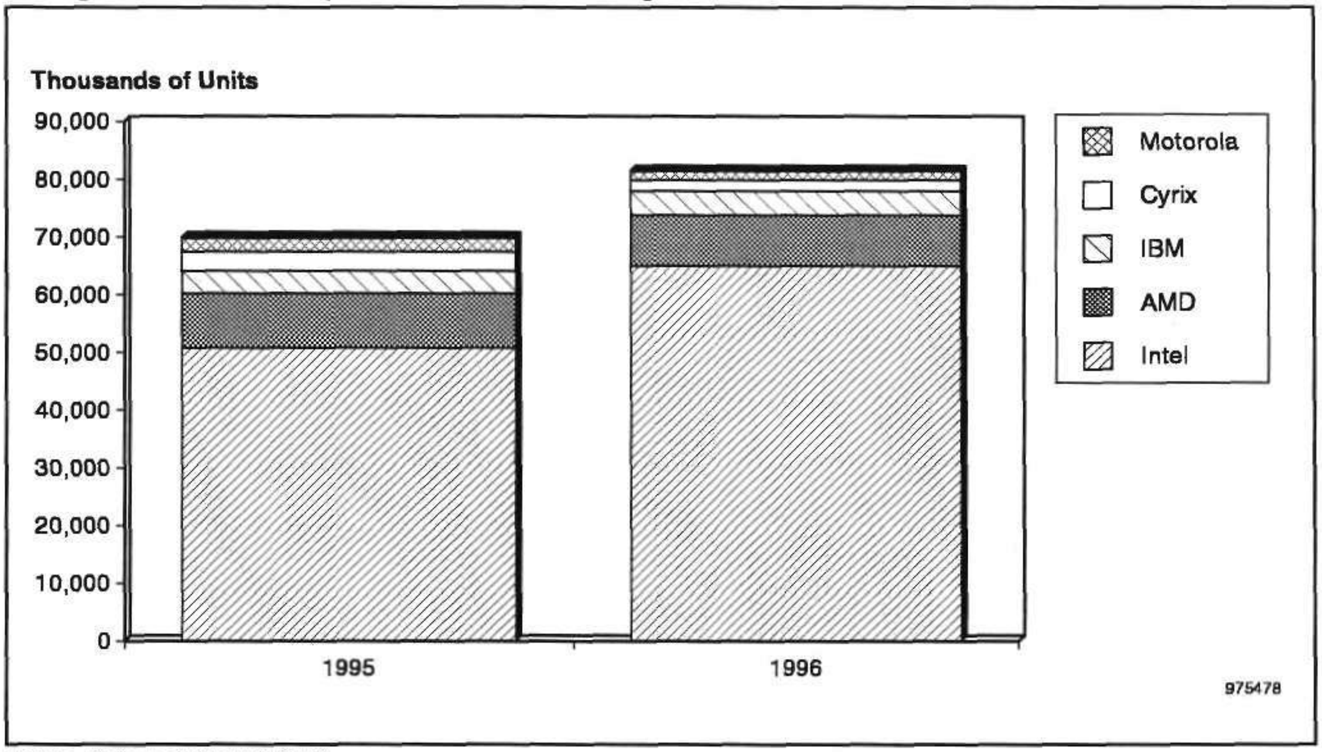
Source: Dataquest (August 1997)

Figure 2-2
Computational Microprocessor Market Share by Revenue, 1995-1996



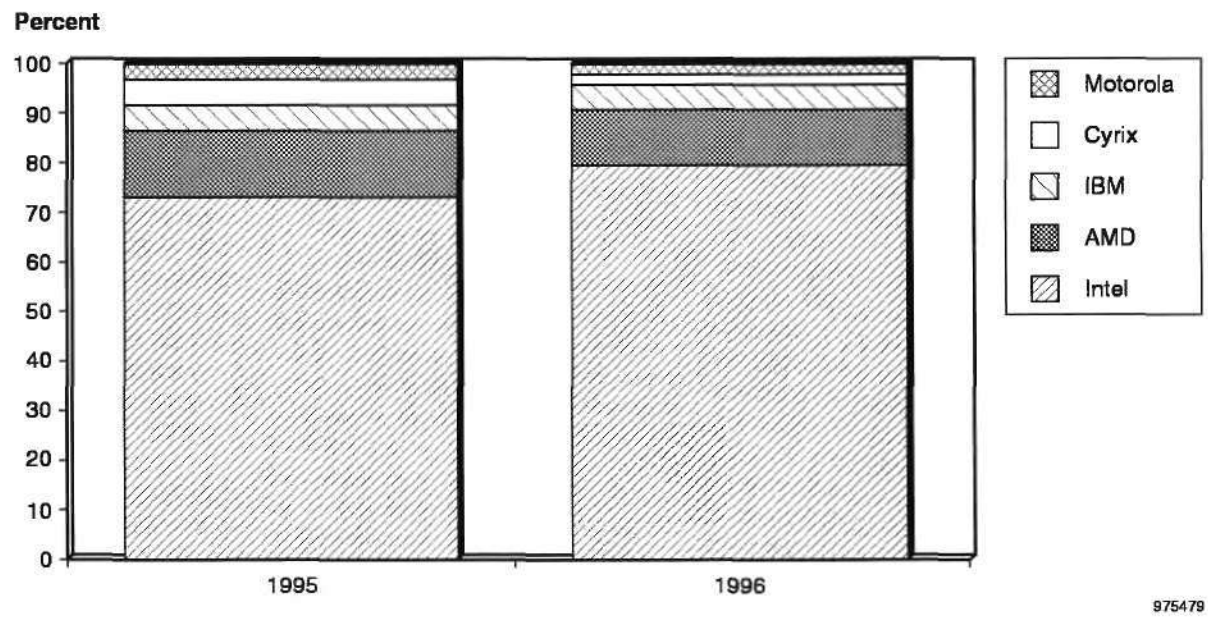
Source: Dataquest (August 1997)

Figure 2-3
Computational Microprocessor Vendor Shipments, 1995-1996



Source: Dataquest (August 1997)

Figure 2-4
Computational Microprocessor Market Share by Unit Shipments, 1995-1996



Source: Dataquest (August 1997)

Dataquest's reporting of the sales of Sun Microsystems' SPARC processors continues to evolve and is slowly catching up with Sun's evolving marketing strategies for such chips. Traditionally, Sun developed these devices, which were then sold by third-party vendors including Texas Instruments and Fujitsu. Dataquest reported such sales as merchant sales for the third party, even when the third party sold the chips to Sun. More recently, Sun converted its relationship with these semiconductor vendors into a contract manufacturing (that is, a foundry) relationship, in which only Sun has the right to sell the products on the open market. Dataquest was able to reassign Fujitsu's 1996 computational SPARC sales to Sun, but Texas Instruments' sales remain in TI's column for 1996. This situation should be completely resolved before next year's survey. Until then, to measure SPARC's role in the marketplace, one must examine the RISC revenue of Sun, TI, and Fujitsu.

Tables 2-3 and 2-4 summarize the 32-bit CISC computational microprocessor market in terms of revenue and unit shipments over the past two years. Figures 2-5, 2-6, 2-7, and 2-8 present this information graphically. For all intents and purposes, the 32-bit CISC market and the x86 market now are one and the same, following the completion of the conversion of the Macintosh line from its earlier 68K base to the PowerPC. The market grew 34 percent in revenue and 18 percent in terms of units, as average selling prices increased. The ASP increase is all the more impressive given the rapid rate at which Intel lowered microprocessor prices to spur personal computer system demand in a year with little technological innovation.

Table 2-3
32-Bit CISC Computational Microprocessor Vendors by Revenue (Millions of Dollars)

1995 Rank	1996 Rank	Company	1995 Revenue ($M)	1996 Revenue ($M)	1995-1996 Growth (%)	1995 Market Share (%)	1996 Market Share (%)
1	1	Intel	10,365	14,675	42	90	96
2	2	Advanced Micro Devices	743	300	-60	6	2
4	3	IBM	67	174	160	1	1
3	4	Cyrix	205	160	-22	2	1
6	5	Texas Instruments	16	18	13	0	0
8	6	SGS-Thomson	0	8	NA	0	0
5	7	Motorola	45	0	-100	0	0
7	8	United Microelectronics	15	0	-100	0	0
		Total Market	**11,456**	**15,335**	**34**	**100**	**100**

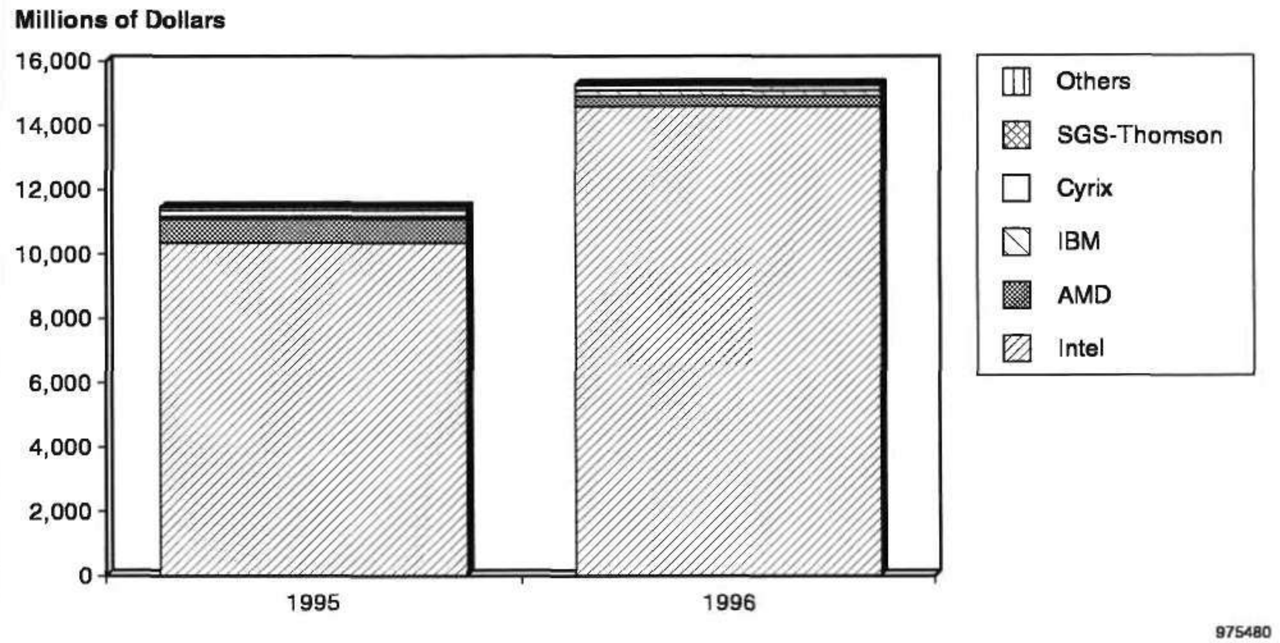
NA = Not available
Source: Dataquest (August 1997)

Table 2-4
32-Bit CISC Computational Microprocessor Vendors by Unit Shipments (Thousands of Units)

1995 Rank	1996 Rank	Company	1995 Units (K)	1996 Units (K)	1995-1996 Growth (%)	1995 Market Share (%)	1996 Market Share (%)
1	1	Intel	50,806	65,000	28	76	83
2	2	Advanced Micro Devices	9,482	8,802	-7	14	11
3	3	Cyrix	3,404	1,920	-44	5	2
4	4	IBM	1,685	1,721	2	3	2
6	5	Texas Instruments	116	820	607	0	1
8	6	SGS-Thomson	0	75	NA	0	0
5	7	Motorola	1,113	0	-100	2	0
7	8	United Microelectronics	10	0	-100	0	0
		Total Market	**66,616**	**78,338**	**18**	**100**	**100**

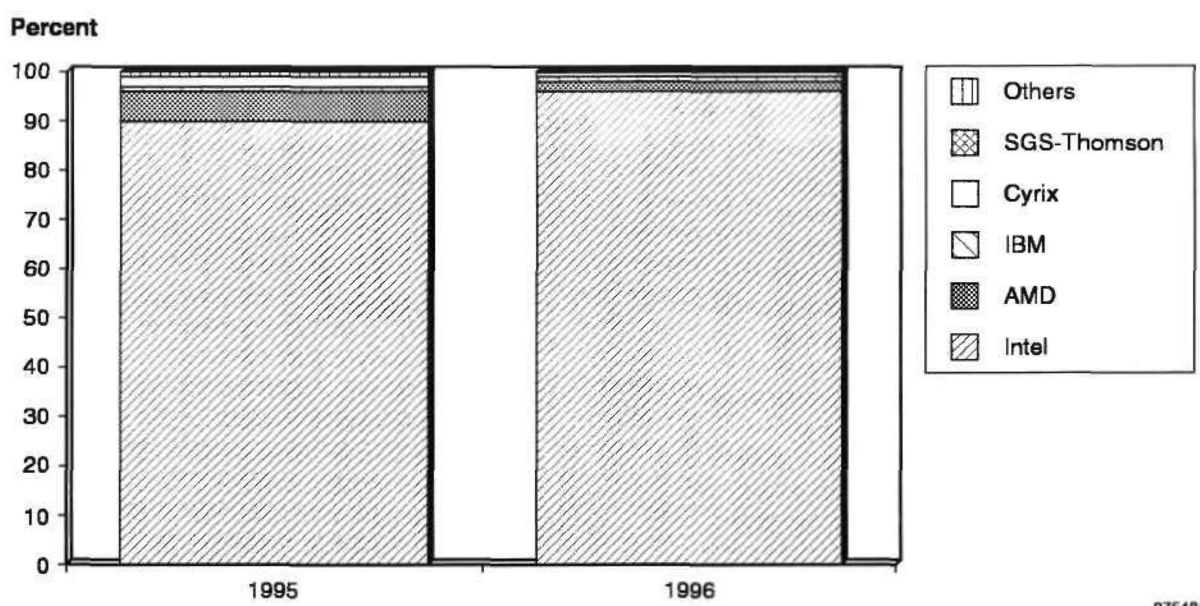
NA = Not available
Source: Dataquest (August 1997)

Figure 2-5
32-Bit CISC Computational Microprocessor Revenue, 1995-1996



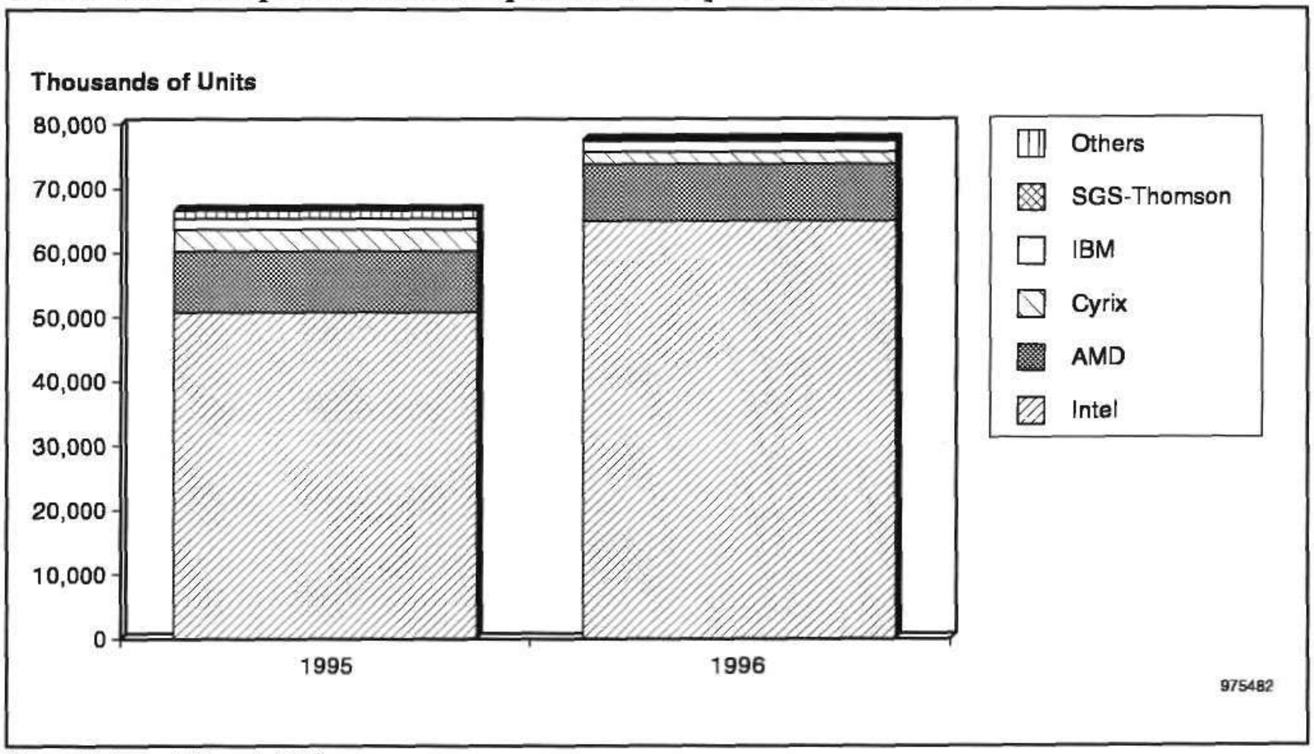
Source: Dataquest (August 1997)

Figure 2-6
32-Bit CISC Computational Microprocessor Market Share by Revenue, 1995-1996



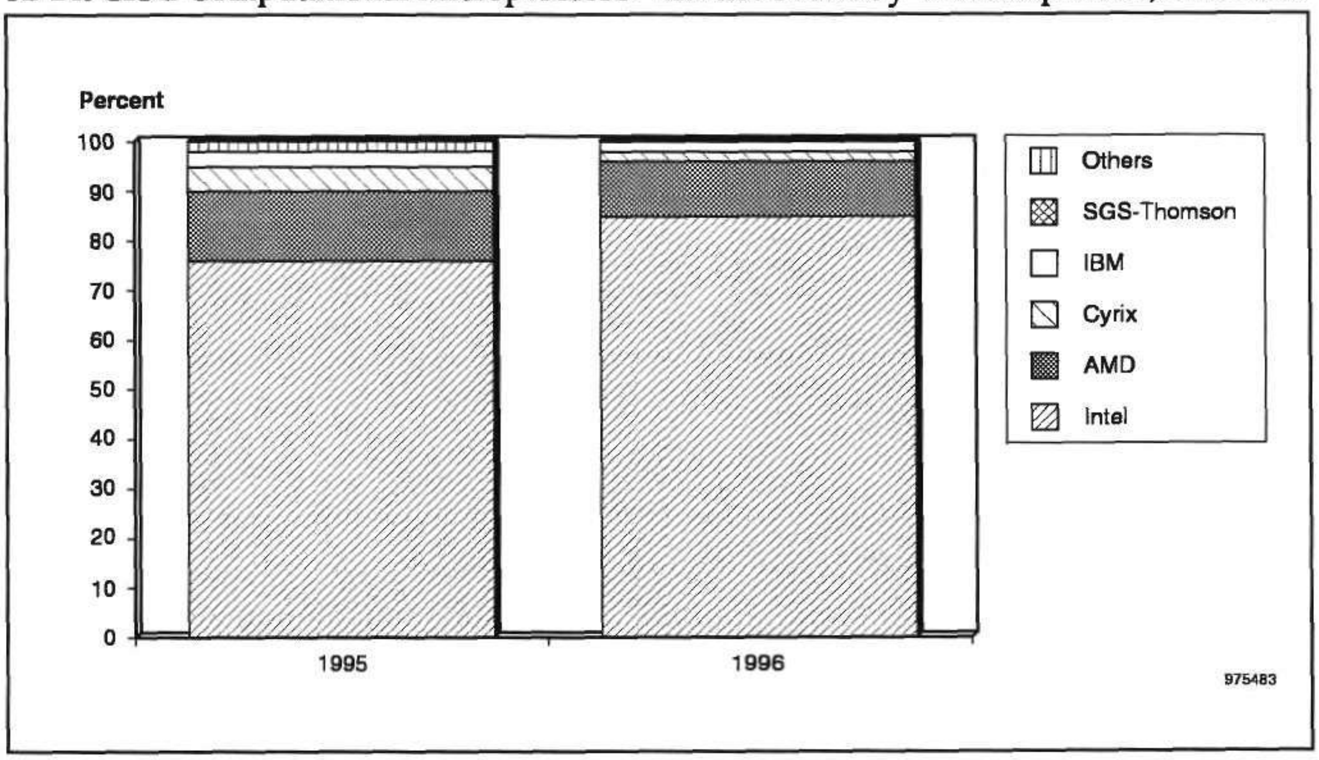
Source: Dataquest (August 1997)

Figure 2-7
32-Bit CISC Computational Microprocessor Shipments, 1995-1996



Source: Dataquest (August 1997)

Figure 2-8
32-Bit CISC Computational Microprocessor Market Share by Unit Shipments, 1995-1996



Source: Dataquest (August 1997)

Intel, from a large base, and IBM, from a small base, both grew faster than the overall market while other vendors grew more slowly and lost share. AMD saw unit volumes and prices fall, driving revenue down 60 percent from the prior year. Cyrix unit volume dropped by 44 percent, but revenue decreased at only half that rate, as the prices it could charge for its fast 6x86 vastly exceeded what it charged for "me-too" 486 technology in the prior year. Cyrix initially set prices for its 6x86 at parity with those charged by Intel for similarly performing devices but quickly retreated from this position after its partner, IBM, adopted a more aggressive pricing strategy. Even then, Cyrix was unable to win any designs with major (Tier 1) vendors and had to sell its product at lower prices to less-well-known vendors.

Tables 2-5 and 2-6 summarize the 32/64-bit RISC computational microprocessor market in terms of revenue and unit shipments over the past two years. Figures 2-9, 2-10, 2-11, and 2-12 present this information graphically. This market grew 32 percent as measured by dollars, but only 12 percent in terms of units. Unlike the much larger and highly concentrated CISC market, the RISC market remains fragmented in terms of both architectures and vendors. In 1996, PowerPC, PA-RISC, and Alpha all outgrew the market in terms of units, while SPARC held its own. The SGI/MIPS architecture dramatically lost share in computational markets while dramatically gaining share in the embedded arena, where it dominates. Comparisons in year-to-year revenue changes in this segment are complicated by the lack of data for Digital in 1995 and Hewlett-Packard in both years. With the partial data at hand, Dataquest concludes that SPARC and MIPS revenue increased, driven by dramatic ASP growth, while PowerPC revenue decreased, driven by rapidly eroding ASPs as Apple played Motorola and IBM off one another.

Table 2-5
32/64-Bit RISC Computational Microprocessor Vendors by Revenue (Millions of Dollars)

1995 Rank	1996 Rank	Company	1995 Revenue ($M)	1996 Revenue ($M)	1995-1996 Growth (%)	1995 Market Share (%)	1996 Market Share (%)
1	1	IBM	525	439	-16	52	33
7	2	Digital	0	235	NA	0	18
3	3	Motorola	176	209	19	18	16
2	4	Texas Instruments	180	195	8	18	15
8	5	Sun Microsystems	0	170	NA	0	13
5	6	NEC	39	40	3	4	3
6	7	Toshiba	32	32	0	3	2
9	8	Integrated Device Technology	0	3	NA	0	0
4	9	Fujitsu	51	0	-100	5	0
10	10	Hewlett-Packard	0	0	NA	0	0
		Total Market	**1,003**	**1,323**	**32**	**100**	**100**

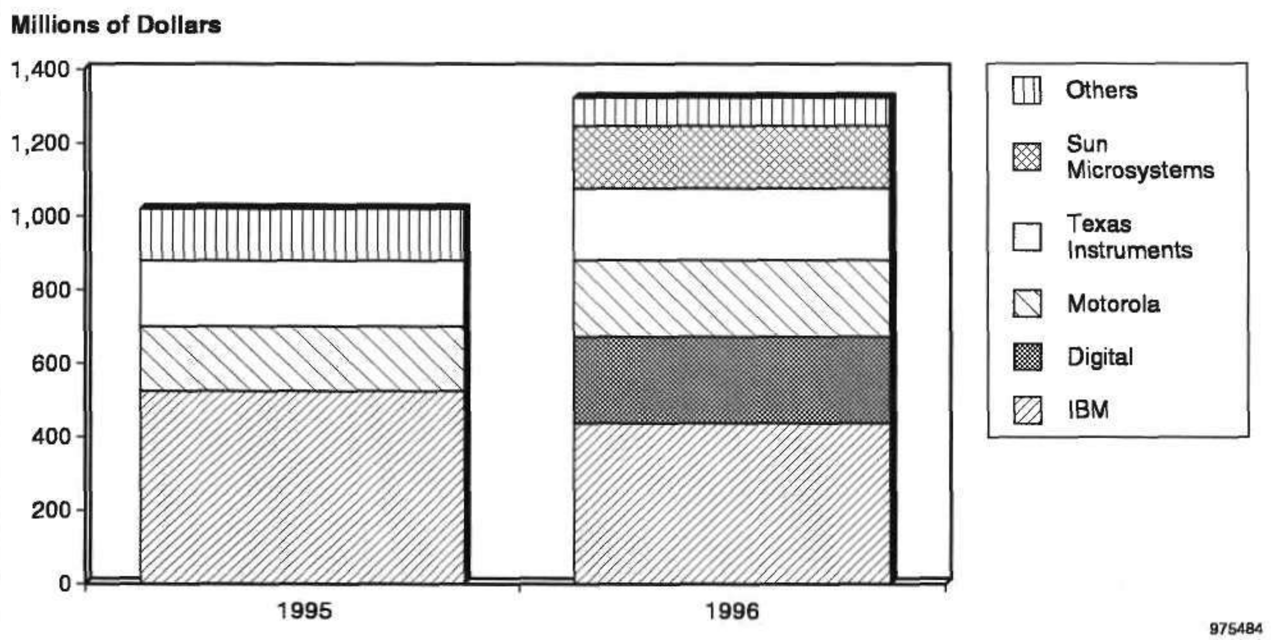
NA = Not available
Source: Dataquest (August 1997)

Table 2-6
32-/64-Bit RISC Computational Microprocessor Vendor Shipments (Thousands of Units)

1995 Rank	1996 Rank	Company	1995 Units (K)	1996 Units (K)	1995-1996 Growth (%)	1995 Market Share (%)	1996 Market Share (%)
1	1	IBM	2,121	2,510	18	43	45
2	3	Motorola	1,250	1,507	21	25	27
10	5	Sun Microsystems	0	525	NA	0	9
6	10	Hewlett-Packard	225	300	33	5	5
7	2	Digital	165	300	82	3	5
3	4	Texas Instruments	445	279	-37	9	5
5	6	NEC	268	100	-63	5	2
9	7	Toshiba	105	40	-62	2	1
8	8	Integrated Device Technology	125	10	-92	3	0
4	9	Fujitsu	270	0	-100	5	0
		Total Market	**4,974**	**5,571**	**12**	**100**	**100**

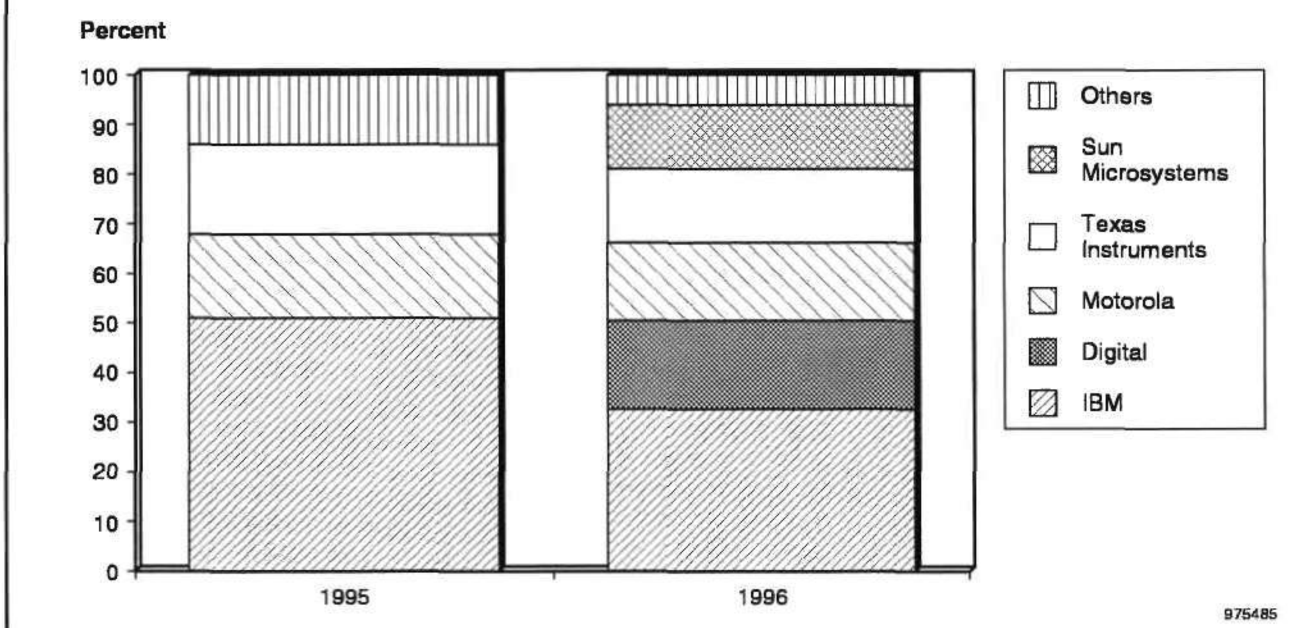
NA = Not available
Source: Dataquest (August 1997)

Figure 2-9
32-/64-Bit RISC Computational Microprocessor Revenue, 1995-1996



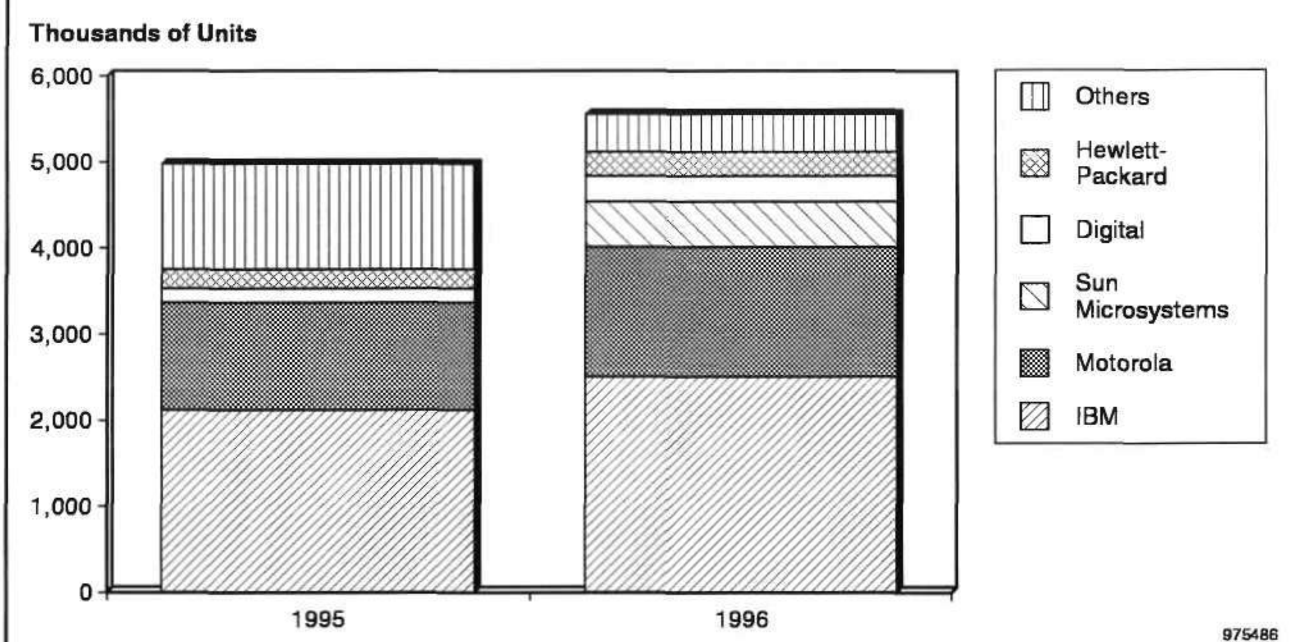
Source: Dataquest (August 1997)

Figure 2-10
32-/64-Bit RISC Computational Microprocessor Market Share by Revenue, 1995-1996



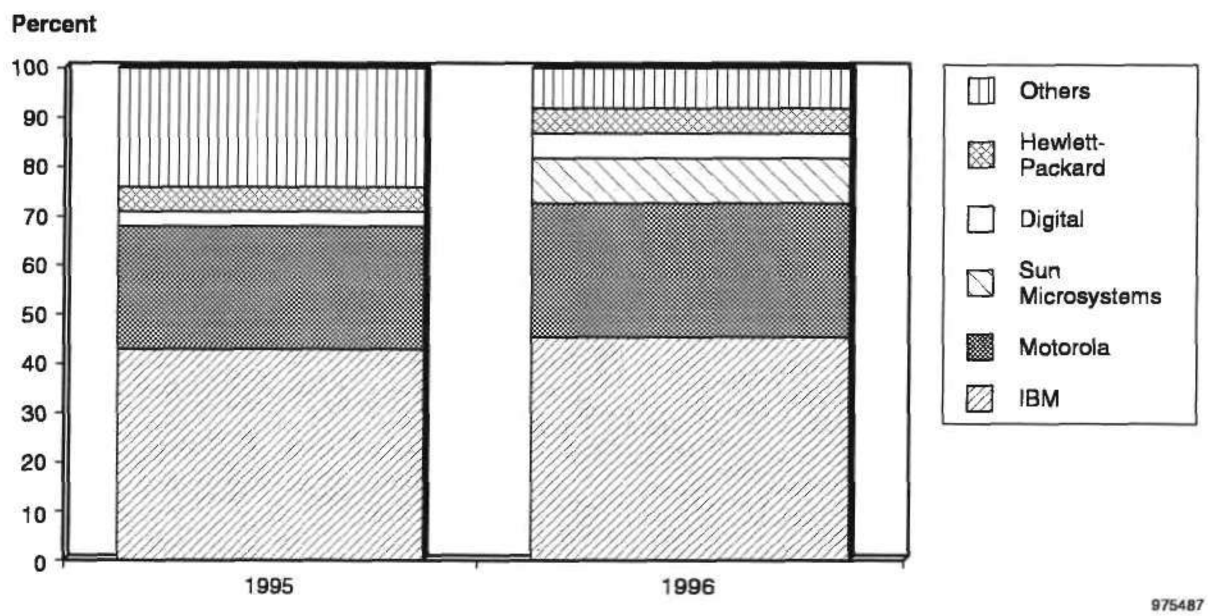
Source: Dataquest (August 1997)

Figure 2-11
32-/64-Bit RISC Computational Microprocessor Shipments, 1995-1996



Source: Dataquest (August 1997)

Figure 2-12
32-/64-Bit RISC Computational Microprocessor Market Share by Unit Shipments, 1995-1996



Source: Dataquest (August 1997)

Analysis of Computational Microprocessor Vendor Performance

Intel

Intel described itself as "hitting on all cylinders" as its processor sales grew 42 percent to $14.7 billion on a 28 percent increase in unit shipments to 65 million processors. Along the way, it managed to collect 96 cents out of every dollar customers spent for personal computer microprocessors in 1996, up from 90 cents in the prior year. The company slowly ramped its Pentium Pro line, and by the fourth quarter Intel found itself production constrained for these expensive parts. Given the dearth of new technology to excite buyers, Intel aggressively drove price and performance parameters, moving the 133-MHz Pentium processor from the high end of its line at the end of 1995 to the entry level just 12 months later. This performance increase, when combined with price decreases for DRAM and CD-ROM, maintained a 17 percent unit growth in the market and helped make PC vendors very successful, as long as they could manage the logistics and their expenses well. Dataquest expects that 1997 will prove a more challenging year for Intel as it begins the massive shift to Pentium II and faces revitalized competition from AMD and Cyrix later in the year.

AMD

AMD watched as the 486 market evaporated before its K5 microprocessor could take up the slack, losing market share, unit share, and real money as a consequence. The company provided an all-too-realistic display of the impact an 18-month schedule slip can have in a world of 36-month product cycles. The company wisely placed its emphasis on integrating its

NexGen acquisition and readying the K6 for market, a task that required close cooperation between its development and manufacturing organizations. By year's end, the company had achieved competitive low-end performance with its K5 and could demonstrate K6 devices with impressive clock speeds. AMD needs to continue executing in this new, more precise manner if it is to avoid a repetition of the disasters of 1996.

Cyrix

Like AMD, Cyrix had a bad year as it sought first to stabilize and then to sell its 6x86 microprocessor. Cyrix flirted briefly with the notion of charging Intel-style prices for Intel-style performance, but it discovered it had to give prospective purchasers a strong incentive to stray from "Intel Inside." Following the laws of classic economics, volume picked up as prices fell, and by year's end Cyrix was selling almost as many chips as it (or, more accurately, IBM) could manufacture. The loss of momentum proved fatal to CEO Jerry Rogers and almost sank the company as inventory built while cash shrank. Newly arrived CFO and acting CEO Jay Swent managed to put a tourniquet on the company's losses and get the company prepared to launch its low-cost MediaGX processor and 6x86MX processor early in 1997. The recent announcement that Compaq Computer will market low-cost MediaGX-based systems will hopefully usher in a new, more profitable era for the company.

IBM

IBM, the only vendor to participate in both the 32-bit RISC and the 32-bit CISC arenas, had vastly different experiences in each segment. Its PowerPC continued to lead the RISC market in terms of revenue and units, but the company saw revenue decrease in response to declining ASPs. In the CISC segment, where IBM manufactures most of the Cyrix-designed chips that are sold under the IBM and Cyrix brands, IBM's revenue grew rapidly on flat unit volumes—selling prices increased dramatically for the 6x86 over the 486-based products offered in the prior year. The IBM PC Company was one of the few major system vendors to include some non-Intel processors in its products, although such products tended to be destined for offshore markets where Intel's branding programs present less of a sales issue for a system vendor.

Motorola

Until this year, Motorola derived computational microprocessor revenue from both its 68K CISC line and its PowerPC RISC offerings. In 1996, Motorola's 68K was sold only into embedded markets and had no presence whatsoever in the computational segment. In its PowerPC business, Motorola maintained a consistent ASP on a year-to-year basis and managed to grow both unit volumes and revenue by about 20 percent.

Sun

With its UltraSPARC offering, unveiled late in 1995, Sun once again regained a measure of respectability with regard to microprocessor (and workstation) performance. UltraSPARC also enabled Sun to collect a reasonable tariff for its products, which translated into a 58 percent increase in SPARC revenue to $365 million on a 12 percent increase in unit volume to 804,000 units. Because of the previously mentioned problem of matching SPARC computational revenue with the appropriate vendors in 1995 and 1996, Dataquest bases these comparisons on the total RISC revenue and shipments for Sun, Fujitsu, and TI.

Chapter 3
Computational Microprocessor Forecast, 1997-2001

Can Intel Retain the Market Share Gains It Achieved in 1996?

Dataquest anticipates that the market for computational microprocessors will grow at a CAGR of 17 percent from 83.3 million units in 1996 to almost twice that number, 173 million, in the year 2001. Revenue for the segment will grow even more rapidly at 21 percent, from $17 billion in 1996 to $40.6 billion in the year 2001. (This forecast, like all long-term Dataquest forecasts, presumes that the world does not end on January 1, 2000, as a result of the infamous millennium bug.)

Overall Computational Microprocessor Forecast, 1997-2001

Dataquest bases its computational microprocessor forecast on the system-level forecasts produced by its Computer Systems and Peripherals group, which separately researches personal computer, workstation, and server markets and maintains forecasts for each market. Dataquest's Client/Server Computing program tracks proprietary mainframes, midrange servers, and personal computer servers. The advanced Desktops and Workstations program tracks both proprietary RISC workstations from traditional vendors and the new class of x86-based workstations running Windows NT, sold as workstations rather than as personal computers. The Personal Computers program monitors and forecasts personal computers of all sizes and shapes, including PCs marketed as servers. The Personal Computer Semiconductors and Applications program incorporates all these forecasts, eliminates some double-counting that occurs across these services, and uses proprietary models to translate end-unit system demand into unit microprocessor demand and vendor revenue. Later in this report, Dataquest further analyzes the composition of the x86 segment that includes the bulk of all computational microprocessor unit shipments and revenue.

Table 3-1 contains a highly condensed summary of the above-mentioned system forecasts. Table 3-2 and Figure 3-1 display the computational microprocessor demand needed to meet the forecast system demand. Table 3-3 and Figure 3-2 display the revenue generated by the sale of these microprocessors, using average selling price forecasts included in Table 3-4.

Table 3-1
Computational Microprocessor Consumption by Product Category, 1995-2001 (Millions of Dollars)

	1995	1996	1997	1998	1999	2000	2001	1995-2000 CAGR (%)
Server—Proprietary	23	38	59	84	117	162	203	48
Server—RISC	637	712	815	935	1,077	1,241	1,417	14
Server—x86	308	564	929	1,411	1,974	2,615	2,833	53
Workstation—RISC	841	829	855	923	994	1,070	1,125	5
Workstation—x86	214	604	816	1,228	1,719	2,200	3,506	59
PC—x86	64,980	76,432	88,256	102,189	117,877	136,010	156,470	16
PC—68K	1,680	169	12	-	-	-	-	NA
PC—RISC	3,236	3,923	4,619	5,609	6,012	6,592	7,522	15
Total	**71,921**	**83,271**	**96,361**	**112,379**	**129,770**	**149,890**	**173,077**	**16**

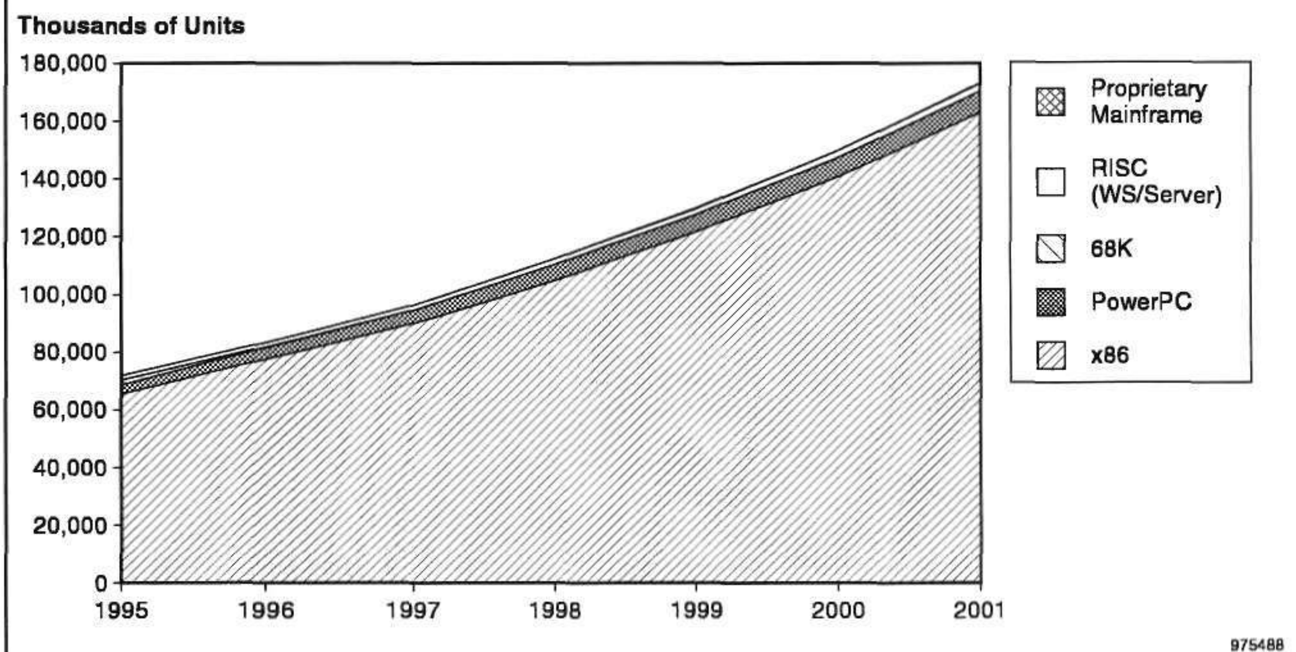
NA = Not available
Source: Dataquest (August 1997)

Table 3-2
Forecast of Computational Microprocessor Shipments, 1995-2001 (Thousands of Units)

	1995	1996	1997	1998	1999	2000	2001	1995-2000 CAGR (%)
x86	65,503	77,600	90,001	104,828	121,570	140,825	162,810	17
PowerPC	3,236	3,923	4,619	5,609	6,012	6,592	7,522	15
68K	1,680	169	12	-	-	-	-	NA
RISC (WS/Server)	1,479	1,541	1,670	1,858	2,071	2,310	2,543	9
Prop. Mainframe	23	38	59	84	117	162	203	48
Total	**71,921**	**83,271**	**96,361**	**112,379**	**129,770**	**149,890**	**173,077**	**16**

NA = Not available
Source: Dataquest (August 1997)

Figure 3-1
Forecast of Computational Microprocessor Shipments, 1995-2001



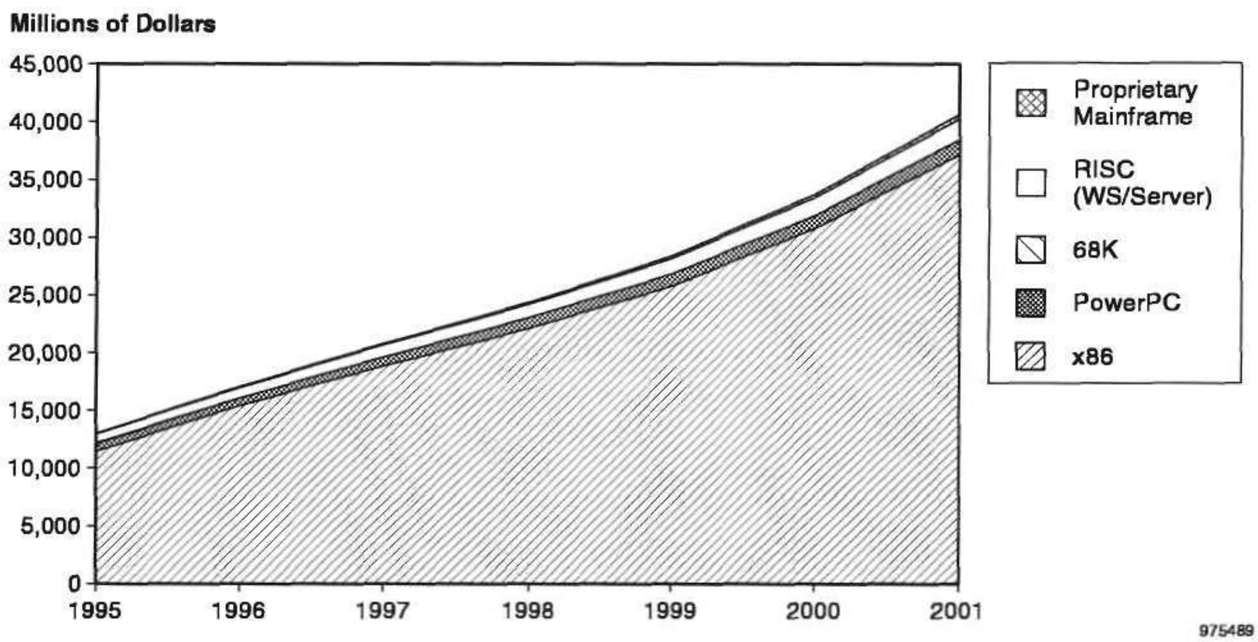
Source: Dataquest (August 1997)

Table 3-3
Forecast of Computational Microprocessor Revenue, 1995-2001 (Millions of Dollars)

	1995	1996	1997	1998	1999	2000	2001	1995-2000 CAGR (%)
x86	11,443	15,412	18,857	22,102	25,797	30,743	37,122	22
PowerPC	673	632	774	946	1,021	1,151	1,372	11
68K	68	-	-	-	-	-	-	
RISC (WS/Server)	775	918	1,050	1,175	1,319	1,513	1,739	14
Prop. Mainframe	46	77	119	168	234	324	406	48
Total	13,005	17,038	20,800	24,391	28,370	33,732	40,639	21

Source: Dataquest (August 1997)

Figure 3-2
Forecast of Computational Microprocessor Revenue, 1995-2001



Source: Dataquest (August 1997)

Table 3-4
Forecast of Computational Microprocessor ASPs, 1995-2001 (Dollars)

	1995	1996	1997	1998	1999	2000	2001	1995-2000 CAGR (%)
x86	175	199	210	211	212	218	228	5
PowerPC	208	161	168	169	170	175	182	-3
68K	41	-	-	-	-	-	-	
RISC (WS/Server)	524	596	629	633	637	655	684	5
Prop. Mainframe	2,000	2,000	2,000	2,000	2,000	2,000	2,000	0
All Computational MPU ASP	181	205	216	217	219	225	235	4

Source: Dataquest (August 1997)

x86 Computational Microprocessor Forecast, 1997-2001

Dataquest forecasts that the market for x86 microprocessors used in personal computers, workstations, and servers will grow from 77.6 million units in 1996 to 163 million units in the year 2001. The revenue associated with these processors will grow from $15.4 billion to $37.1 billion over the same period.

The Dataquest Personal Computers Worldwide program tracks and forecasts personal computer shipments by system generation. Until recently, a simple and straightforward mapping between microprocessor generations and PC generations could be used, but the vagaries of clever marketers and clever lawyers force Dataquest to take a more complicated approach in its latest forecasts. The clever marketers named their products so as to suggest they were one generation more advanced than their architecture would suggest; thus, there are the AMD 5X86 and the Cyrix 5x86, both of which provided high-end 486 performance and fit into 486 CPU sockets (Socket 3). Dataquest counts systems containing these devices as fourth-generation systems and tallies the processors as fourth-generation microprocessors.

To further complicate matters, Cyrix named its Pentium-equivalent processor the "6x86," suggesting that it corresponds in meaningful ways to Intel's Pentium Pro line. Dataquest assumes that if it's priced like a Pentium, performs like a Pentium, and plugs into a Pentium socket, then it should be classified as a fifth-generation part, and Dataquest has proceeded on this basis.

To make things even more complicated, AMD and Cyrix have positioned their parts (the K6 and 6x86MX, respectively) that compete with Intel's Pentium II and Pentium Pro offerings as sixth-generation parts, although they plug into Pentium-style sockets (Socket 7). The Dataquest Semiconductors research group assumes that if it's priced like a Pentium II and performs like a Pentium II (which several magazine reviews have suggested), then it should be classified like a Pentium II, even if it plugs into a Socket 7. Dataquest has therefore classified these devices as members of the sixth generation of computational microprocessors. The Dataquest Personal Computers Worldwide program measures the generation of a personal computer based on its motherboard and thus classifies all Socket 7 PCs as fifth-generation systems, even if they contain AMD K6 or Cyrix 6x86MX processors.

Alert users may notice that Dataquest's forecasts for personal computer systems and forecasts for microprocessors may not always line up precisely when cut by generation. Dataquest does reflect these differences in its proprietary forecasting models, thereby ensuring that every forecast system will have an appropriate microprocessor assigned to it.

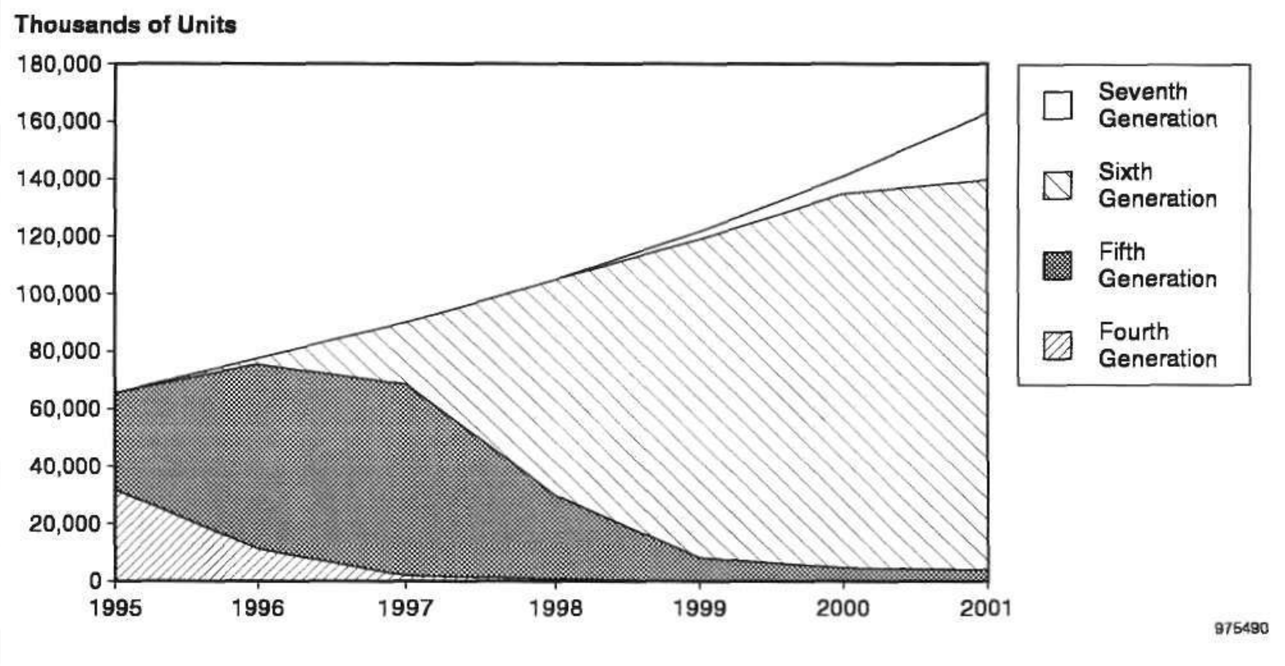
Table 3-5 and Figure 3-3 provide Dataquest's x86 forecast by processor generation. Table 3-6 and Figure 3-4 translate these unit shipments into equivalent revenue, based on the average selling price assumptions included in Table 3-7 and Figure 3-5.

Table 3-5
Forecast of x86 Computational Microprocessor Shipments by Generation, 1995-2001 (Thousands of Units)

	1995	1996	1997	1998	1999	2000	2001
Fourth-Generation x86	31,804	11,400	2,106	786	0	0	0
Fifth-Generation x86	33,599	64,200	66,592	29,064	8,267	4,665	4,070
Sixth-Generation x86	100	2,000	21,303	74,978	110,759	130,184	135,539
Seventh-Generation x86	0	0	0	0	2,544	5,976	23,200
Total	**65,503**	**77,600**	**90,001**	**104,828**	**121,570**	**140,825**	**162,810**

Source: Dataquest (August 1997)

Figure 3-3
x86 Computational Microprocessor Shipments by Generation, 1995-2001



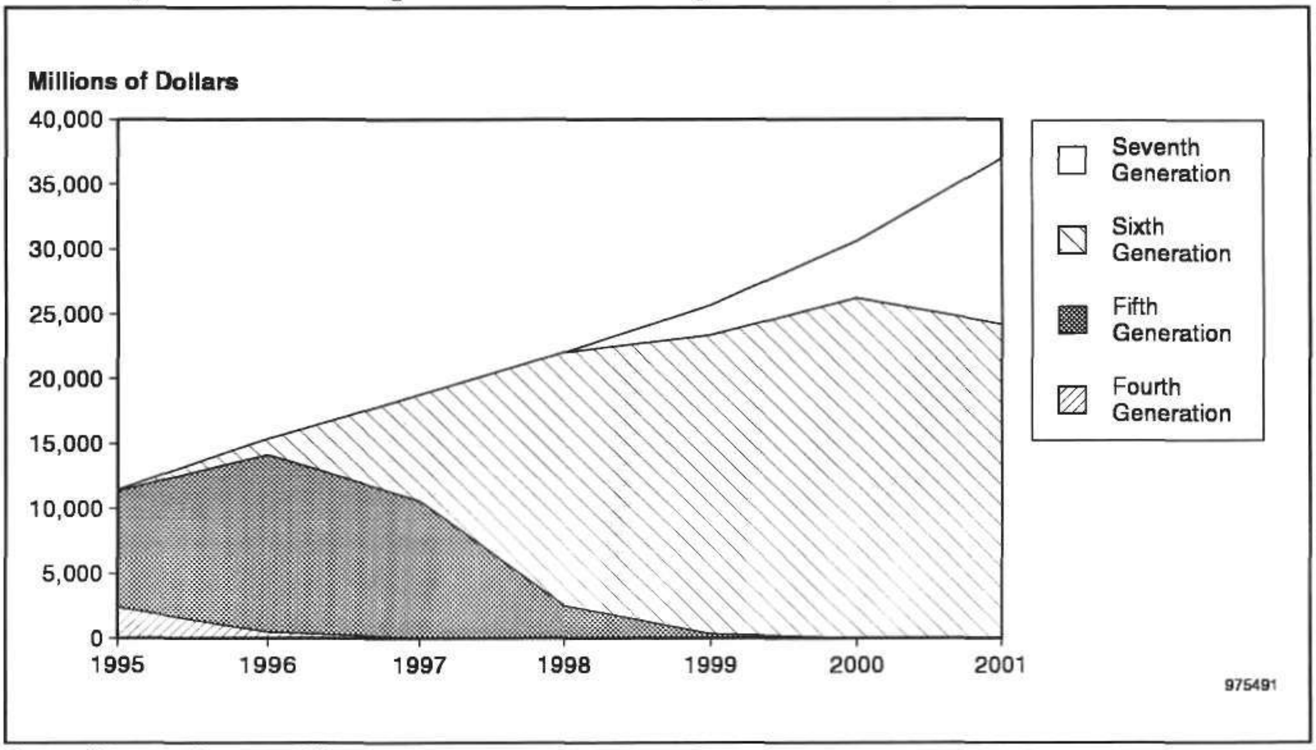
Source: Dataquest (August 1997)

Table 3-6
Forecast of x86 Computational Microprocessor Revenue by Generation, 1995-2001 (Millions of Dollars)

	1995	1996	1997	1998	1999	2000	2001
Fourth-Generation x86	2,433	518	74	25	0	0	0
Fifth-Generation x86	8,910	13,629	10,558	2,565	357	0	0
Sixth-Generation x86	90	1,250	8,158	19,434	23,035	26,213	24,191
Seventh-Generation x86	0	0	0	0	2,313	4,425	12,809
Others	9	15	68	79	91	106	122
Total	11,443	15,412	18,857	22,102	25,797	30,743	37,122

Source: Dataquest (August 1997)

Figure 3-4
x86 Computational Microprocessor Revenue by Generation, 1995-2001



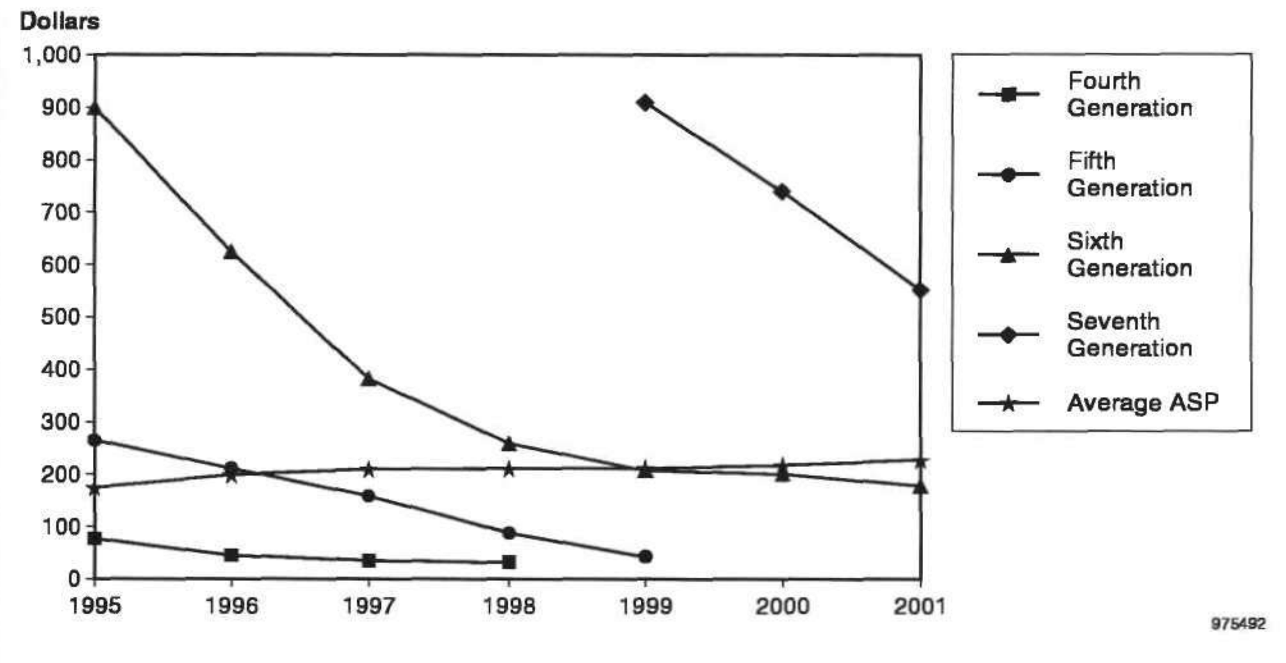
Source: Dataquest (August 1997)

Table 3-7
Forecast of x86 Computational Microprocessor ASPs by Generation, 1995-2001 (Dollars)

	1995	1996	1997	1998	1999	2000	2001
Fourth-Generation x86	77	45	35	32	-	-	-
Fifth-Generation x86	265	212	159	88	43	0	-
Sixth-Generation x86	900	625	383	259	208	201	178
Seventh-Generation x86	-	-	-	-	909	740	552
Average ASP	175	199	210	211	212	218	228

Source: Dataquest (August 1997)

Figure 3-5
x86 Computational Microprocessor ASP by Generation, 1995-2002 (Dollars)



Source: Dataquest (August 1997)

Although Dataquest normally forecasts markets rather than vendor market shares, the unique situation of Intel's enormous market share forces us to make an exception here. Tables 3-8 and 3-9 apportion the shipment forecast (presented above) into "Intel" and "non-Intel" (clone) segments. Figures 3-6 and 3-7 present these shipment forecasts by vendor and by generation, respectively. Tables 3-10 and 3-11 translate these shipments into revenue based on ASP assumptions set forth in Table 3-12 (for Intel) and Table 3-13 (for other vendors). Figures 3-8 and 3-9 present these revenue forecasts by vendor and by generation, respectively.

Table 3-8
Forecast of Intel x86 Computational Microprocessor Shipments by Generation, 1995-2001 (Thousands of Units)

	1995	1996	1997	1998	1999	2000	2001
Fourth-Generation x86	17,157	3,000	0	0	0	0	0
Fifth-Generation x86	33,549	60,000	56,881	23,979	4,468	0	0
Sixth-Generation x86	100	2,000	14,220	55,952	82,652	94,652	95,488
Seventh-Generation x86	0	0	0	0	2,234	4,982	16,851
Intel Total	**50,806**	**65,000**	**71,101**	**79,931**	**89,354**	**99,634**	**112,339**

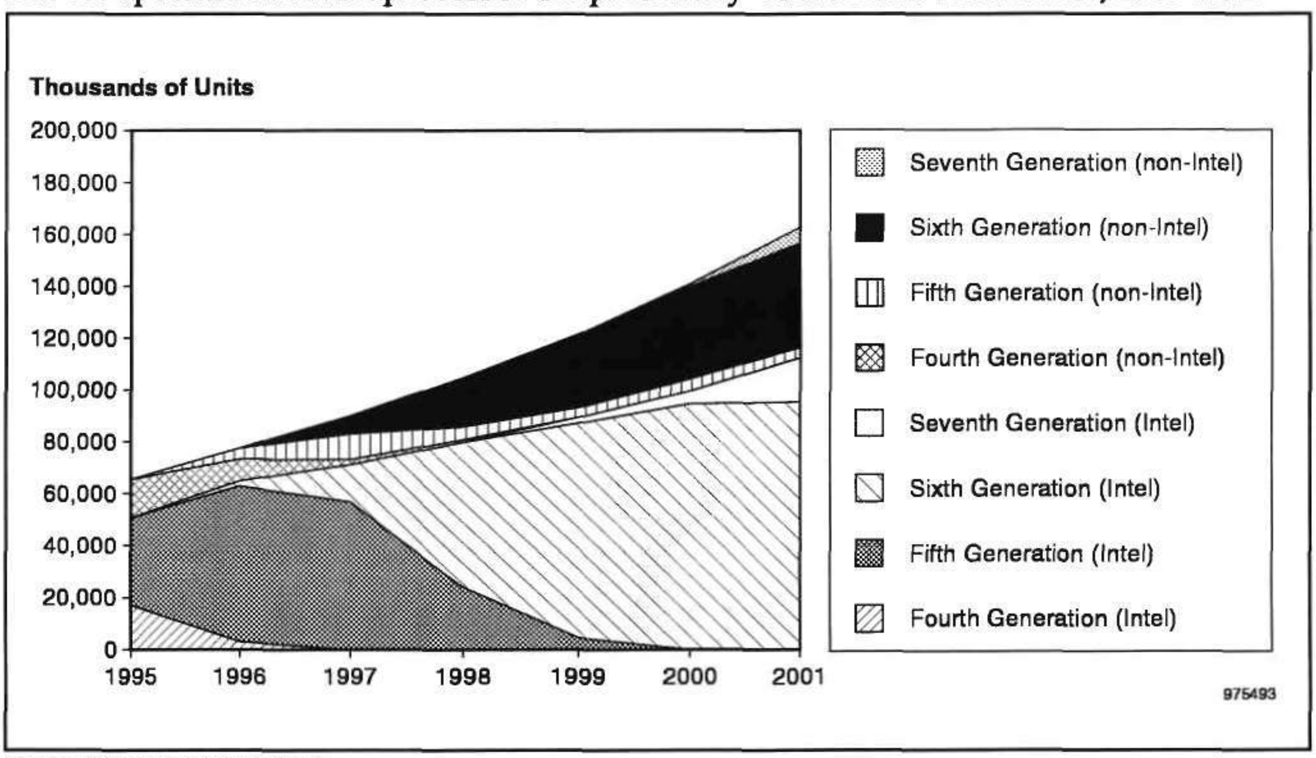
Source: Dataquest (August 1997)

Table 3-9
Forecast of Non-Intel x86 Computational Microprocessor Shipments by Generation, 1995-2001 (Thousands of Units)

	1995	1996	1997	1998	1999	2000	2001
Fourth-Generation x86	14,647	8,400	2,106	786	0	0	0
Fifth-Generation x86	50	4,200	9,711	5,084	3,799	4,665	4,070
Sixth-Generation x86	0	0	7,083	19,026	28,107	35,532	40,051
Seventh-Generation x86	0	0	0	0	310	995	6,350
Non-Intel Total	**14,697**	**12,600**	**18,900**	**24,897**	**32,216**	**41,191**	**50,471**

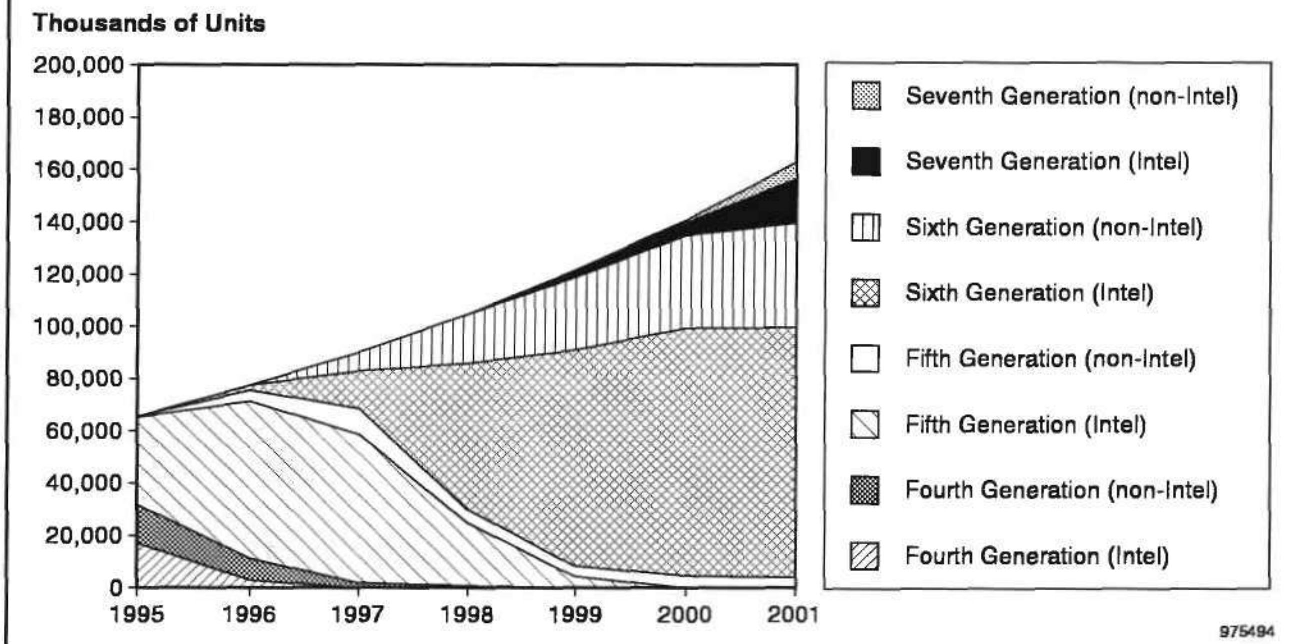
Source: Dataquest (August 1997)

Figure 3-6
x86 Computational Microprocessor Shipments by Vendor and Generation, 1995-2001



Source: Dataquest (August 1997)

Figure 3-7
x86 Computational Microprocessor Shipments by Generation and Vendor, 1995-2001



Source: Dataquest (August 1997)

Table 3-10
Forecast of Intel's x86 Computational Microprocessor Revenue by Generation, 1995-2001 (Millions of Dollars)

	1995	1996	1997	1998	1999	2000	2001
Fourth-Generation x86	1,407	225	0	0	0	0	0
Fifth-Generation x86	8,890	13,200	9,954	2,518	357	0	0
Sixth-Generation x86	90	1,250	6,399	16,226	19,010	21,297	19,336
Seventh-Generation x86	0	0	0	0	2,122	3,861	10,110
Intel Total	**10,387**	**14,675**	**16,353**	**18,744**	**21,490**	**25,158**	**29,447**

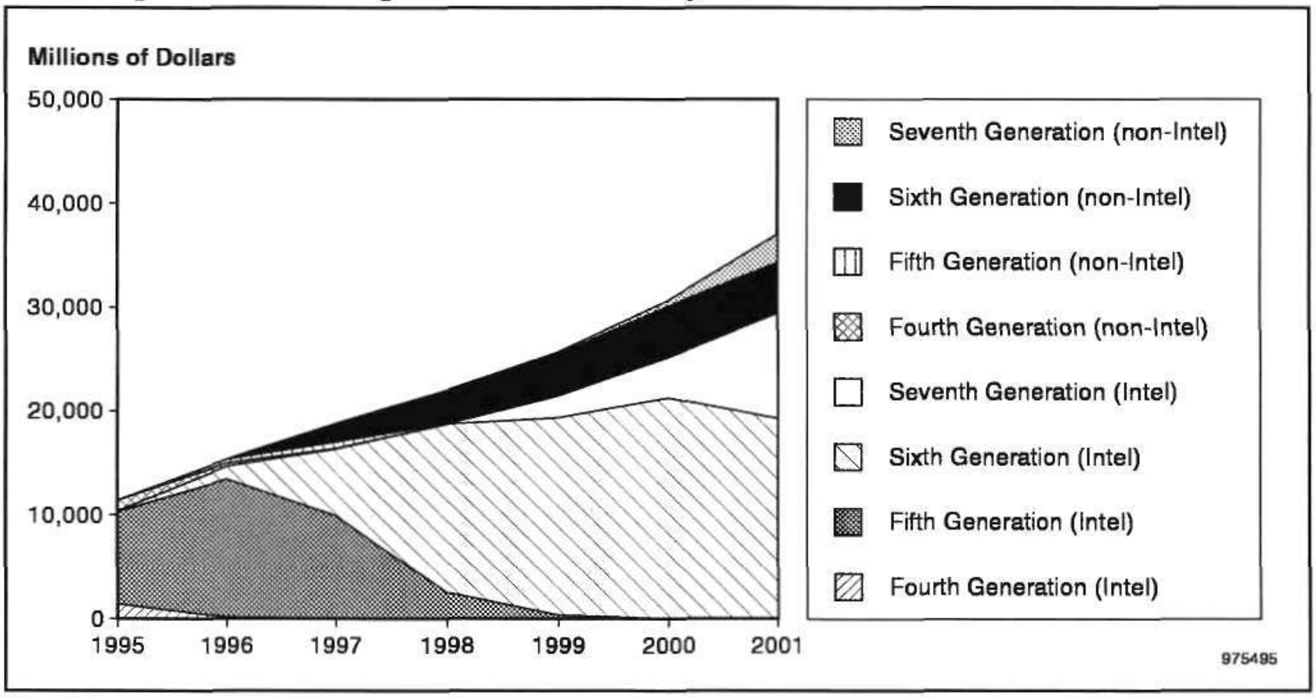
Source: Dataquest (August 1997)

Table 3-11
Forecast of Non-Intel x86 Computational Microprocessor Revenue by Generation, 1995-2001 (Millions of Dollars)

	1995	1996	1997	1998	1999	2000	2001
Fourth-Generation x86	1,026	293	74	25	0	0	0
Fifth-Generation x86	20	429	604	47	0	0	0
Sixth-Generation x86	0	0	1,759	3,208	4,025	4,916	4,855
Seventh-Generation x86	0	0	0	0	191	564	2,699
Non-Intel Total	**1,046**	**722**	**2,437**	**3,280**	**4,216**	**5,480**	**7,554**

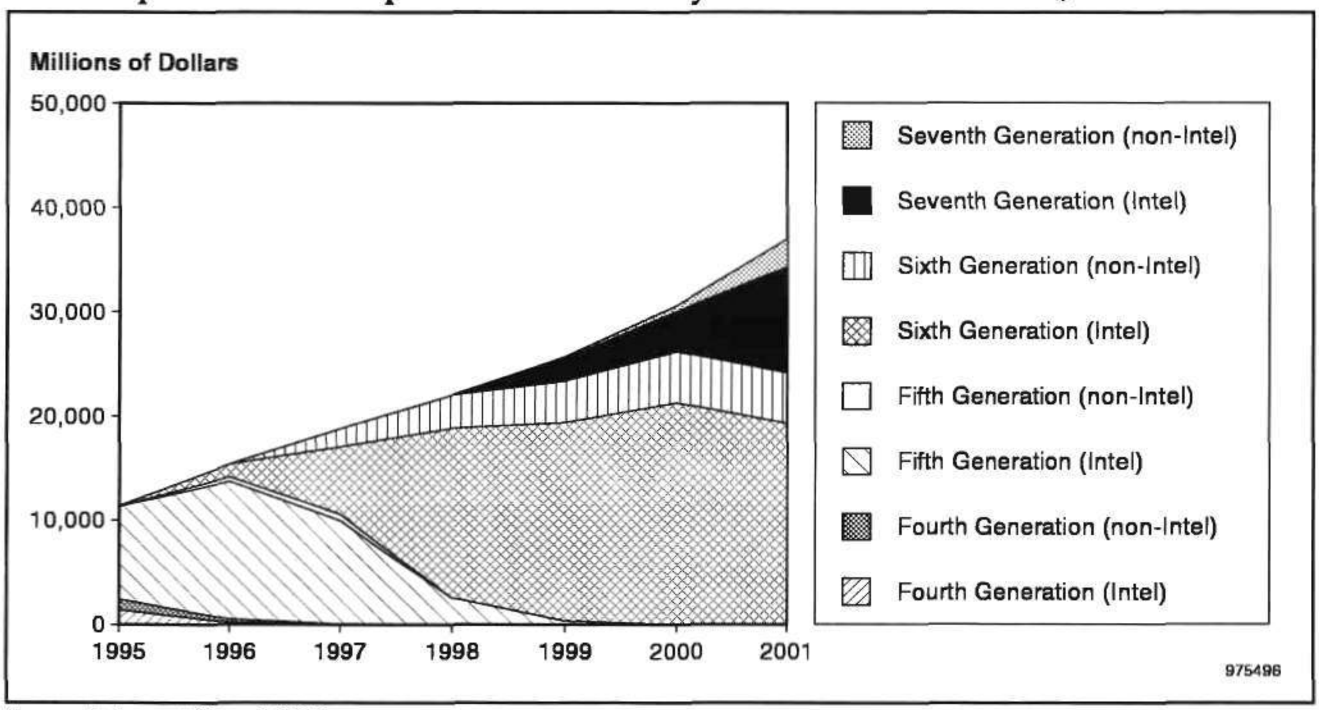
Source: Dataquest (August 1997)

Figure 3-8
x86 Computational Microprocessor Revenue by Vendor and Generation, 1995-2001



Source: Dataquest (August 1997)

Figure 3-9
x86 Computational Microprocessor Revenue by Generation and Vendor, 1995-2001



Source: Dataquest (August 1997)

Dataquest's model projects that following a dismal showing in 1996, when non-Intel x86 processors captured only 5 percent of x86 revenue and

Table 3-12
Forecast of Intel x86 Computational Microprocessor ASP by Generation, 1995-2001 (Dollars)

	1995	1996	1997	1998	1999	2000	2001
Fourth-Generation x86	82	75	-	-	-	-	-
Fifth-Generation x86	265	220	175	105	80	56	-
Sixth-Generation x86	900	625	450	290	230	225	203
Seventh-Generation x86	-	-	-	-	950	775	600
Average Intel x86 ASP	204	226	230	235	241	253	262

Source: Dataquest (August 1997)

Table 3-13
Forecast of Non-Intel x86 Computational Microprocessor ASP by Generation, 1995-2001 (Dollars)

	1995	1996	1997	1998	1999	2000	2001
Fourth-Generation x86	70	35	35	32	-	-	-
Fifth-Generation x86	400	102	62	9	0	-	-
Sixth-Generation x86	-	-	248	169	143	138	121
Seventh-Generation x86	-	-	-	-	617	567	425
Average Non-Intel x86 ASP	71	57	129	132	131	133	150

Source: Dataquest (August 1997)

16 percent of unit shipments, these products will rebound and account for 13 percent of all revenue ($2.5 billion) and 21 percent of all unit shipments (18.9 million units) in 1997. By the year 2000, the non-Intel component of this market will capture 18 percent of all revenue ($5.5 billion) and 29 percent of all unit shipments (41 million units). We anticipate that Intel will only grudgingly cede this market share, and Intel's competitors will be forced to sell their wares at a steep discount to the prices offered by Intel. The most likely scenario sees Intel abandoning the sub-$100 processor market to its competitors, who can then drive their own growth based on the increasing market for sub-$1,000 personal computers. Tables 3-14, 3-15, and 3-16 summarize the limited share erosion we anticipate Intel to experience over the next five years, and the discount from Intel's prices that its competitors must offer in order to make these gains. Figure 3-10 displays our projections for Intel, non-Intel, and overall ASP over the period.

Table 3-14
Comparison of x86 Computational Microprocessor Revenue for Intel and Others, 1995-2001 (Millions of Dollars)

	1995	1996	1997	1998	1999	2000	2001
Intel	10,387	14,675	16,353	18,744	21,490	25,158	29,447
Non-Intel	1,056	737	2,504	3,358	4,307	5,586	7,676
Market Total	11,443	15,412	18,857	22,102	25,797	30,743	37,122
Intel Market Share (Percent)	91	95	87	85	83	82	79

Source: Dataquest (August 1997)

Table 3-15
Comparison of x86 Computational Microprocessor Shipments for Intel and Others, 1995-2001 (Thousands of Units)

	1995	1996	1997	1998	1999	2000	2001
Intel	50,806	65,000	71,101	79,931	89,354	99,634	112,339
Non-Intel	14,697	12,600	18,900	24,897	32,216	41,191	50,471
Market Total	65,503	77,600	90,001	104,828	121,570	140,825	162,810
Intel Market Share (Percent)	78	84	79	76	74	71	69

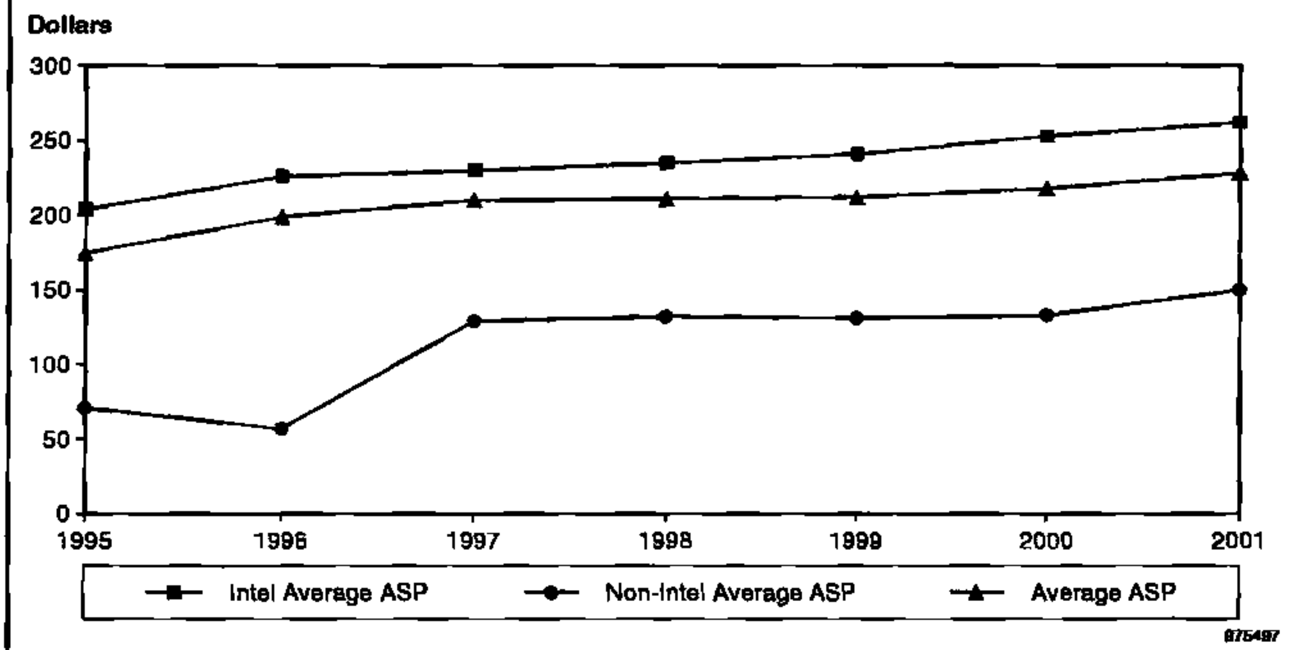
Source: Dataquest (August 1997)

Table 3-16
Comparison of x86 Computational Microprocessor ASP for Intel and Others, 1995-2001 (Dollars)

	1995	1996	1997	1998	1999	2000	2001
Intel	204	226	230	235	241	253	262
Non-Intel	71	57	129	132	131	133	150
Overall Market Average	175	199	210	211	212	218	228
Non-Intel Discount (Percent)	65	75	44	44	46	47	43

Source: Dataquest (August 1997)

Figure 3-10
x86 Computational Microprocessor ASP for Intel and Others, 1995-2001 (Dollars)



Source: Dataquest (August 1997)

Computational x86 Rolling Eight-Quarter Shipment Forecast, 1996-1999

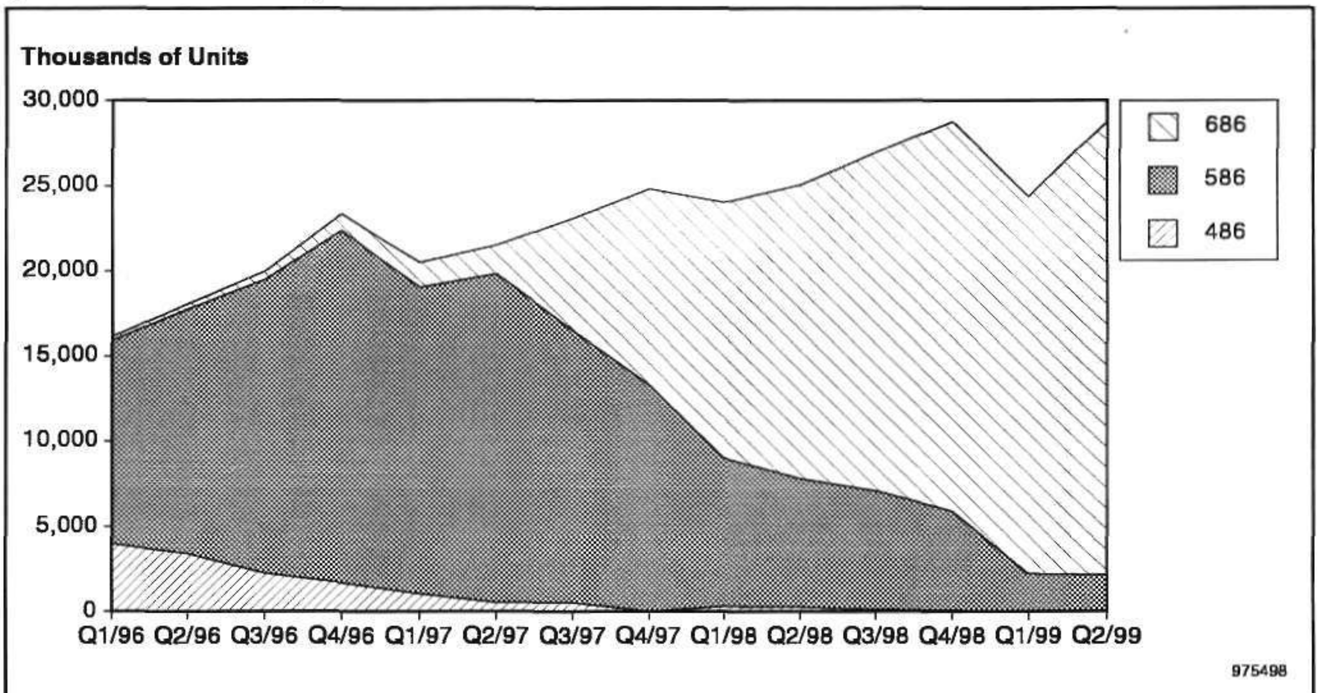
At the speed with which performance is evolving in today's personal computer market, generational transitions can be missed in annual forecasts. Dataquest provides the following estimate of such transitions on a quarter-by-quarter basis to assist its clients in their planning activities. In this forecast, we attempt to capture overall seasonality and anticipated product introductions from major vendors. When referring to Table 3-17 and Figure 3-11, the reader is advised to recall that Dataquest's definition of a sixth-generation microprocessor includes not only Intel's Pentium Pro and Pentium II lines, but also the AMD K6 and the Cyrix 6x86MX processors. This model forecasts that shipments of fifth-generation microprocessors peaked in the recently completed second quarter of 1997 and will fall slowly over the next six quarters.

Table 3-17
Quarterly x86 Computational Microprocessor Shipments by Generation, 1996-1999 (Thousands of Units)

	Fourth Generation	Fifth Generation	Sixth Generation	Total
Q1/96	3,990	11,960	200	16,150
Q2/96	3,420	14,352	300	18,072
Q3/96	2,280	17,222	500	20,002
Q4/96	1,710	20,666	1,000	23,376
Q1/97	1,053	17,980	1,491	20,524
Q2/97	527	19,312	1,704	21,542
Q3/97	527	15,982	6,604	23,113
Q4/97	0	13,318	11,504	24,822
Q1/98	314	8,719	14,996	24,029
Q2/98	275	7,557	17,245	25,077
Q3/98	118	6,975	19,869	26,962
Q4/98	79	5,813	22,868	28,760
Q1/99	0	2,232	22,152	24,384
Q2/99	0	2,149	26,582	28,732

Source: Dataquest (August 1997)

Figure 3-11
Quarterly x86 Computational Microprocessor Shipments by Generation, 1996-1999 (Thousands of Units)



Source: Dataquest (August 1997)

Other Computational Microprocessor Architectures

PowerPC

The recent announcement that Microsoft will no longer enhance the PowerPC version of its Windows NT operating system restricts the computational market for PowerPC to the Apple Macintosh and IBM AIX environments, neither of which is likely to experience dramatic growth over the foreseeable future. Dataquest forecasts that the Macintosh market will grow more slowly than the overall PC market, thus restricting opportunities for PowerPC vendors. Dataquest anticipates that IBM and Motorola will both dedicate increasing portions of their marketing activities toward embedded PowerPC opportunities and products.

SPARC

Although the unit growth of RISC-based workstations has slowed to a crawl, Dataquest anticipates that Sun still has ample growth opportunities in the midrange and high-end server market, where it has achieved credibility with the information service departments of major corporations, and which the Windows NT/Pentium II juggernaut cannot easily service.

Alpha

Alone among the RISC microprocessors that emerged in the late 1980s, Alpha attempts to address compatibility with the huge installed base of x86 software applications. This feature, incorporated late in 1996 in Digital's version of Windows NT 4.0 and referred to as FX!32, has yet to make its presence fully felt. Dataquest remains hopeful that with its clear performance advantages, x86 compatibility story, and increasing price aggressiveness, Alpha may yet find its niche in the market.

MIPS

The MIPS architecture once presented a major threat to the x86 desktop domination, but that threat continues to fade with the passing of Windows NT for this architecture. Although the MIPS design continues to excel in embedded applications (every Nintendo 64 includes two processors, and every Sony Playstation one), it struggles in computational applications.

PA-RISC

Although Hewlett-Packard has been visibly working with Intel on its next-generation Merced program, HP continues to enhance its PA-RISC product line and plans a smooth transition to the 64-bit Intel environment beginning late in this decade. The recently announced PA-8500 incorporates an extremely large on-chip cache (the first ever for an HP processor) that should increase performance and substantially decrease system cost.

Chapter 4
1996 Personal Computer Core Logic Market Review

Market Overview

A popular rumor holds that following Intel's serious entry into the core logic market in 1993, all other participants abandoned that market and left it all to Intel. According to Dataquest, in 1996 Intel increased its share of the core logic market from 32 to 66 percent measured in dollars, and from 22 to 56 percent measured in units. Some vendors threw in the towel, and abandoned the market. Those that based their business on this market battened down the hatches and prepared to ride out the storm. Many see a glimmer of hope on the horizon, as Intel begins to emphasize its Pentium II designs and leaves the socket 7 arena to x86 clone vendors and alternative chipset suppliers.

Intel entered the largely moribund core logic arena in order to drive its own technology initiatives, including the high speed Peripheral Component Interconnect bus (PCI) and the newer Universal Serial Bus (USB). Along the way, it discovered that it could produce core logic chipsets using recently decommissioned, fully depreciated microprocessor production equipment and thus gain an economic advantage. This equipment reuse strategy has allowed it to increase the pace at which it delivers new microprocessor technology, and it is this pace that in turn serves to stimulate market growth, a key Intel concern.

Intel's entry led to a shakeout and consolidation of vendors within the segment. Missing entirely from this year's list are ACC Microelectronics, Chips and Technologies, Cypress, Oak Technologies, Symphony Laboratories, Weitek, and Western Digital. UMC sold its core logic business to ITE, and Cirrus Logic sold its Pico Power division to National Semiconductor. VLSI Technologies, once a major player in the segment, concluded that it could earn higher profits by focusing its design and manufacturing resources elsewhere and exited the segment entirely. The vendors that have survived Intel's onslaught have had to learn how to design their products more quickly and how to achieve higher levels of system performance. Although they generally price their products at a discount to Intel's, the absolute cost savings (Intel's average chipset sells for less than $25) do not allow them to sell products that seriously compromise system-level performance.

As silicon densities have increased, core logic vendors have moved to expand product features as a means to preserve ASPs, a trend Dataquest expects will continue. Two years ago, the core logic absorbed the typical PC disk controller. Last year, keyboard controllers and real-time clocks were popular integration candidates. This year, parallel and serial port controllers, along with USB and IEEE 1394 ("Firewire") support will moving on-chip. Some vendors offer versions that integrate audio capabilities, while others integrate graphics accelerators. Core logic vendors serve as miniature vacuum cleaners, sucking up miscellaneous system functions as Moore's law permits vendors to integrate more and more function on each chip.

Table 4-1
x86 Core Logic Vendors, Ranked by 1996 Total Revenue (Millions of Dollars)

1995 Rank	1996 Rank	Vendor	1995 Desktop	1996 Desktop	1995 Mobile	1996 Mobile	1995 Total	1996 Total	1996 Market Share (%)	1995-1996 Growth (%)
1	1	Intel	445.5	922.0	-	50.0	445.5	972.0	66	118
2	2	SiS	178.0	124.2	1.8	5.1	179.8	129.3	9	-28
4	3	OPTi	116.3	33.6	8.8	50.4	125.1	84.0	6	-33
7	4	ALI	52.8	70.7	4.0	7.4	56.8	78.1	5	38
5	5	ITE(UMC)	108.0	48.0	3.2	19.0	111.2	67.0	5	-40
3	6	VIA	138.0	59.0	2.0	5.0	140.0	64.0	4	-54
8	7	National	-	-	-	39.2	-	39.2	3	NA
6	8	Cirrus	-	-	58.5	28.0	58.5	28.0	2	-52
		Others	200.2	-	59.2		259.4	-	0	-100
		Total	**1,238.8**	**1,257.5**	**137.5**	**204.2**	**1,376.3**	**1,461.7**	**100**	**6**

NA = Not available
Source: Dataquest (August 1997)

Table 4-2
x86Core Logic Vendors, Ranked by 1996 Total Unit Shipments (Thousands of Units)

1995 Rank	1996 Rank	Vendor	1995 Desktop	1996 Desktop	1995 Mobile	1996 Mobile	1995 Total	1996 Total	1996 Market Share (%)	1995-1996 Growth (%)
1	1	Intel	16,500	38,417	-	1,786	16,500	40,202	56	144
2	2	SiS	10,600	8,118	98	325	10,698	8,443	12	-29
4	3	ITE (UMC)	9,000	4,830	185	890	9,185	5,720	8	-38
6	4	ALI	4,400	5,100	350	500	4,750	5,600	8	18
5	5	OPTi	7,500	1,976	400	2,191	7,900	4,168	6	-47
3	6	VIA	9,200	3,726	100	250	9,300	3,976	6	-57
8	7	National	-	-	-	1,925	-	1,925	3	NA
7	8	Cirrus	-	-	3,000	1,375	3,000	1,375	2	-54
		Others	11,610	-	2,655		14,265	-	0	-100
		Total	**68,810**	**62,167**	**6,788**	**9,242**	**75,598**	**71,409**	**100**	**-7**

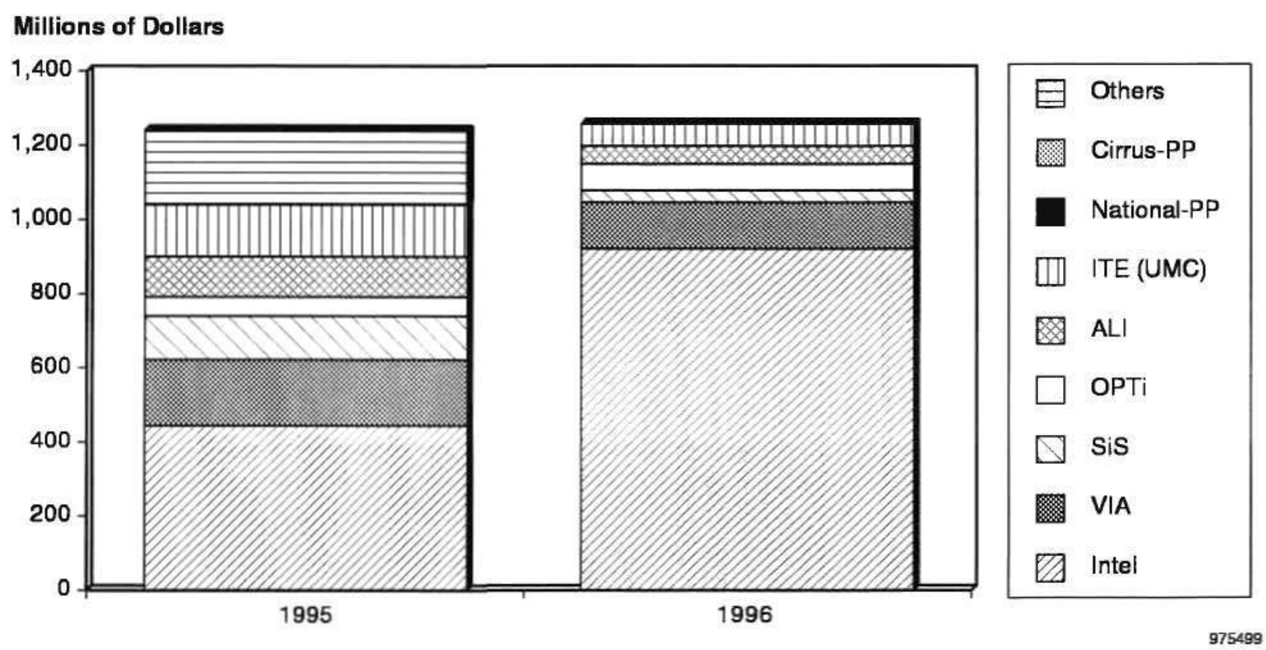
NA = Not available
Source: Dataquest (August 1997)

Table 4-3
x86 Core Logic Vendors, Ranked by 1996 Overall ASP (Dollars)

1995 Rank	1996 Rank	Vendor	1995 Desktop	1996 Desktop	1995 Mobile	1996 Mobile	1995 Overall	1996 Overall	1995-1996 Growth (%)
1	1	Intel	27.00	24.00	-	28.00	27.00	24.18	-10
2	2	Cirrus	-	-	19.50	20.39	19.50	20.39	5
8	3	National	-	-	-	20.39	-	20.39	NA
4	4	OPTi	15.51	17.00	22.00	23.00	15.84	20.15	27
3	5	SiS	16.79	15.30	18.06	15.69	16.80	15.31	-9
5	6	VIA	15.00	15.83	20.00	20.00	15.05	16.10	7
7	7	ALI	12.00	13.86	11.43	14.80	11.96	13.95	17
6	8	ITE(UMC)	12.00	9.94	17.30	21.35	12.11	11.71	-3
		Other	17.24	-	22.31	-	18.19	-	NA
		Total	**18.00**	**20.23**	**20.26**	**22.09**	**18.21**	**20.47**	-

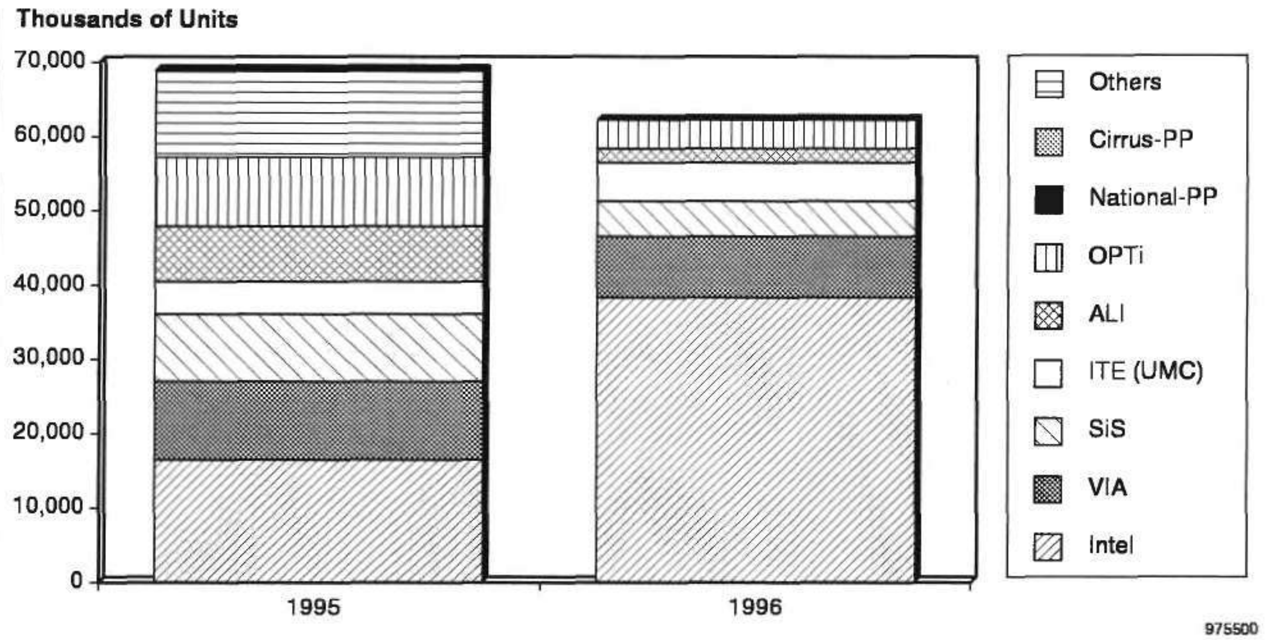
NA = Not available
Source: Dataquest (August 1997)

Figure 4-1
x86 Core Logic Revenues, 1995-1996



Source: Dataquest (August 1997)

Figure 4-2
x86 Core Logic Shipments, 1995-1996



Source: Dataquest (August 1997)

Major Core Logic Suppliers

Intel

Intel more than doubled its desktop core logic shipments, paced by the introduction of the high-performance Triton II chipset (430HX) and the lower-cost Triton VX (430VX) model originally intended to support the ill-fated uniform memory architecture (UMA) concept. Intel began deliveries of its Mobile Triton (430MX) logic, specifically optimized for power-sensitive mobile environments, and delivered almost 2 million sets of this logic. This was an impressive achievement, given that the major vendors of mobile systems still prefer to roll their own core logic instead of using any vendor's off-the-shelf products. Intel also launched its 440FX chipset that significantly lowered the cost of building Pentium Pro-based desktop systems. Dataquest anticipates that Intel will introduce its 440LX chipset, optimized for the Pentium II environment with the Accelerated Graphics Port (AGP) late in 1997. It will attempt to utilize the AGP feature to induce users to upgrade from older Pentium-based systems lacking AGP.

Silicon Integrated Systems

SiS lost share in 1996, as its sales of desktop-oriented core logic fell almost 30 percent while it was able to make only minor gains in mobile units to make up the difference. SiS and other personal computer chipset vendors plan to exploit Intel's migration from the socket 7 platform to the slot 1 platform in 1998 as a means to staunch the loss of market share they have experienced to date. As Intel intends to use the AGP features in its next version of Pentium II core logic to drive the market towards Pentium II, SiS plans to add similar AGP features to its Pentium-style core logic devices. AMD and Cyrix will require these features in Socket 7 motherboards to offer competitive system level features in 1998, and they will need at least one of the Intel-alternative chip sets to support this capability at a competitive performance level. Intel's microprocessor competitors cannot survive in the long term without core logic optimized for their chips, and Intel's core logic competition will find the going even tougher should there be no PC microprocessor alternatives to Intel.

OPTi

Like SiS, OPTi saw sales fall by more than 30 percent. OPTi moved to strengthen its mobile offering, but its gains in mobile failed to offset substantial losses in the desktop portion of its business. Like SiS, OPTi hopes to service the Socket 7 infrastructure that Intel is leaving behind in its migration to Pentium II.

VIA

Like other core logic vendors, VIA saw its share drop precipitously as Intel strengthened its hold on desktop core logic. VIA worked with AMD to add AGP features to its Pentium-style core logic devices. AMD based its recently introduced 640 and 645 chipsets on technology licensed from VIA. X86 clone vendors like AMD and Cyrix will require AGP support in Socket 7 motherboards in order to offer competitive system level features in 1998, and these vendors will need at least one of the Intel-alternative chip sets to support this capability at a competitive performance level.

Chapter 5

Forecast of Personal Computer Core Logic Market, 1997-2001

Dataquest anticipates that the market for personal computer core logic will grow from $1.6 billion in 1996 to $2.6 billion in the year 2001. Sales of Socket 7-oriented logic peaked in 1996 at about $1.2 billion and will slowly decline to $460 million by the year 2001. A symbiotic relationship must develop between alternative x86 vendors (like AMD and Cyrix) and core logic vendors if either party is to survive on a long-term basis. The technology licensing arrangement between Via and AMD may be the first demonstration of this emerging relationship.

Tables 5-1, 5-2, and 5-3 present Dataquest's forecast of x86 core logic revenue, unit shipments, and ASP by socket/slot type, respectively. Figure 5-1 shows x86 core logic shipment forecasts by socket/slot type. Table 5-4 and Figure 5-2 presents Dataquest's projections for x86 core logic unit shipments if x86 clone vendors extend the life of Socket 7.

Table 5-1
Forecast of x86 Core Logic Revenue, 1995-2001 (Millions of Dollars)

	1995	1996	1997	1998	1999	2000	2001
Socket 3 (486)	415	146	27	9	0	0	0
Socket 7 + Mobile P5	941	1,220	1,073	657	489	462	461
Socket 8	20	200	267	0	0	0	0
Slot 1 + Mobile P6	0	0	693	1,790	2,232	2,177	2,101
Proprietary	0	0	0	0	0	0	0
Unknown/Others	0	0	0	0	0	0	0
Total	**1,376**	**1,566**	**2,060**	**2,457**	**2,720**	**2,639**	**2,561**

Source: Dataquest (August 1997)

Table 5-2
Forecast of x86 Core Logic Shipments, 1995-2001 (Thousands of Units)

	1995	1996	1997	1998	1999	2000	2001
Socket 3 (486)	31,678	11,200	2,106	786	0	0	0
Socket 7 + Mobile P5	33,599	64,200	71,515	43,792	32,575	35,532	40,051
Socket 8	100	2,000	3,555	0	0	0	0
Slot 1 + Mobile P6	0	0	10,665	55,952	82,652	94,652	95,488
Proprietary	0	0	1,260	3,250	2,583	3,257	2,442
Unknown/Others	126	200	900	1,048	3,760	7,385	24,828
Total	**65,503**	**77,600**	**90,001**	**104,828**	**121,570**	**140,825**	**162,810**

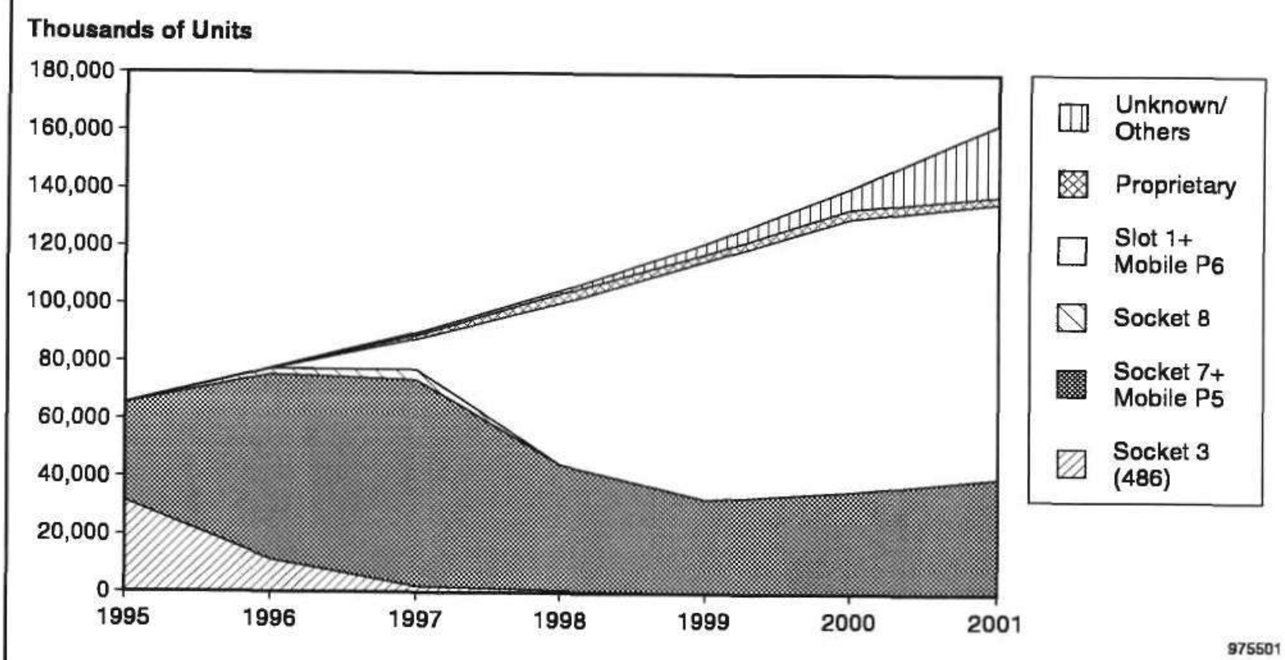
Source: Dataquest (August 1997)

Table 5-3
Forecast of x86 Core Logic ASP, 1995-2001 (Dollars)

	1995	1996	1997	1998	1999	2000	2001
Socket 3 (486)	13	13	13	12	-	-	-
Socket 7 + Mobile P5	28	19	15	15	15	13	12
Socket 8	199	100	75	-	-	-	-
Slot 1 + Mobile P6	-	-	65	32	27	23	22
Proprietary	-	-	0	0	0	0	0
Unknown/Others	-	-	0	0	0	0	0
Total	**18**	**20**	**23**	**23**	**22**	**19**	**16**

Source: Dataquest (August 1997)

Figure 5-1
x86 Core Logic Shipments by Socket/Slot Type, 1995-2001



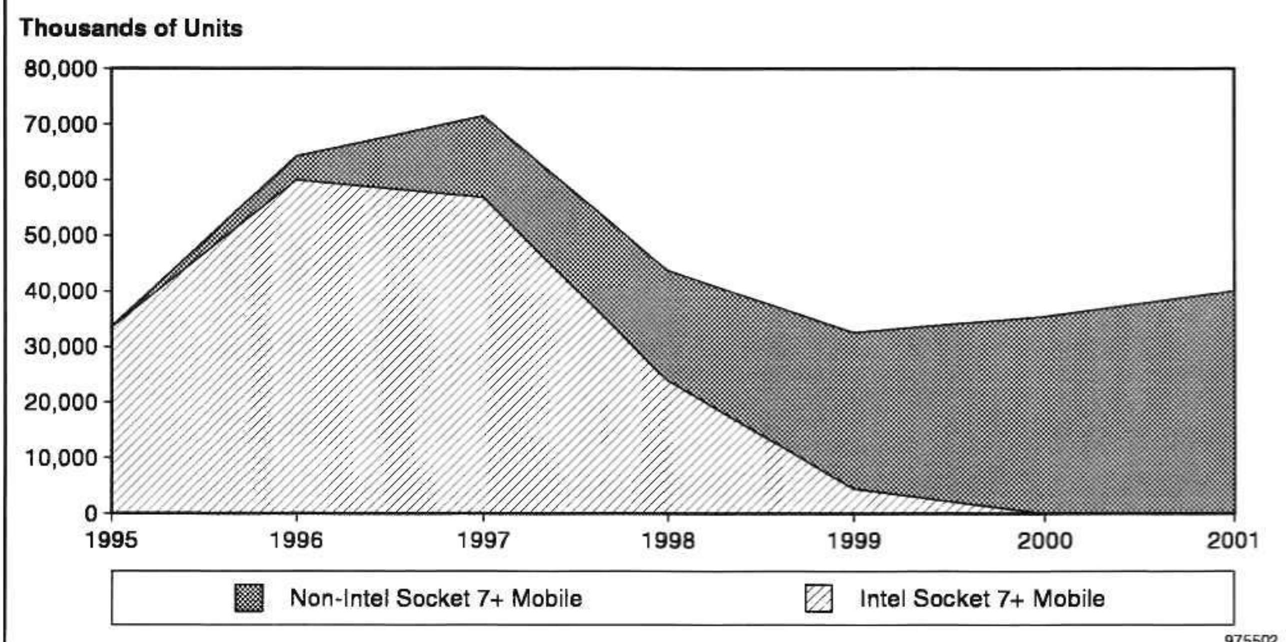
Source: Dataquest (August 1997)

Table 5-4
x86 Clone Vendors Extend the Life of Socket 7 Unit Shipments (Thousands of Units)

	1995	1996	1997	1998	1999	2000	2001	2002
Intel Socket 7 + Mobile	33,549	60,000	56,881	23,979	4,468	0	0	0
Non-Intel Socket 7 + Mobile	50	4,200	14,634	19,812	28,107	35,532	40,051	42,313
Total Socket 7+ Mobile	**33,599**	**64,200**	**71,515**	**43,792**	**32,575**	**35,532**	**40,051**	**42,313**

Source: Dataquest (August 1997)

Figure 5-2
x86 Clone Vendors Extend the Life of Socket 7 Unit Shipments



Source: Dataquest (August 1997)

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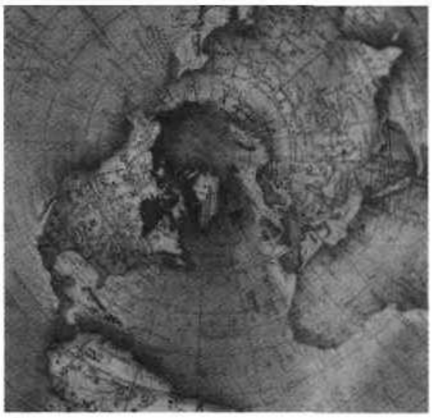

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Sound and Vision: Trends for the PC Graphics and PC Audio Chip Markets

Market Trends

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Trends for
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Program: Personal Computer Semiconductors and Applications Worldwide
Product Code: PSAM-WW-MT-9701
Publication Date: June 16, 1997
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Market Trends

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Filing: Market Trends

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Chapter 1
Executive Summary

PC multimedia is like the weather in Boston—the only constant is change. New chip vendors are always trying to establish a foothold in the market to take their share of the billions of dollars in revenue just as the most successful vendors endeavor to keep their socket ownership from one design cycle to the next. The result is a parade of success stories and rising stars that burn brightly for a few years only to be eclipsed by a bigger, brighter star mixed with those few vendors who put in a solid showing year in and year out.

Audio features will become ubiquitous by the turn of the century. Intel's AC-97 initiative, as well as lower prices for the "Sound Blaster on a single chip" products, will enable corporate PCs to have basic audio features. Consumer PCs will lead the charge into a new class of DSP-based audio controllers offering high-end features, such as 3-D positional sound, wave guide synthesis, and support for AC-3. Revenue growth in the low teens is forecast for 1997; 1998 will usher much stronger growth followed by a slowdown as the attach rate saturates at 100 percent in the following years.

This year the PC graphics controller market has a new No. 1 as S3 knocked Cirrus Logic out of the position it held for the last two years as the world's biggest graphics chip vendor. S3 and ATI posted outstanding unit shipment and revenue growth with unit shipments essentially doubling for both vendors. Many graphics vendors are steeling themselves for a rough market in 1997 as competition erodes ASPs and could limit revenue growth to single digits in spite of the transition to 3-D graphics. 3-D graphics will become pervasive as consumer PCs get 3-D for games and corporate PCs get 3-D for free. TV display and output capabilities are the next free feature for graphics vendors to integrate. Integrated memory will be pivotal for the mobile graphics segment over the next few years.

The markets for graphics and audio chips in PCs will continue to give vendors roller coaster rides for the next few years as price competition and rapid technology shifts continue to characterize these markets. Look for high levels of competition to force many of the current vendors out of this business over the next two years.

Project Analyst: Geoff Ballew

Chapter 2
Introduction and Methodology

This document is the first in a series of four that provide reference information and analysis about the markets for semiconductor devices in personal computers. The three books discuss graphics controllers, audio controllers, core logic chipsets, microprocessors, and an overview that includes a model of total semiconductor content for PCs.

The information in this report is gathered from both primary and secondary sources. Primary sources include surveys and interviews of industry vendors and customers, as well as analyst knowledge and opinions. Secondary sources include government and trade sources on sales, production, trade, and public spending. Semiconductor content assumptions are based on both surveys of producing OEMs and physical teardown evaluations by Dataquest analysts of representative personal computers.

The forecast methodology is based on various methods and assumptions, depending on the specific market. To form a solid basis for projecting system demand and capital, government and consumer spending, assumptions are made for various regions of the world. For specific markets, saturation and displacement dynamics are considered as well. Key exogenous factors such as new software introductions, exchange rate changes, and government policies are also considered. Semiconductor content forecasts are based on interviews of system marketers and designers (including makers of enabling semiconductor technology), along with an analysis of historical trends.

Chapter 3
PC Audio Market Trends

The PC audio chip market has come of age as an essential element of the PC semiconductor market. Audio features are standard on virtually all notebook PCs and are a mainstay of consumer PCs. The age of multimedia has also carried audio features into the realm of corporate desktops. Corporate buyers of PCs will not pay extra for audio features, but they are getting them anyway. As Dataquest's market data and forecasts show, the PC audio market is big and getting bigger. This market has evolved over the past three years from a high-margin, low-competition business to a lower-margin, high-competition business. Intellectual property (IP) lawsuits and some clever engineering have leveled the playing field with respect to legacy software compatibility, leaving the future battles to be won on price and performance rather than the IP issues of yesteryear.

Market Share Statistics

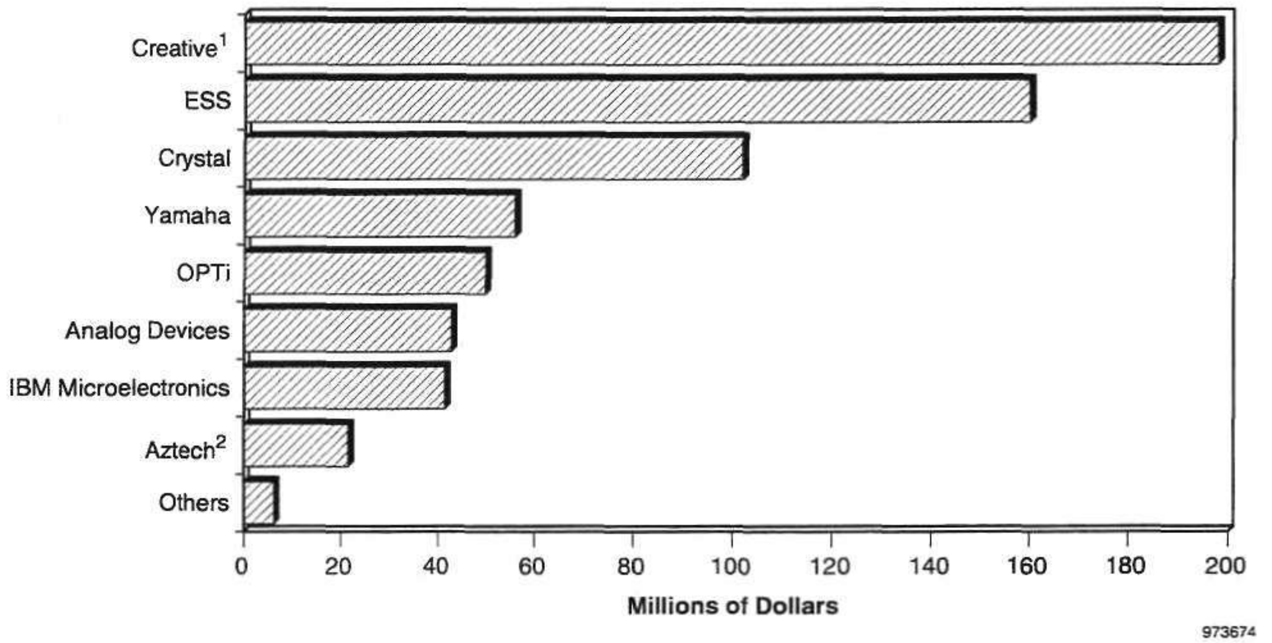
Creative Technologies has long been the biggest PC audio vendor because of the company's dominance in the PC sound card market. This year, Dataquest included custom chips in the market share rankings for Creative and Aztech. This brings Creative back to the top of the PC audio chip rankings ahead of both ESS Technology and Crystal Semiconductor, each of whom had higher revenue from pure chip-level sales. The reason for including chip value shipped at the board level is to characterize market influence and impact more accurately. Table 3-1 and Figure 3-1 show the 1996 market share data for PC audio chips. These market share numbers do not include revenue from standalone FM synthesis chips, standalone wave table synthesis chips, or wave table sample ROMs.

Table 3-1
1996 PC Audio Chip Market Share (Units in Thousands)

Vendor	Standalone Codecs	Chipsets Shipped on Board-Level Products	Chipsets Sold as Chips	Total Units	Chip Revenue ($M)	ASP ($)	Market Share (%)
Creative[1]	-	7,370	7,660	15,030	198.0	13.2	29.2
ESS	-	-	13,000	13,000	160.0	12.3	23.6
Crystal	5,000	-	4,900	9,900	102.0	10.3	15.0
Yamaha	-	-	7,000	7,000	56.0	8.0	8.3
OPTi	-	-	6,000	6,000	50.0	8.3	7.4
Analog Devices	4,250	-	3,077	7,327	42.8	5.8	6.3
IBM Microelectronics	-	-	1,800	1,800	41.4	23.0	6.1
Aztech[2]	-	3,500	50	3,550	21.6	6.1	3.2
Others	-	-	419	419	6.2	14.8	0.9
Total	9,250	10,870	43,906	64,026	678.0	10.6	100.0

[1] Creative's board shipments are estimated at 7.4 million units; all numbers include units consumed internally for board-level sales.
[2] Aztech's board shipments are estimated at 3.5 million units; all numbers include units consumed internally for board-level sales.
Source: Dataquest (April 1997)

Figure 3-1
1996 PC Audio Chip Market Share



[1] Creative's board shipments are estimated at 7.4 million units; all numbers include units consumed internally for board-level sales.
[2] Aztech's board shipments are estimated at 3.5 million units; all numbers include units consumed internally for board-level sales.
Source: Dataquest (May 1997)

PC Audio Trends

PC audio is constantly evolving, and 1997 is a watershed year. The market for PC audio chips has become a commodity one with comparable products from multiple vendors. One consequence is that vendors are scrambling to differentiate their products and are being forced to innovate and bring new features to market faster. These dynamics are changing the market; the industry is witnessing the dawning of a new age. PC audio is beginning to move to the PCI bus and wave table audio is scoring big against the legacy frequency modulation (FM) synthesis. The following sections discuss several key trends for the PC audio and PC audio chip markets.

Shipments and Pricing

PC OEMs continue to add audio chipsets to a higher percentage of their PCs each year. Dataquest estimates that about 40 percent of the PCs shipped in 1996 included basic audio capabilities, and that virtually 100 percent of PCs shipped will include such features in the year 2001.

Competition has become fierce in the audio chip market as all major vendors continue to offer a variety of single-chip audio subsystems for basic Sound Blaster compatibility. Pricing for a single-chip product featuring an ISA plug-and-play interface, digital controller, FM synthesis, and audio codec averaged $12 for the year, but finished the year below $10. The price for the same product is likely to fall another 50 percent by the end of 1997.

Bus Interface Issues

ISA will begin to fade as PCI emerges as the next bus interface for PC audio.

The transition to PCI will increase the opportunity for PC OEMs to leverage the PC main memory for storing wave table samples instead of adding megabytes of memory to the audio subsystem. Some implementations will continue to use ROM for the standard set of samples and use main memory for custom sounds supplied with entertainment software. Dedicated audio RAM will be limited to high-end implementations and those that depend on the ISA bus instead of PCI.

Many game developers have expressed a desire to use custom wave table samples to enhance their software. The downloadable samples standard (DLS) is supported by a number of hardware and software vendors.

Synthesis Techniques

New emphasis on audio quality will drive wave table synthesis to replace FM over the next two years as the primary synthesis technique. FM synthesis will continue to be included in systems for compatibility with legacy software. Hardware support for FM synthesis could fade in the next few years in favor of software FM synthesis as the ISA bus is replaced by PCI.

Software wave table synthesis is shipping on many PCs today. Dataquest expects almost every PC shipping for Christmas 1997 to include wave table capability if an audio subsystem is provided. For most systems, the wave table synthesis is done by software. About one in three sound cards last year shipped with hardware wave table features, not including daughtercards sold as wave table upgrades through retail channels.

Wave guide synthesis will replace wave table synthesis for some instruments, particularly for wind instruments such as flutes and clarinets. Wave guide synthesis requires considerably more processing power and will increase demand for advanced DSP-like audio processors and media engines.

AC-97

Intel's Audio Codec 1997 (AC-97) initiative is taking root with a variety of products this year conforming to the standard. AC-97 specifies an audio codec with a standardized interface. An Audio Controller 1997 specification is also part of the initiative, but these functions may be provided in hardware or software. The basic idea is to partition the analog functions into a separate chip from the digital functions. The codec is a mixed-signal chip that includes a digital interface to the rest of the PC and a variety of analog ports to peripherals such as speakers and microphones.

Emphasis on audio quality and hardware/software scalability is overriding the previous trends of producing single-chip subsystems and minimizing costs.

Low-end AC-97 implementations will simply have an AC-97 codec and use software running on the host CPU instead of a hardware controller.

Other implementations will include a hardware controller, but will maintain the partitioning of a digital controller and a separate, mixed-signal chip for the codec.

The long-term goal of AC-97 is to remove analog audio from the PC entirely and replace it with digital audio connections to all peripherals. Those peripherals needing analog-to-digital or digital-to-analog conversion will need to provide that capability internally. This transition is unlikely to occur before the year 2000.

Other Trends

USB audio will garner press attention as the path for digital audio out of the box, but few PCs will ship with USB speakers in 1997. Digital-ready PCs (as Intel labels them) will ship in volume. These PCs will be able to redirect audio output to the USB port, but will ship with analog speakers for cost and compatibility reasons.

Standard audio chips will face increasing market pressure from PC-oriented programmable digital signal processors (pDSPs) and media processors. Examples of PC-oriented pDSPs include Crystal Semiconductor's CS4610 (see Table 3-2) and Oak Technology's OTI-611. These chips are programmable DSPs, but feature PCI bus and AC-97 interfaces as well as other dedicated hardware features that tailor them for PC audio and telephony applications.

Current Product Offerings

Table 3-2 lists some key features of several PC audio chips from leading vendors.

Sample Block of Diagrams of Audio Subsystems

Figure 3-2 illustrates the configuration for a single-chip audio subsystem. Figure 3-3 illustrates a two-chip audio subsystem that uses an AC-97 codec.

Market Forecast

Dataquest forecasts two major trends for the audio chip market. First, Dataquest expects audio to become a standard feature on all PCs by the year 2000. The attach rate of audio chips to new PCs continues to increase and is driving revenue growth for 1997 despite high levels of competition in the market for single-chip products. Growth for 1997 should break into double digits even as ASPs decline. As price pressure eases in 1998, Dataquest expects a revenue growth rate percentage in the high 20s. Growth will be slower following 1998 because the attach rate will saturate at 100 percent.

A second major trend centers on the implementation of Intel's AC-97 initiative and a new emphasis on audio quality. This trend includes the shift to wave table synthesis, the higher analog performance of AC-97 codecs compared to integrated codecs, and an emerging class of advanced, programmable PC audio chip products.

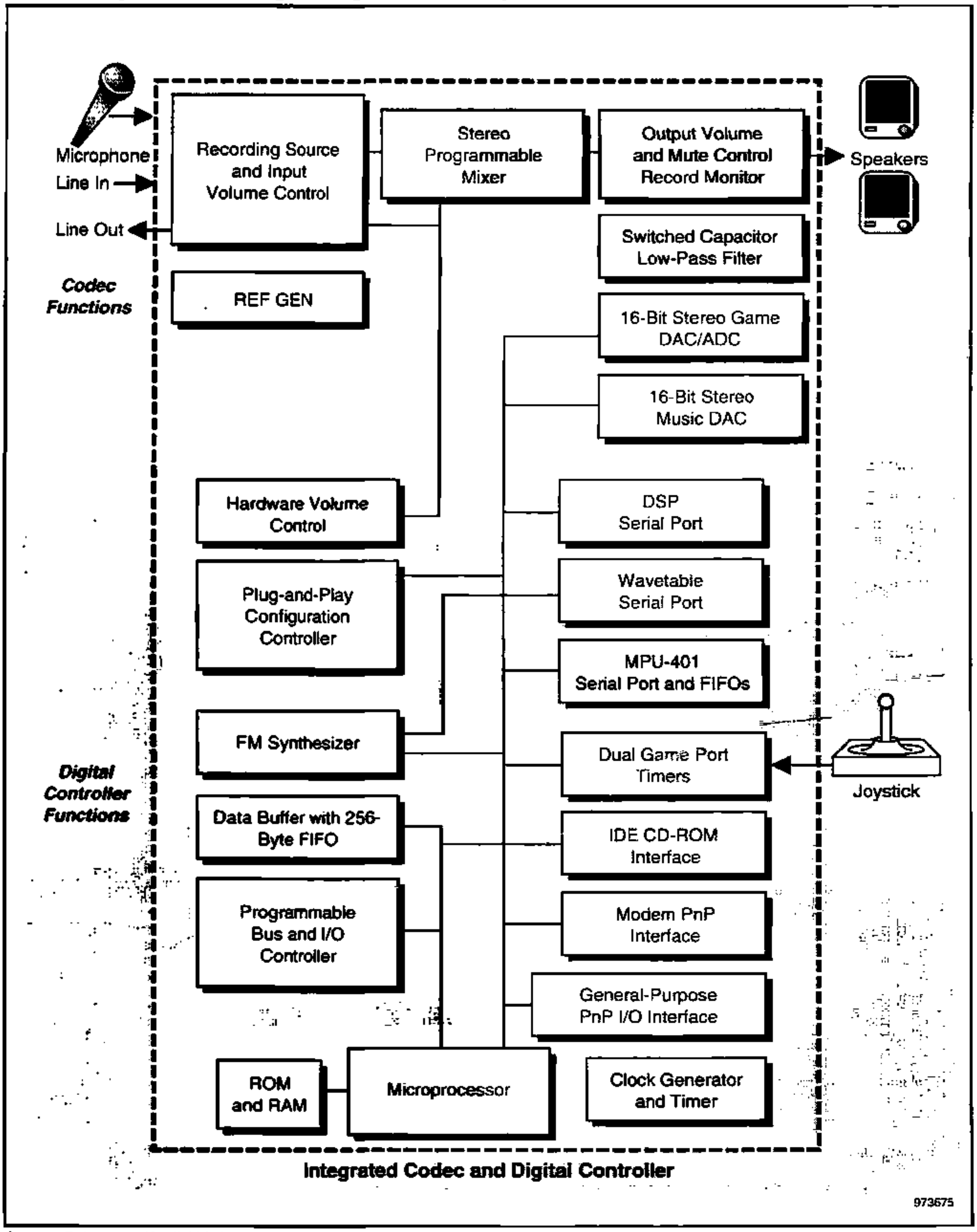
Table 3-3 and Figure 3-4 show the forecast for PC audio chip shipments and revenue.

Table 3-2
Features of Many Popular PC Audio Chips

Vendor	Product Name/Code	Product Type	Synthesis	Spatial Enhancement	True 3-D Sound	Interface	Package
Creative Technologies	Vibra	Integrated controller/ codec	FM	Yes	No	ISA	TQFP-100
Crystal Semi-conductor	CS4237B	Integrated controller/ codec	FM	SRS	No	ISA	TQFP-100
	CS4238B	Integrated controller/ codec	FM	Qsound	No	ISA	TQFP-100
	CS4610	Controller	WT, WG	None	Yes	PCI	PQFP-100
	CS4297	AC-97 codec	NA	None	NA	AC-97	TQFP-48
ESS Technology	ES1878	Integrated controller/ codec	FM	None	No	ISA	TQFP-100
	ES690	Controller	WT	None	No	MPU-401	PQFP-52
IBM Micro-electronics	MWave	Controller	FM	None	No	ISA	PQFP-240
Oak Technology	TelAudia, OTI-610	Controller	WT	None	Yes	PCI	PQFP-160
Opti	OptiSound 82C931	Integrated controller/ codec	FM	None	No	ISA	PQFP-100
S3	SonicVibes	Integrated controller/ codec	FM, WT	SRS	No	PCI or ISA	PQFP-160
VLSI	Songbird VL82C829	Controller	FM, WT, WG	None	Yes	PCI	PQFP-160
Yamaha	OPL3-SA	Integrated controller/ codec	FM	None	No	ISA	TQFP-100
	OPL4-ML	Controller	FM, WT	None	No	ISA	TQFP-100

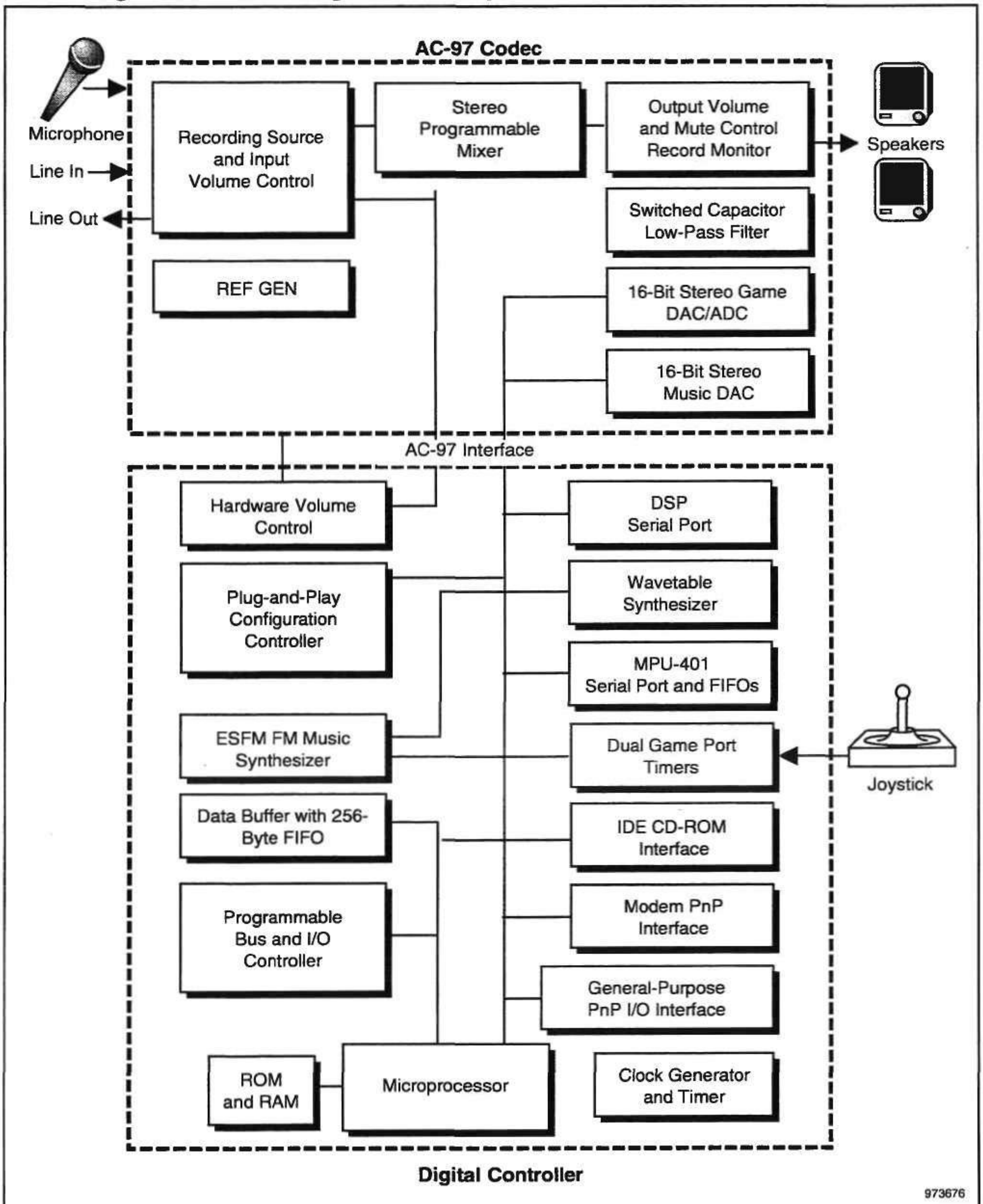
Source: Dataquest (April 1997)

Figure 3-2
Block Diagram for a Single-Chip Audio Subsystem



Source: Dataquest (April 1997)

Figure 3-3
Block Diagram for a Two-Chip Audio Subsystem That Uses an AC-97 Codec



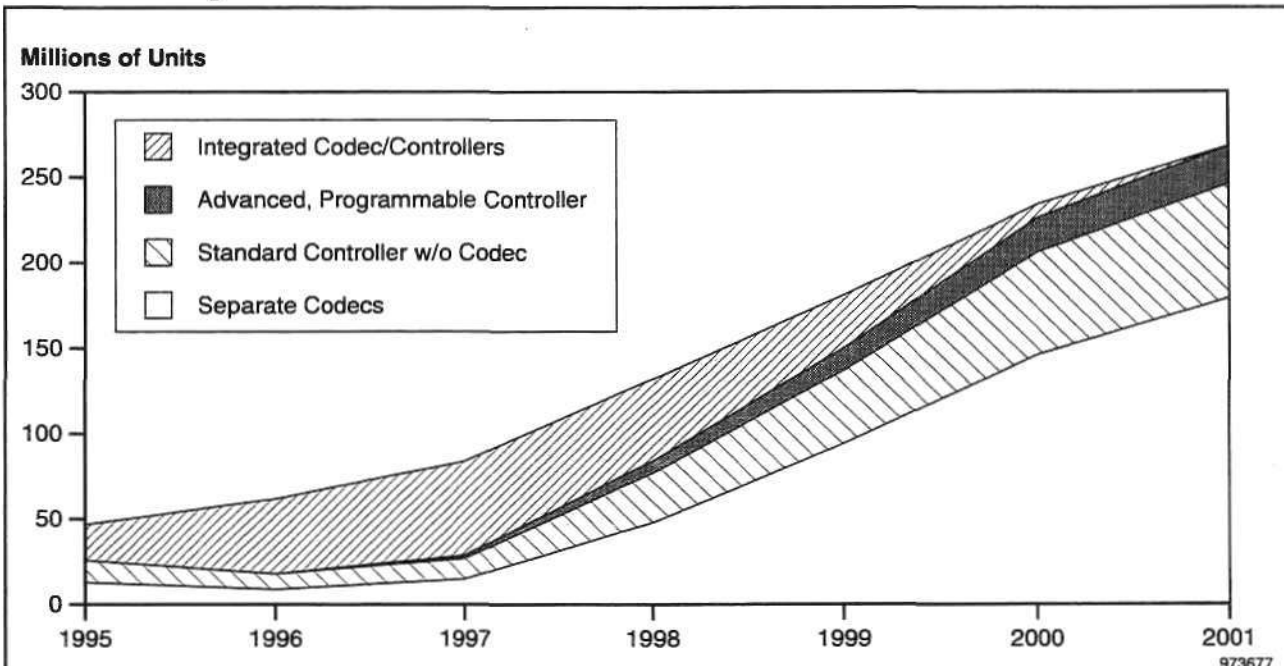
Source: Dataquest (April 1997)

Table 3-3
PC Audio Chip Forecast

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
PC Audio Chips (K Units)	47,392	64,026	84,338	131,071	181,311	234,048	267,852	33.1
Growth Year-to-Year (%)	-	30.9	36.0	55.4	38.3	29.1	14.4	NA
PC Audio Chip Revenue ($M)	484.6	678.0	719.6	893.8	1,036.4	1,150.4	1,183.5	13.3
Growth Year-to-Year	-	31.1	13.3	24.2	16.0	11.0	-37.9	NA
PCs (K Units)	60,171	71,651	84,694	98,693	114,178	131,700	151,601	16.2
Separate Codecs (K Units)	13,251	9,250	15,232	47,662	93,782	146,040	178,568	80.8
Separate Hardware Controllers (K Units)	13,251	9,250	13,821	35,747	56,269	80,322	89,284	57.4
Standard (K Units)	13,251	9,250	11,748	28,955	43,327	60,241	66,963	48.6
Advanced Programmable (K Units)	0	0	2,073	6,792	12,942	20,080	22,321	NA
Software Controllers Using CPU (K Units)	0	0	1,410	11,916	37,513	65,718	89,284	NA
Integrated Codec/Controllers (K Units)	20,890	45,526	55,285	47,662	31,261	7,686	0	-100.0

NA = Not available
Source: Dataquest (May 1997)

Figure 3-4
PC Audio Chip Forecast



Source: Dataquest (May 1997)

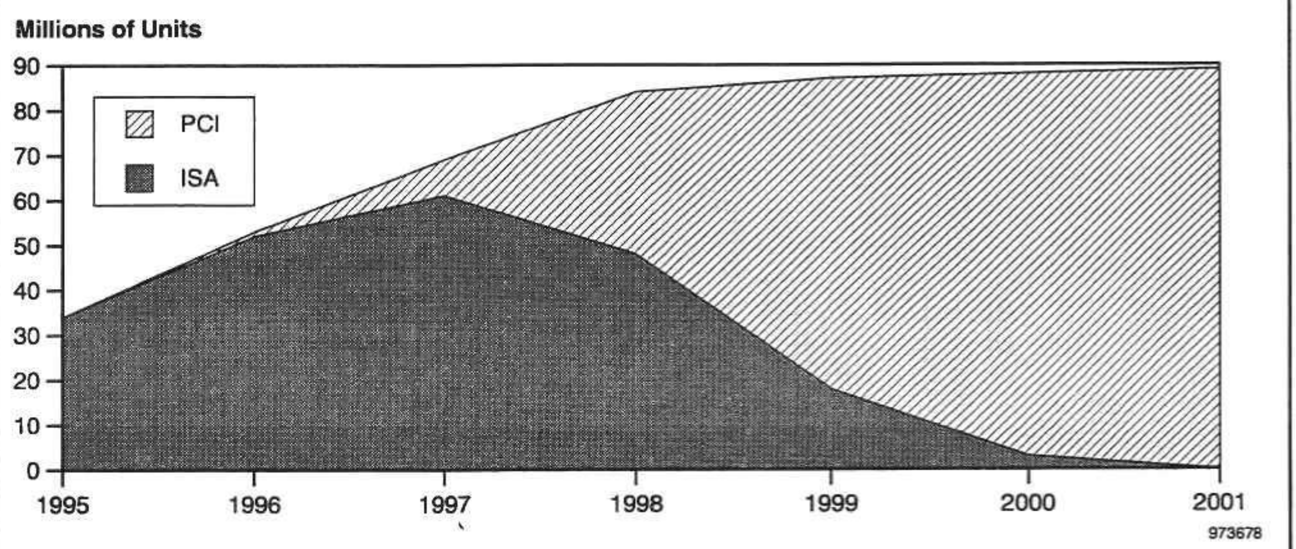
The PC audio chip market is finally showing signs of moving to PCI from the ISA bus (see Table 3-4 and Figure 3-5). Performance and greater flexibility are the primary motivators for the change, while compatibility with legacy software was the anchor that kept PC audio moored to the ISA bus. Some clever engineering by chip vendors appears to have solved compatibility issues, so barriers to change may now be limited to cost. Two companies, S3 and VLSI, view the transition from ISA to PCI as an opportunity for new vendors to stake a claim in this market. Each has introduced a PCI-based audio chip, though S3 has hedged its bet by making the SonicVibes product compatible with ISA, too.

Table 3-4
Bus Interface Forecast for PC Audio Chips (Percent)

	1995	1996	1997	1998	1999	2000	2001
ISA	100	99	88	57	21	4	0
PCI	0	1	12	43	79	96	100

Source: Dataquest (May 1997)

Figure 3-5
Bus Interface Forecast for PC Audio Controllers



Source: Dataquest (May 1997)

Chapter 4
PC Graphics Market Trends

PC graphics are a highly visible and volatile part of the PC semiconductor market. Price pressure continues as all major vendors and a host of start-ups have brought 3-D products to market. The relative availability of foundry capacity has enabled these vendors to start a price-busting, margin-eroding, attempted-socket-stealing price war, and the effect promises to be dramatic. Overall, this price competition will speed the adoption of new features that consumers will use and corporate buyers will get for free.

Dataquest believes that 1997 and 1998 will be highly competitive years for PC graphics chip companies. Consolidation is expected among the second- and third-tier vendors as they scramble for design-wins. The current market leaders are strong and are likely to remain high-volume suppliers for several years, but competition is increasing. Dozens of companies view the transition to 3-D graphics as an opportunity to enter the PC graphics chip market. As a result, the market is more crowded than it has been for years. Many vendors will exit this market if they fail to secure good design-wins in 1998. Small players will fail or be bought for their intellectual property; larger players may simply choose to cancel product lines. In the meantime, commodity graphics vendors will face lower margins as those companies who are desperate for sales fuel the price war. Exceptions will exist when companies have a product that is "ahead of the curve," such as Neomagic's current advantage in embedded memories, which the company refers to as integrated DRAM, or IDRAM. The transition to AGP could produce additional exceptions as some vendors beat others to market.

PC Graphics Key Trends

Key trends for the PC graphics chip market are discussed in the following sections.

3-D Graphics

The industry will see a rapid shift to 3-D graphics for deskbound PCs as low-end 3-D chips approach price-parity with some 2-D products.

The industry will see a rising tide of 3-D-accelerated notebook PCs as most major vendors begin shipping LCD controllers with 3-D features.

Graphics vendors will continue to search for the "killer app" for 3-D hardware acceleration in corporate PC applications. Until a "killer app" is found, 3-D chips in corporate PCs will follow a "push" rather than a "pull" model. This "push" model will continue the trend of low-end 3-D performance coupled with fast 2-D performance.

Software 3-D will likely meet the business application requirements of most users until real 3-D applications are found for mainstream business users. Real-time data visualization and file manager navigation are the most likely compelling applications for 3-D acceleration in corporate PCs. Limiting factors are the number of corporate users who have real-time data visualization needs and the lack of a 3-D file manager application from Microsoft. Corporate buyers will be reluctant to pay extra for 3-D performance in business PCs until a compelling corporate application is found.

3-D hardware for consumer PCs is no longer a question; it should be considered a requirement as software 3-D lags in both performance and quality.

Bus Interface

PCI will continue as the dominant interface for graphics controllers through 1998 because of the sheer volume of new Pentium/PCI systems that will be sold, as well as the dominance of PCI in the installed base for the next few years.

AGP will replace PCI in 1998 for PCs with sixth-generation processors (Pentium Pro class) and will dominate the graphics chip market as those PCs replace Pentium/PCI systems.

Digital Video Processing

Basic digital video acceleration has essentially become ubiquitous. Basic capabilities are color space conversion from YUV to RGB, scaling in both X and Y directions, and the ability to share graphics memory between YUV and RGB data. Room for improvement in these areas remains.

TV features continue to grow and will be standard for consumer PCs by the end of 1998. Key TV features are flicker filters for displaying interlaced video on progressive-scan monitors and TV output for displaying graphics on interlaced monitors. TV output requires filtering as well as data format and frequency conversion.

Motion compensation engines for MPEG-2 will ship in the majority of graphics controllers in 1998.

Future graphics controllers and media processors will have 1394 interfaces for moving digital video data into the multimedia subsystem, eventually eliminating the need for the current video ports on graphics controllers. This transition will take years to develop but will be spurred by DVD shipments.

Graphics Memory

Embedded memory will gain popularity for notebook graphics controllers, driven by issues of cost, board space, and power consumption in mobile PCs.

SGRAM will replace EDO DRAM as the mainstream graphics memory with the unit crossover expected in the first half of 1998. SGRAM shipments will ramp heavily in Q3 and Q4 1997.

Software APIs

Direct3D will become the most common API for consumer and corporate 3-D graphics applications. OpenGL will remain dominant for professional 3-D applications such as authoring, CAD/CAM, and scientific tools.

Proprietary APIs will continue to be used selectively, particularly those associated with specific families of graphics chips. An example is the 3Dfx's Glide API. New versions of common APIs for software 3-D could boost performance of legacy software on MMX-enabled PCs, but will be eclipsed by Direct3D in the long run.

Programmability and Media Processors

Graphics controllers are likely to have programmable cores in the future to increase their versatility.

Long-term trends of adding functions and features to standard graphics controllers will narrow the gap between graphics controllers and media processors. These two product categories will increasingly blend together and it will be difficult to distinguish where one begins and the other ends.

The graphics controller is the most likely multimedia peripheral to challenge the media processor category for being the center of the multimedia subsystem in a typical PC. Of course, the host CPU will continue to play an important role in multimedia processing in almost all PCs.

Current Product Offerings

Table 4-1 compares the features of a variety of graphics controllers shipping this year.

Sample Block Diagrams of Graphics Controllers

Figures 4-1 and 4-2 show functional block diagrams of mainstream desktop and mobile graphics controllers, respectively.

Implementation Issues

The transition from PCI to AGP changes the implementation of graphics chips because of the special features of the AGP interface. AGP uses a higher bus clock frequency, 66 MHz instead of 33 MHz for PCI, as well as a special interface to main memory. Figure 4-3 shows the basic differences between PCI and AGP graphics implementations.

Limitations with AGP will influence whether PC OEMs choose to add the graphics controller on an add-in card or solder it down on the motherboard. Add-in cards allow greater configuration flexibility, but are more expensive than motherboard implementations. Implementation trends generally oscillate between motherboard and add-in card as system OEMs balance system cost against their ability to add leading-edge technologies. Leading-edge graphics chips are typically implemented on add-in cards and then shift to motherboard designs as they mature.

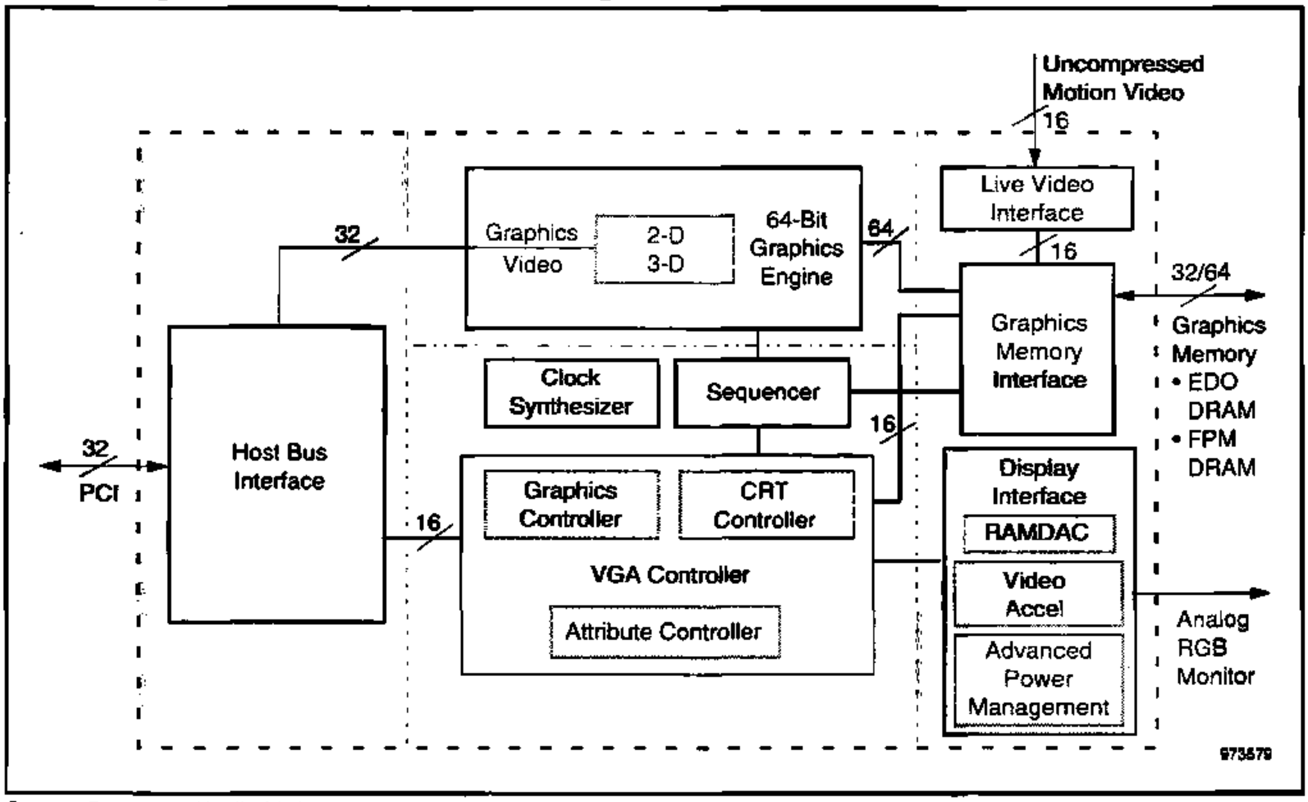
AGP will buck the latter half of that trend because of current design limitations. Dataquest expects AGP will linger at the add-in card stage longer than usual. A PC can have only one AGP device, so a motherboard implementation of an AGP graphics chip is not upgradable. PCI does not impose this limitation because PCs typically have two or three unused PCI slots and users can disable the motherboard graphics and use an empty slot for a new graphics card in most cases. AGP systems will have empty PCI slots, but not extra AGP slots. Upgrading the graphics subsystem on a PC with a motherboard AGP graphics chip would necessarily mean a downgrade to PCI. For this reason, Dataquest expects system vendors to favor add-in card solutions until Christmas 1998, when Pentium II systems will be solidly positioned for mainstream corporate desktops and home PCs.

Table 4-1
Comparison of PC Graphics Controller Products

Company	Product Name	Product Code	Target Platform	2-D+ video	3-D	TV Features	MPEG-2 Motion Compensation	Bus Interface	Package	Memory Type
3Dfx	Voodoo Graphics	NA	Deskbound	No	Yes	No	No	PCI	PQFP	EDO
	Voodoo Rush	NA	Deskbound	No	Yes	No	No	PCI	PQFP	EDO
3DLabs	Permedia	NA	Deskbound	Yes	Yes	No	No	PCI	BGA-256	SGRAM
Alliance	ProMotion	AT3D	Deskbound	Yes	Yes	No	No	PCI	PQFP-208	EDO
ATI	3D RAGE II	NA	Deskbound	Yes	Yes	Yes	No	PCI	PQFP-208	EDO
	3D RAGE II+DVD	NA	Deskbound	Yes	Yes	Yes	Yes	PCI	PQFP-208	SGRAM
	3D RAGE III PRO	NA	Deskbound	Yes	Yes	Yes	Yes	AGP/PCI	BGA-256	SGRAM
	3D RAGE LT	NA	Mobile	Yes	Yes	Yes	No	PCI	BGA-256	EDO/SGRAM
Avance	ALG25128	ALG25128	Deskbound	Yes	No	No	No	PCI	PQFP	EDO
Chips & Technologies	HiQVideo/65550	65550	Mobile	Yes	No	No	No	PCI/VL	T/PQFP-208, BGA-256	EDO
	HiQVideo/65554	65554	Mobile	Yes	No	No	No	PCI	BGA-256	EDO
Chromatic	Mpact/3600	3600	Deskbound	Yes	Yes	Yes	Yes	PCI	-	RDRAM
Cirrus Logic	VisualMedia/GD-5480	GD-5480	Deskbound	Yes	No	No	No	PCI	PQFP	SGRAM
	Laguna/GD-5460	GD-5460	Deskbound	Yes	No	No	No	PCI	PQFP-208	RDRAM
	Laguna3D/GD-5464	GD-5464	Deskbound	Yes	Yes	No	No	PCI	PQFP-208	RDRAM
	Laguna3D/AGP	GD-5465	Deskbound	Yes	Yes	No	No	AGP/PCI	PQFP-208	RDRAM
	VisualMedia	GD-7555	Mobile	Yes	No	No	No	PCI	BGA, PQFP-256	EDO
	VisualMedia	GD-7556	Mobile	Yes	No	Yes	No	PCI	BGA, PQFP-256	EDO
Intel	Auburn	NA	Deskbound	Yes	Yes	No	No	AGP	unknown	SGRAM
NeoMagic	MagicGraph	128ZV	Mobile	Yes	No	No	No	PCI	PQFP-176	Integrated
nVidia	Riva 128	NA	Deskbound	Yes	Yes	Unknown	Unknown	AGP/PCI	BGA	SGRAM
Rendition	Verite	R1000	Deskbound	Yes	Yes	No	No	PCI	PQFP	EDO
S3 Inc.	ViRGE/VX	NA	Deskbound	Yes	Yes	No	No	PCI	BGA	VRAM
	ViRGE/DX	NA	Deskbound	Yes	Yes	No	No	PCI	PQFP	EDO
	ViRGE/GX	NA	Deskbound	Yes	Yes	No	No	PCI	-	SGRAM
	ViRGE/GX2	NA	Deskbound	Yes	Yes	Yes	No	PCI	-	SGRAM
	ViRGE/MX	NA	Mobile	Yes	Yes	Yes	No	PCI	-	EDO/SGRAM
Trident	3DImage	975	Deskbound	Yes	Yes	Yes	No	PCI	PQFP-208	SGRAM
	3DImage	975DVD	Deskbound	Yes	Yes	Yes	Yes	PCI	PQFP-208	SGRAM
	3DImage	985	Deskbound	Yes	Yes	Yes	No	AGP/PCI	BGA-316	SGRAM
	3DImage	985DVD	Deskbound	Yes	Yes	Yes	Yes	AGP/PCI	BGA-316	SGRAM
	Cyber	9385	Mobile	Yes	No	No	No	PCI	T/PQFP, BGA-256	SGRAM
	3D Cyber	9397	Mobile	Yes	No	Yes	No	PCI	BGA-316	SGRAM

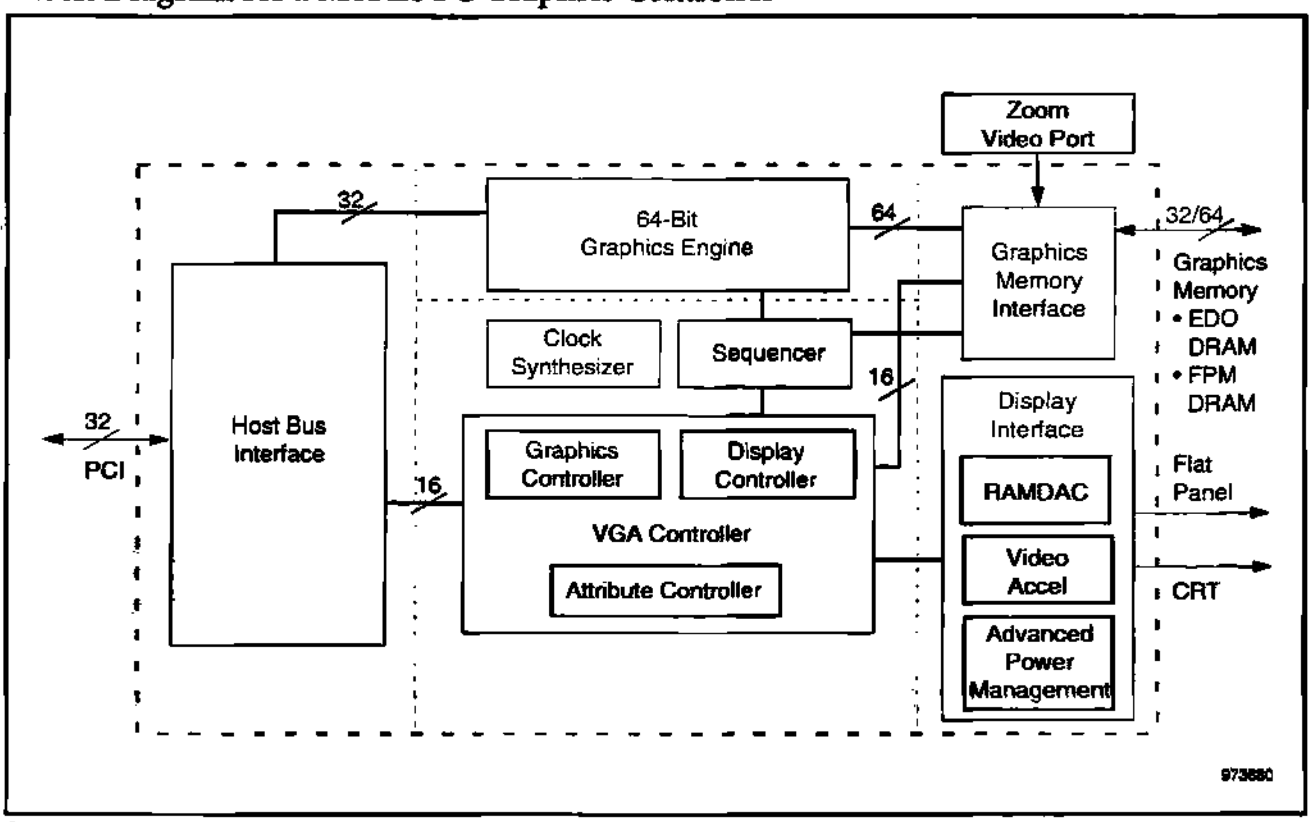
NA = Not available
Source: Dataquest (May 1997)

Figure 4-1
Block Diagram for a Deskbound PC Graphics Controller



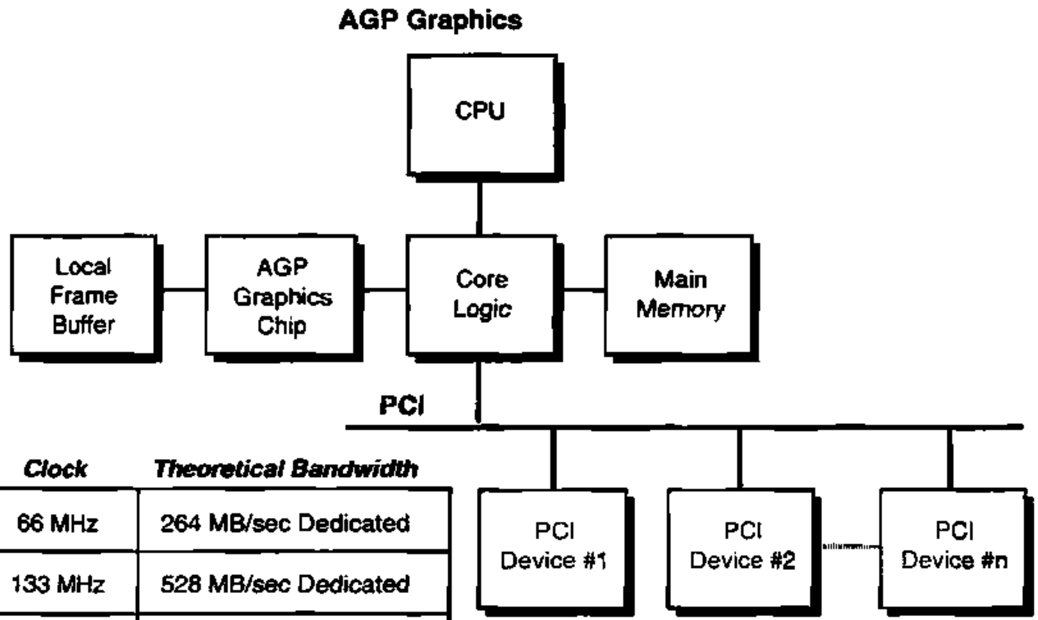
Source: Dataquest (April 1997)

Figure 4-2
Block Diagram for a Mobile PC Graphics Controller

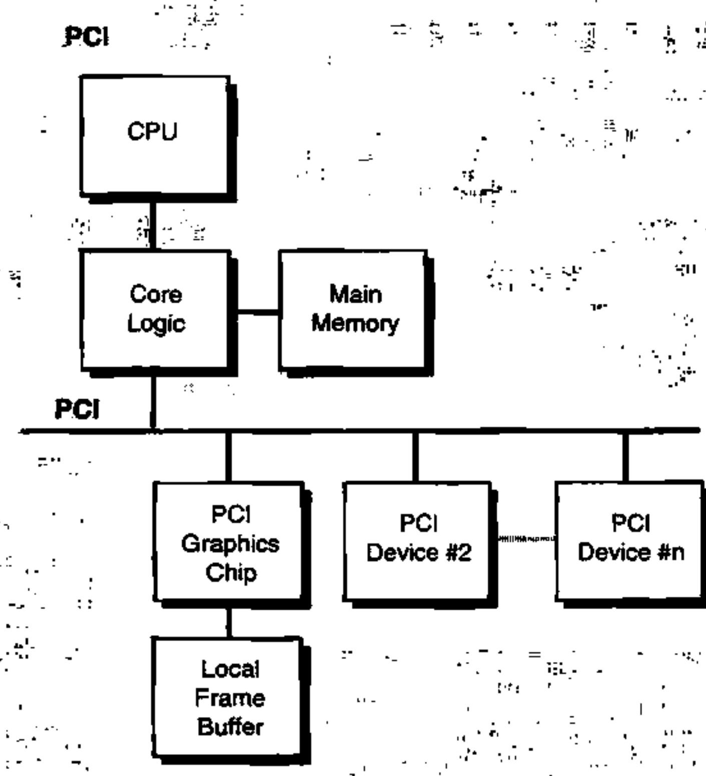


Source: Dataquest (April 1997)

Figure 4-3
Graphics Implementations: PCI versus AGP



	Clock	Theoretical Bandwidth
1x AGP	66 MHz	264 MB/sec Dedicated
2x AGP	133 MHz	528 MB/sec Dedicated
PCI	33 MHz	132 MB/sec Shared



973681

Source: Dataquest (April 1997)

Market Share

It is no surprise that S3 tops the market share rankings for 1996. S3's popular Trio64V+ chip won many designs and paved the way for the transition to 3-D graphics with the pin-compatible ViRGE. Other notable success stories of the year include ATI Technologies, Trident Microsystems, and NeoMagic. ATI doubled its unit volume again this year to reach the 10 million-unit mark. Trident grew its revenue at twice the rate of its unit shipments with strong design-wins at several top-tier PC OEMs, including IBM and NEC. NeoMagic stormed the mobile graphics market with the industry's first graphics controller that has an integrated frame buffer. The company answered the question, "Can they really do it?" by shipping a whopping 1 million units last year, up from just a few thousand the previous year. Tables 4-2, 4-3, and 4-4 show the vendor market share for the PC graphics controller market with breakouts for deskbound and mobile PC graphics markets. Figures 4-4, 4-5, and 4-6 present vendor revenue for each market segment, respectively.

Market Forecast

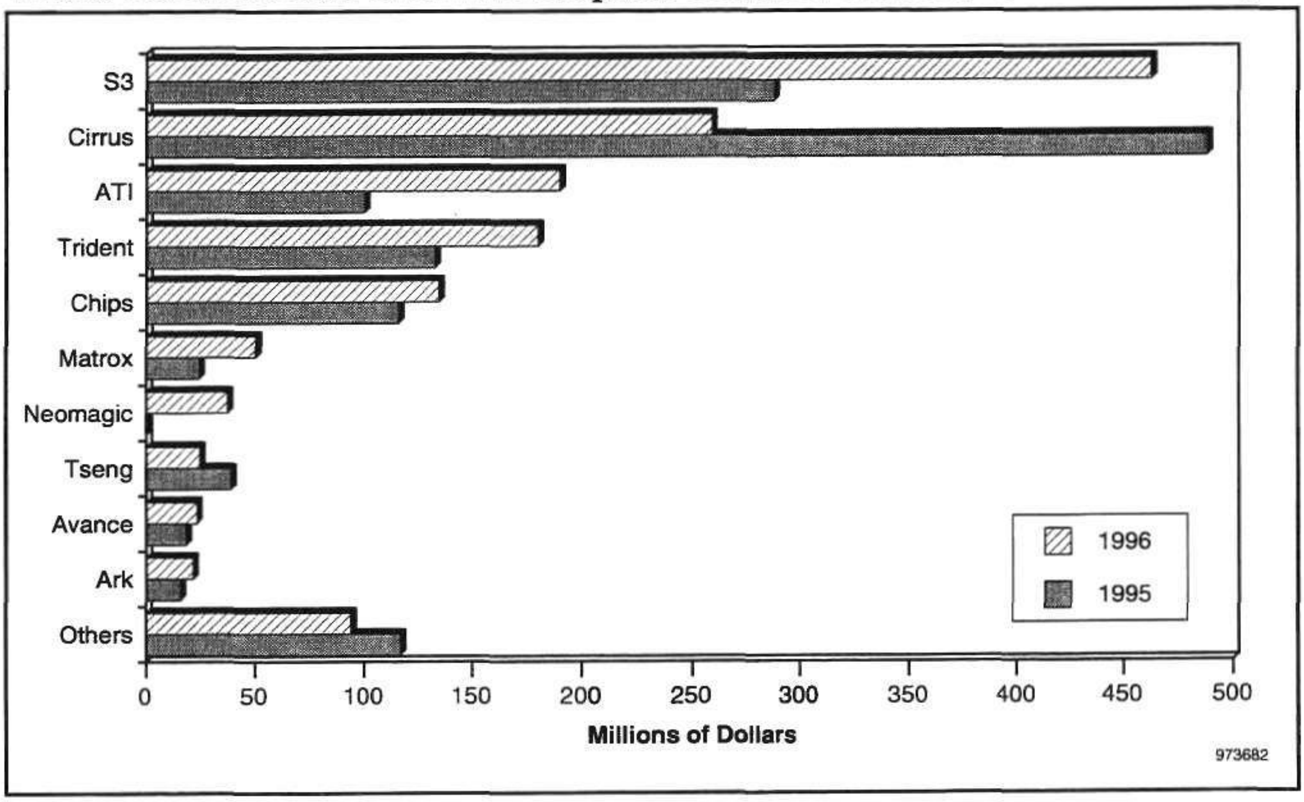
Dataquest forecasts three defining trends for the PC graphics controllers market. First, high levels of competition today will dampen revenue growth for 1997. The second and third defining trends are, respectively, the transition to greater use of IDRAM, and the increasing popularity of advanced, programmable designs like media processors. Strong revenue growth will follow the sluggish growth for 1997, fueled by rising ASPs on both the deskbound and the mobile segments of the graphics controller market.

Table 4-2
Vendor Market Share for PC Graphics Controllers

	1995 Units (K)	1996 Units (K)	Change (%)	1995 Revenue ($M)	1996 Revenue ($M)	Change (%)	1995 Rank	1996 Rank	1996 Market Share (%)
S3	15,500	29,038	87.3	288	462.8	60.7	2	1	31.3
Cirrus	26,900	17,250	-35.9	488.1	259	-46.9	1	2	17.5
ATI	5,000	10,000	100.0	100	190	90.0	5	3	12.9
Trident	10,791	12,750	18.2	132.8	180	35.5	3	4	12.2
Chips	6,425	6,430	0.1	115.9	134.5	16.0	4	5	9.1
Matrox	850	1,950	129.4	24.6	50.14	103.8	8	6	3.4
Neomagic	5	1,070	21,300.0	0.2	37.5	18,650.0	NA	7	2.5
Tseng	3,000	1,500	-50.0	39	25	-35.9	6	8	1.7
Avance	1,417	1,800	27.0	18.4	23.4	27.2	9	9	1.6
Ark	1,300	1,800	38.5	15.6	21.6	38.5	10	10	1.5
Others	6,480	5,810	-10.3	117	94	-19.7	NA	NA	6.4
Total	77,668	89,398	15.1	1339.6	1477.9	10.3	NA	NA	100.0

NA = Not available
Source: Dataquest (April 1997)

Figure 4-4
Vendor Revenue for the Overall PC Graphics Controller Market (Millions of Dollars)



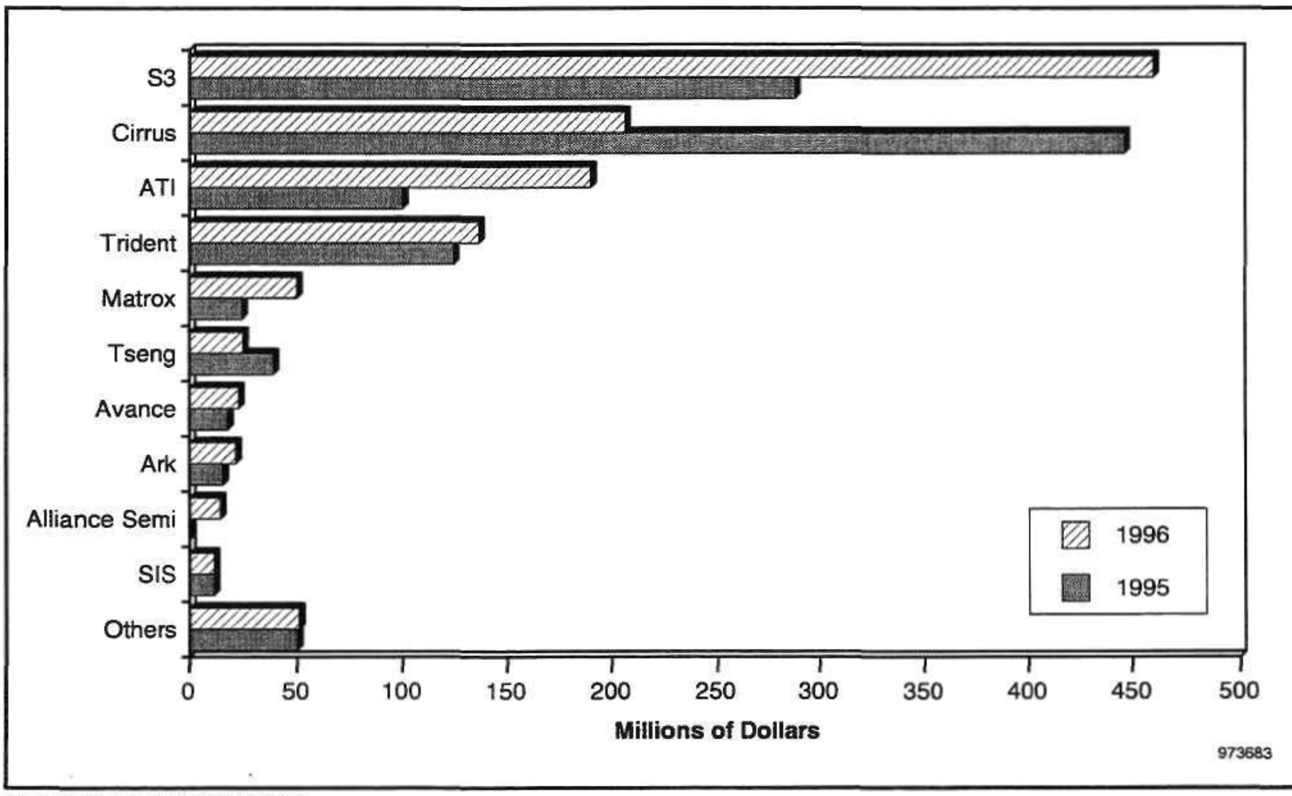
Source: Dataquest (April 1997)

Table 4-3
Vendor Market Share for Deskbound PC Graphics Controllers

	1995 Units (K)	1996 Units (K)	Change (%)	1995 Revenue ($M)	1996 Revenue ($M)	Change (%)	1995 Rank	1996 Rank	1996 Market Share (%)
S3	15,500	28,910	86.5	288	460	59.7	2	1	38.6
Cirrus	25,000	14,750	-41.0	446.3	206.5	-53.7	1	2	17.3
ATI	5,000	10,000	60.0	100	190	90.0	4	3	16.0
Trident	10,381	10,580	1.9	124.6	136.6	9.6	3	4	11.5
Matrox	850	1,950	129.4	24.6	50.14	103.8	6	5	4.2
Tseng	3,000	1,500	-50.0	39	25	-35.9	5	6	2.1
Avance	1,417	1,800	27.0	18	23	27.2	7	7	2.0
Ark	1,300	1,800	38.5	15.6	21.6	38.5	8	8	1.8
Alliance Semi	0	1,000	NA	0	14.5	NA	NA	9	1.2
SIS	896	900	0.4	11.6	11.6	0.0	10	10	1.0
Others	3,046	3,030	-0.5	50	51	2.0	NA	NA	4.3
Total	66,390	74,220	11.8	1,118	1,190	6.5	NA	NA	100.0

NA = Not available
Source: Dataquest (April 1997)

Figure 4-5
Vendor Revenue for the Deskbound PC Graphics Controller Market (Millions of Dollars)



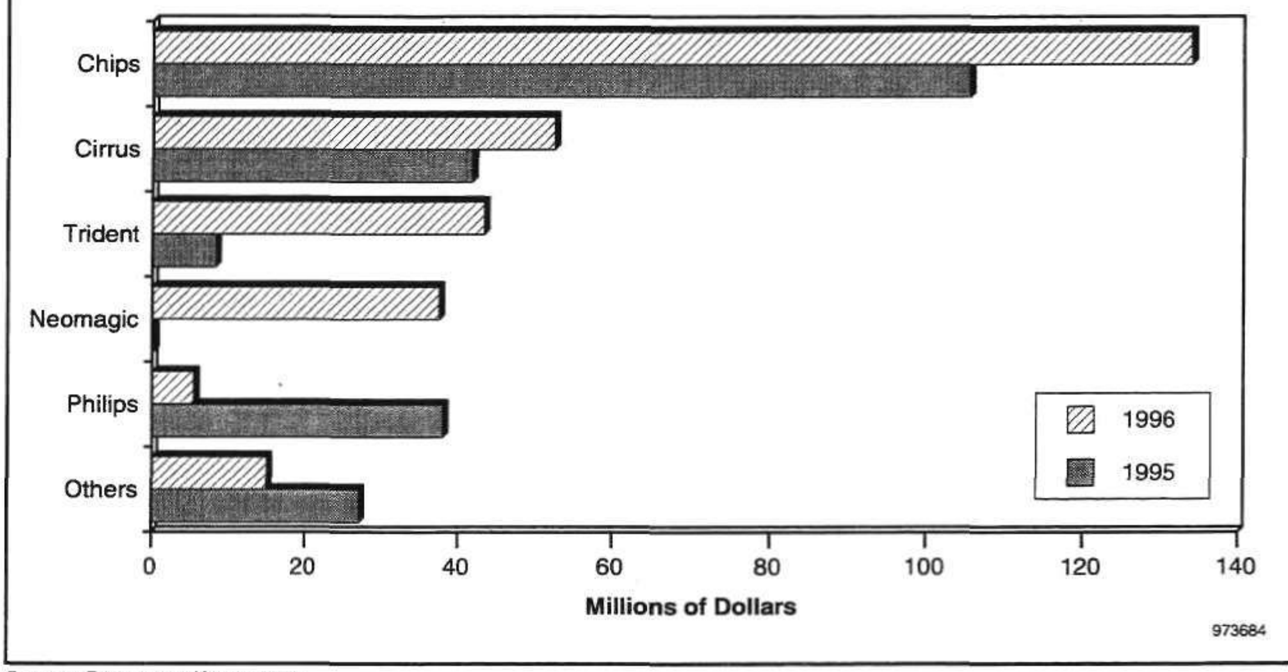
Source: Dataquest (April 1997)

Table 4-4
Vendor Market Share for Mobile PC Graphics Controllers

	1995 Units (K)	1996 Units (K)	Change (%)	1995 Revenue ($M)	1996 Revenue ($M)	Change (%)	1995 Rank	1996 Rank	1996 Market Share (%)
Chips	5,549	6,380	15.0	105.4	134	27.1	1	1	46.6
Cirrus	1,900	2,500	31.6	41.8	52.5	25.6	2	2	18.2
Trident	410	2,170	429.3	8.2	43.4	429.3	4	3	15.1
Neomagic	5	1,070	21,300.0	0.2	37.5	18,650.0	NA	4	13.0
Philips	2,000	300	-85.0	38	5.4	-85.8	3	5	1.9
Others	1,414	758	-46.4	27.26	14.9	-45.3	NA	NA	5.2
Total	11,278	13,178	16.8	221	288	30.3	NA	NA	100.0

NA = Not available
Source: Dataquest (April 1997)

Figure 4-6
Vendor Revenue for the Mobile PC Graphics Controller Market (Millions of Dollars)



Source: Dataquest (April 1997)

Competition is fierce in the graphics market today and will continue through Spring 1998. Almost all current vendors have introduced or announced plans to introduce 3-D graphics controllers. This distinguishes 1997 from 1996, when only two major graphics vendors, S3 and ATI, were shipping single-chip 3-D controllers suitable for high-volume motherboard designs. The price war of 1996 centered on 2-D products, giving S3 and ATI a chance to reap higher margins on their 3-D product offerings. The price war of 1997 has shifted to include 3-D controllers as well as 2-D controllers. Consumer multimedia PCs have been the first designs to get motherboard 3-D, but business PCs will increasingly get 3-D controllers as older 2-D graphics chips are discontinued. This will increase price pressure on low-end 3-D controllers because OEMs are reluctant to pay extra for 3-D for their business product lines. Graphics vendors will push 3-D chips into the business segment, but it will not help to increase ASPs very much.

Strong revenue growth will resume in 1998 and growth should hover around 30 percent for the following three years. Higher ASPs compounded by unit growth will quickly boost market revenue. Vendors will reap higher ASPs the old-fashioned way—they will earn them by putting more features into their products. IDRAM will be the impetus for growth in the mobile graphics segment, and advanced programmable chips will boost the deskbound graphic segment.

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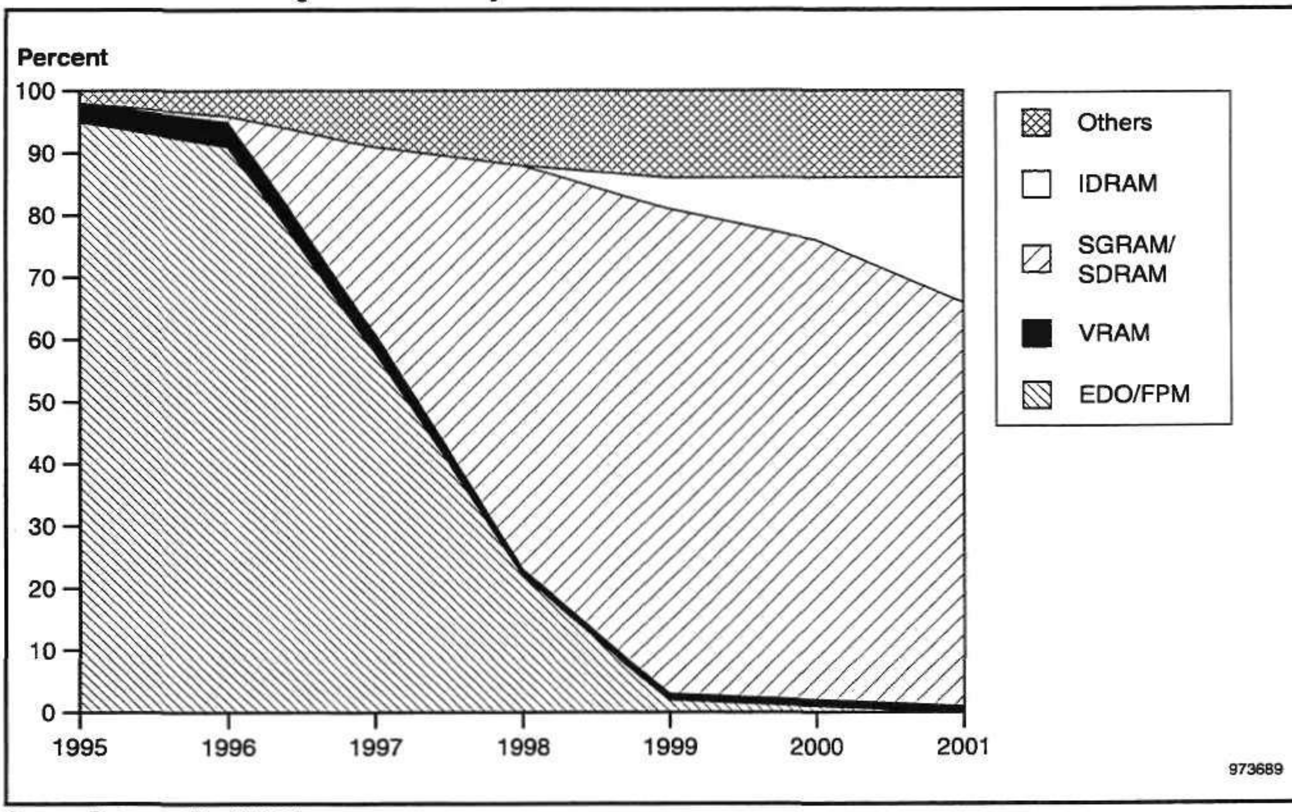
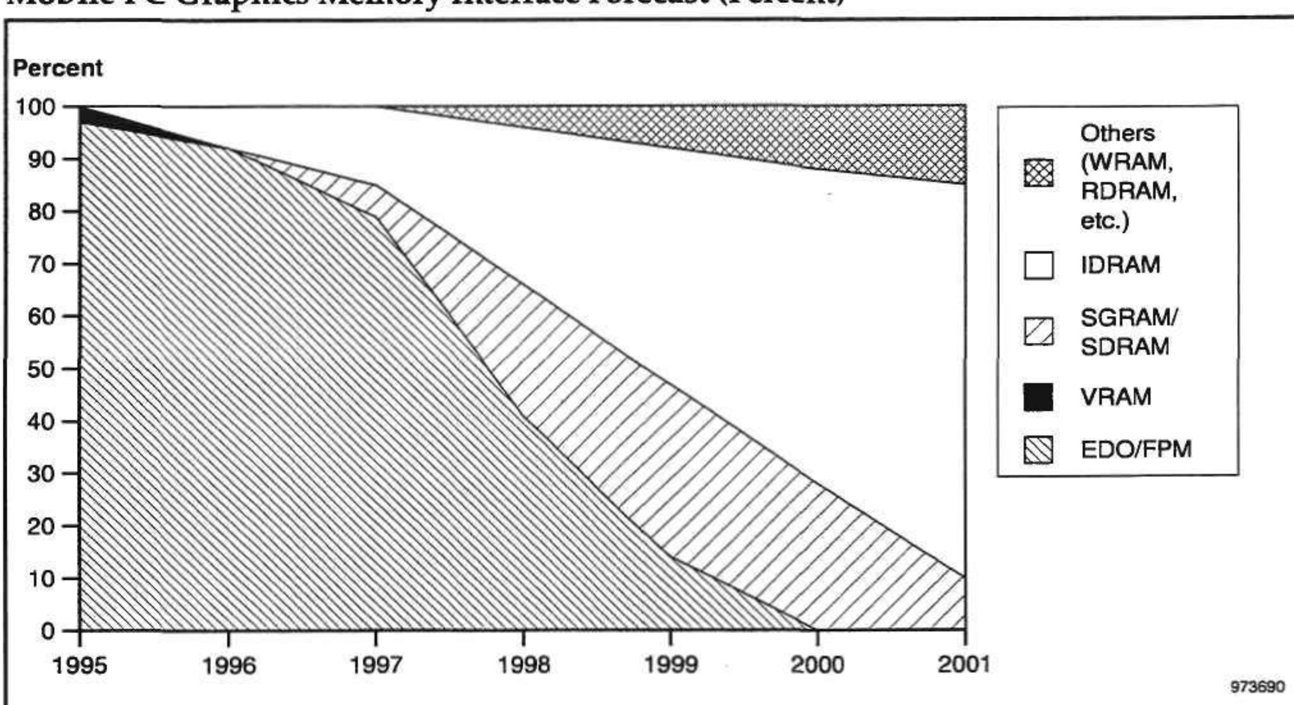
Figure 4-11
Deskbound PC Graphics Memory Interface Market Share Forecast (Percent)



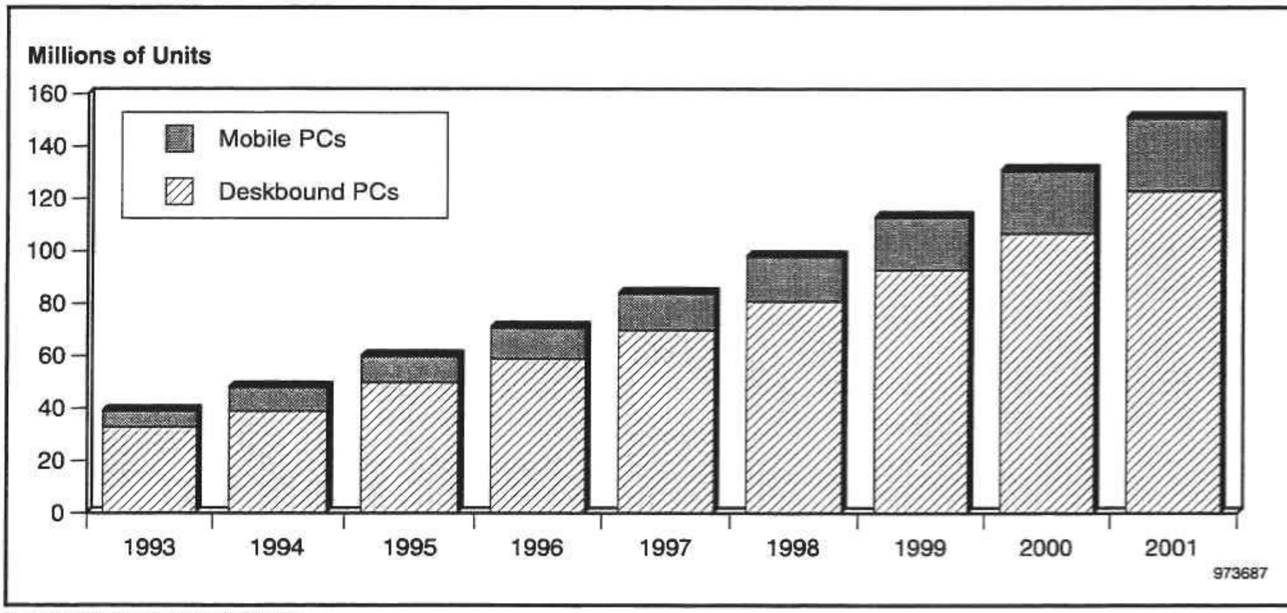
Source: Dataquest (April 1997)

Figure 4-12
Mobile PC Graphics Memory Interface Forecast (Percent)



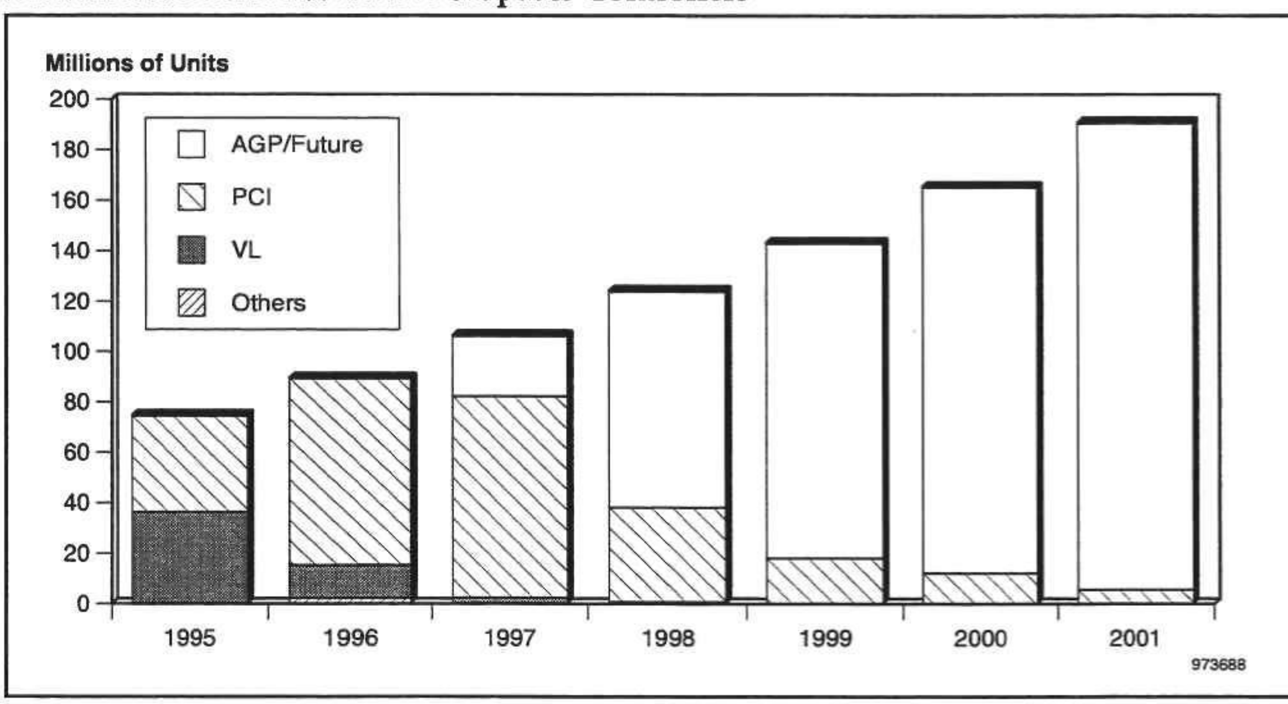
Source: Dataquest (April 1997)

Figure 4-9
PC Unit Shipment Forecast



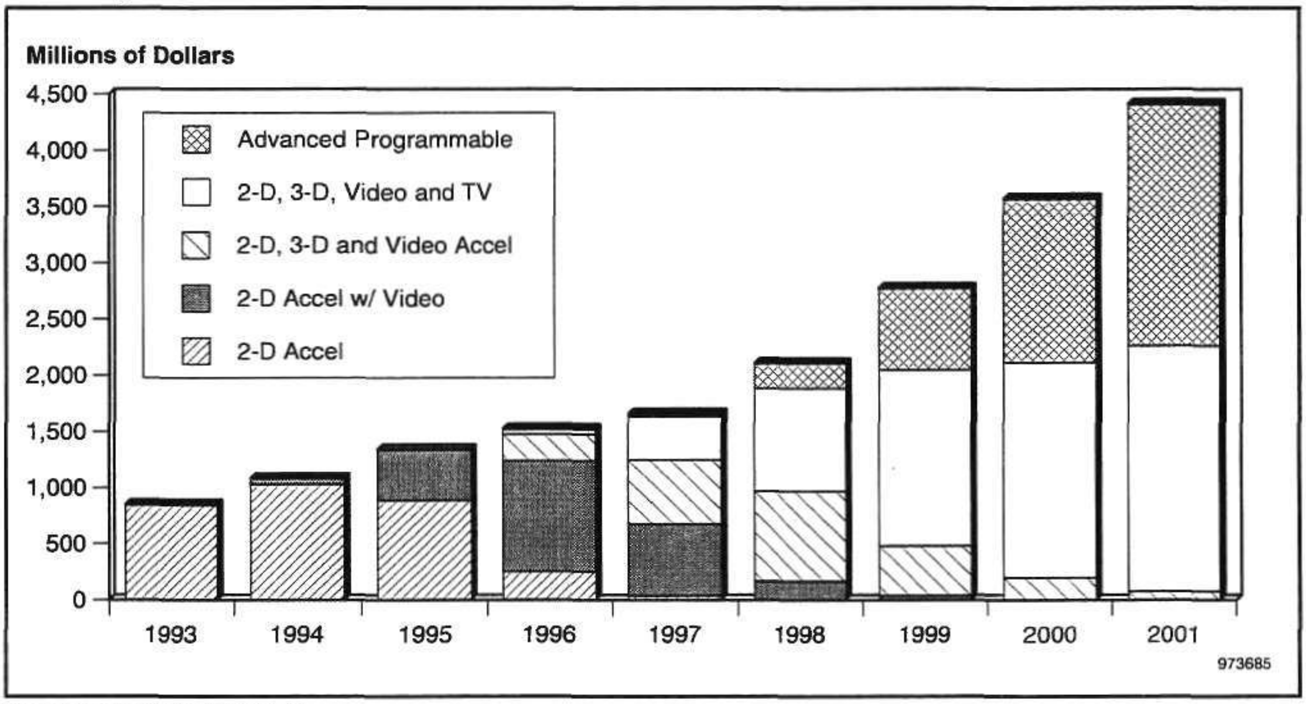
Source: Dataquest (April 1997)

Figure 4-10
Bus Interface Forecast for PC Graphics Controllers



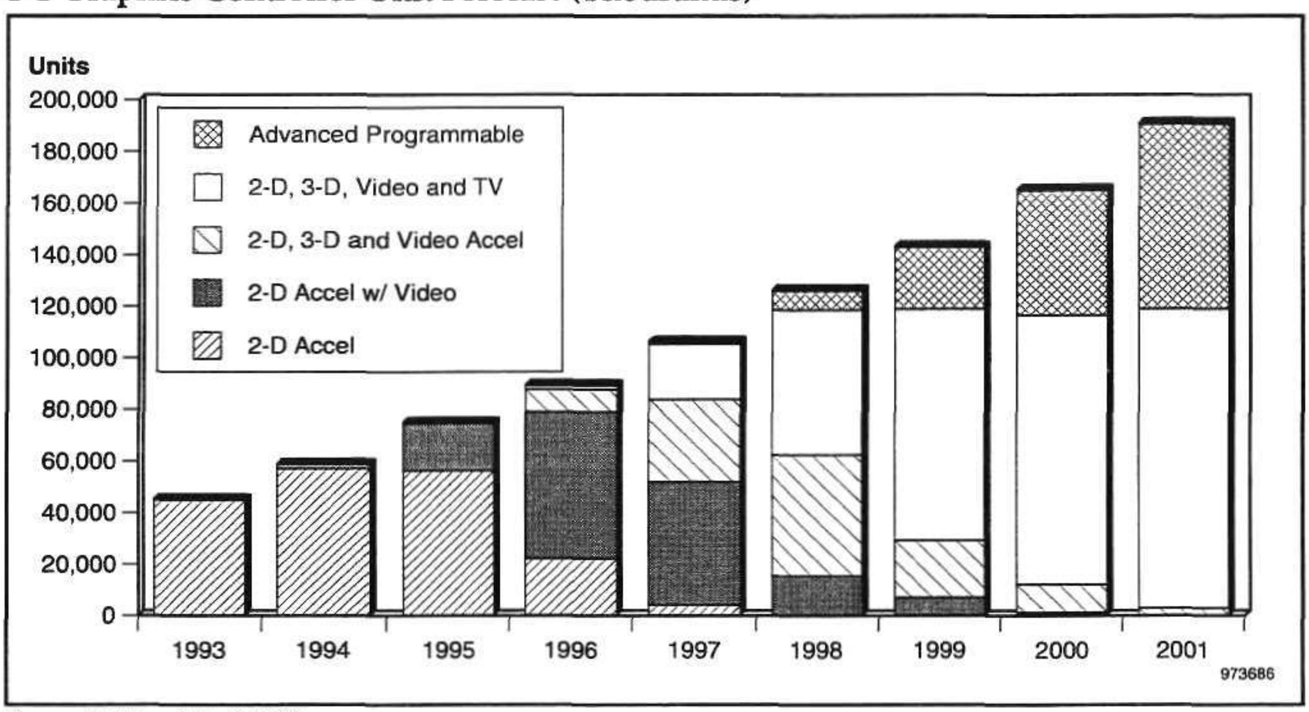
Source: Dataquest (April 1997)

Figure 4-7
PC Graphics Controller Revenue Forecast (Millions of Dollars)



Source: Dataquest (April 1997)

Figure 4-8
PC Graphics Controller Unit Forecast (Thousands)



Source: Dataquest (April 1997)

Table 4-6
PC Graphics Controller Unit Forecast (Thousands of Units)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Desktop										
2-D Accel	39,006	49,161	46,539	16,387	2,705	0	0	0	0	-100.0
2-D Accel with Video	44	1,650	16,862	49,543	36,073	10,477	6,015	0	0	-100.0
2-D, 3-D, and Video Accel	0	0	53	8,765	29,940	36,670	12,031	6,914	0	-100.0
2-D, 3-D, Video, and TV	0	0	0	1,524	20,742	52,386	78,199	82,964	87,429	124.8
Advanced Programmable	0	0	0	8	721	7,334	24,061	48,396	71,533	523.0
Total Desktop Units	39,050	50,811	63,453	76,220	90,181	104,771	120,306	138,273	158,963	15.8
Year-to-Year Desktop Units Growth (%)	NA	30.1	24.9	20.1	18.3	16.2	14.8	14.9	15.0	NA
Deskbound PC Shipments	32,712	39,252	50,259	59,067	69,887	81,194	93,232	107,156	123,190	15.8
Year-to-Year Deskbound PC Shipment Growth (%)	NA	20.0	28.0	17.5	18.3	16.2	14.8	14.9	15.0	NA
Mobile										
2-D Accel	6,010	8,029	9,925	5,930	1,610	0	0	0	0	-100.0
2-D Accel with Video	0	0	1,353	7,248	11,750	4,997	1,139	1,346	0	-100.0
2-D, 3-D, and Video Accel	0	0	0	0	1,931	10,378	10,249	4,037	3,178	NA
2-D, 3-D, Video, and TV	0	0	0	0	805	3,844	11,388	21,528	28,599	NA
Total Mobile Units	6,010	8,029	11,278	13,178	16,096	19,218	22,776	26,910	31,776	19.2
Year-to-Year Mobile Growth (%)	NA	33.6	40.5	16.8	22.1	19.4	18.5	18.2	18.1	NA
Mobile PC Shipments	6,376	8,642	9,912	11,783	14,391	17,183	20,364	24,061	28,411	19.2
Year-to-Year Mobile PC Shipment Growth (%)	NA	35.5	14.7	18.9	22.1	19.4	18.5	18.2	18.1	NA
Total										
2-D Accel	45,016	57,190	56,464	22,317	4,315	0	0	0	0	-100.0
2-D Accel with Video	44	1,650	18,215	56,791	47,822	15,474	7,154	1,346	0	-100.0
2-D, 3-D, and Video Accel	0	0	53	8,765	31,872	47,048	22,280	10,950	3,178	-18.4
2-D, 3-D, Video, and TV	0	0	0	1,524	21,547	56,229	89,587	104,492	116,028	137.8
Advanced Programmable	0	0	0	8	721	7,334	24,061	48,396	71,533	523.0
Total PC Graphics Controller	45,060	58,840	74,731	89,398	106,277	123,989	143,081	165,183	190,739	16.4
Total Year-to-Year Growth (%)	NA	30.6	27.0	19.6	18.9	16.7	15.4	15.4	15.5	NA
Total PC Units	39,088	47,894	60,171	70,850	84,278	98,377	113,596	131,217	151,601	NA
Total Year-to-Year Growth (%)	NA	22.5	25.6	17.7	19.0	16.7	15.5	15.5	15.5	NA

NA = Not available
Source: Dataquest (April 1997)

Table 4-5
PC Graphics Controller Revenue Forecast (Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Desktop										
2-D Accel	692.1	829.0	702.7	147.5	13.5	0	0	0	0	-100.0
2-D Accel with Video	1.2	49.5	413.1	808.0	378.8	89.1	30.1	0	0	-100.0
2-D, 3-D, and Video Accel	0	0	2.4	234.9	524.0	532.1	177.5	92.6	0	-100.0
2-D, 3-D, Video, and TV	0	0	0	41.2	363.0	812.6	1,273.1	1,303.2	1,400.0	102.5
Advanced Programmable	0	0	0	0.3	21.6	220.0	721.8	1451.9	2146.0	504.1
Total Desktop Revenue	693.2	878.5	1,118.1	1,231.8	1,300.9	1,653.8	2,202.5	2,847.6	3,546.0	23.5
Year-to-Year Desktop Growth (%)	NA	26.7	27.3	10.2	5.6	27.1	33.2	29.3	24.5	NA
Mobile										
2-D Accel	155.0	201.1	186.6	106.6	25.8	0	0	0	0	-100.0
2-D Accel with Video	0	0	34.2	181.1	258.5	79.9	13.7	5.4	0	-100.0
2-D, 3-D, and Video Accel	0	0	0	0	50.2	269.8	261.4	102.9	79.4	NA
2-D, 3-D, Video, and TV	0	0	0	0	21.6	103.4	296.1	612.7	786.5	NA
Total Mobile Revenue	155.0	201.1	220.9	287.7	356.1	453.2	571.1	721.1	865.9	24.7
Year-to-Year Mobile Growth (%)	NA	29.7	9.9	30.3	23.8	27.2	26.0	26.3	20.1	NA
Total										
2-D Accel	847.1	1,030.0	889.4	254.1	39.3	0	0	0	0	-100.0
2-D Accel with Video	1.2	49.5	447.3	989.1	637.3	169.0	43.7	5.4	0	-100.0
2-D, 3-D, and Video Accel	0	0	2.4	234.9	574.2	802.0	438.8	195.5	79.4	-19.5
2-D, 3-D, Video, and TV	0	0	0	41.2	384.6	916.0	1,569.2	1,915.9	2,186.4	121.3
Advanced Programmable	0	0	0	0.3	21.6	220.0	721.8	1,451.9	2,146.0	504.1
Total Graphics Controller Revenue	848.2	1,079.5	1,339.0	1,519.5	1,657.0	2,107.0	2,773.6	3,568.7	4,411.9	23.8
Total Year-to-Year Growth (%)	NA	27.3	24.0	13.5	9.0	27.2	31.6	28.7	23.6	NA

NA = Not available
Source: Dataquest (April 1997)

Advanced programmable chips will be quite similar to media processors and may be indistinguishable from them. This segment was added to the forecast to show how media processors might penetrate the traditional graphics market unit volumes. Dataquest believes that graphics controllers will gradually become much more like media processors as graphics vendors strive to add new features focused on processing graphics, digital video, and TV. This should not imply that media processor companies will enjoy a large advantage over existing graphics chip vendors. Evolution, not revolution, is the key here. Traditional graphics vendors have plenty of time to create products in the media processor category, and they will have an advantage if they are able to retain ownership of those sockets as the transition takes place.

Dataquest believes that the graphics controller is the most likely device to grow into the media processor category. Audio controllers are more rapidly becoming programmable, but the graphics controller is the biggest and most expensive peripheral that is common to virtually every PC. The history of the graphics business has been to pull the functions of neighboring chips into the central chip, and this will continue. The lowly VGA controller has been augmented with clocks, a RAMDAC, 2-D acceleration, 3-D acceleration, video acceleration, TV flicker filters, frame buffer memory, nonvolatile memory for basic input/output system (BIOS), and plug-and-play, among others. Each of those items previously required separate chips or were done on the host CPU. This trend continues as graphics controllers assume a greater role in the integration of graphics, digital video, and audio processing.

Tables 4-5 and 4-6 show the market forecast for PC graphics controllers with specific breakouts for the deskbound and mobile market segments. Figures 4-7, 4-8, and 4-9 present the same data graphically. Figure 4-9 shows the PC unit shipment forecast split by deskbound and mobile segments. Figure 4-10 shows the bus interface forecast for PC graphics controllers. Figures 4-11 and 4-12 show the memory interface forecast for the deskbound and mobile PC graphics controller segments, respectively.

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Market Statistics

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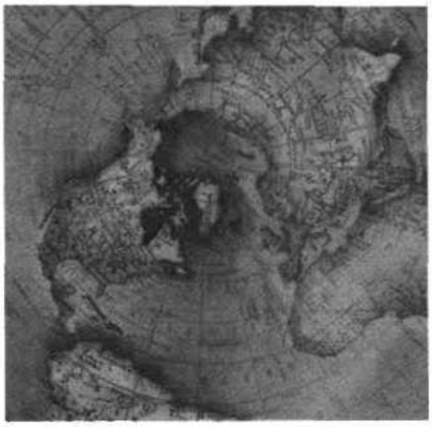

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Dataquest

Competitive Trends for the 1997 PC Graphics and PC Audio Chip Markets

Competitive Trends

Program: Personal Computer Semiconductors and Applications Worldwide
Product Code: PSAM-WW-CT-9701
Publication Date: December 8, 1997
Filing: Reports

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Chapter 1

Executive Summary

Hearing and vision are two of the most important of the human senses. Graphics and audio chips make the computing experience even more compelling by allowing users to experience those senses as they do in real life. The markets for these chips excite people because they are growing, and the products create benefits that people can see and hear. New chip vendors are always trying to establish a foothold in the market to take their share of the billions of dollars in revenue just as the most successful vendors endeavor to keep their socket ownership from one design cycle to the next. The result is a parade of success stories and rising stars that burn brightly for a few years only to be eclipsed by a bigger, brighter star—joined by those few vendors that put in a solid showing year in and year out.

The PC audio chip market will decline this year despite much higher unit shipments. Prices have fallen to half or less what they were at the end of last year. Basic features cost only a few dollars and these bargain prices will help make audio features ubiquitous. Vendors need to sell PCI-based products with high-end features for revenue growth.

Market growth for graphics is driven by new 3-D accelerators and higher unit shipments, but price erosion offsets some of that growth. Integrated memories spur ASP growth too, particularly for the mobile segment of the market. These growth factors will drive the PC graphics controller market to more than $4 billion in 2001. Profits may be more elusive than market growth because of the huge number of vendors and the impending consolidation that this overcrowding will bring.

This document covers the competitive dynamics for the PC graphics controller and PC audio chip markets. Market share statistics and revised market forecasts are included as well as feature comparisons of popular products and brief vendor profiles.

Project Analyst: Geoff Ballew

Chapter 2
Introduction and Methodology

This document provides reference information and analysis about the markets for semiconductor devices in personal computers.

The information in this report is gathered from both primary and secondary sources. Primary sources include surveys and interviews of industry vendors and customers, as well as analyst knowledge and opinions. Secondary sources include government and trade sources on sales, production, trade, and public spending. Semiconductor content assumptions are based on both surveys of producing OEMs and physical teardown evaluations by Dataquest analysts of representative personal computers.

The forecast methodology is based on various methods and assumptions, depending on the specific market. To form a solid basis for projecting system demand and capital, government and consumer spending, assumptions are made for various regions of the world. For specific markets, saturation and displacement dynamics are considered as well. Key exogenous factors such as new software introductions, exchange rate changes, and government policies are also considered. Semiconductor content forecasts are based on interviews of system marketers and designers (including makers of enabling semiconductor technology), along with an analysis of historical trends.

Chapter 3
PC Audio Competitive Trends

The PC audio chip market has come of age as an essential element of the PC semiconductor market. Audio features are standard on virtually all notebook PCs and are a mainstay of consumer PCs. The age of multimedia has also carried audio features into the realm of corporate desktops. Corporate buyers of PCs will not pay extra for audio features, but they are getting them anyway. This market has evolved over the past three years from a high-margin, low-competition business to a lower-margin, high-competition business. Intellectual property (IP) lawsuits and some clever engineering have leveled the playing field with respect to legacy software compatibility, leaving the future battles to be won on price and performance rather than the IP issues of yesteryear.

Market Share Statistics

This year, Dataquest included custom chips in the market share rankings for Creative Technology Ltd. and Aztech Systems Ltd. The reason for including chip value shipped at the board level is to characterize market influence and impact more accurately. Table 3-1 and Figure 3-1 show the 1996 market share data for PC audio chips. These market share numbers do not include revenue from standalone FM synthesis chips, standalone wavetable synthesis chips, or wavetable sample ROMs.

Current Product Offerings

Table 3-2 lists some key features of several PC audio chips from leading vendors. Chapter 5 contains a profile of every vendor listed in Table 3-2.

Market Forecast

Price erosion is making basic audio features very inexpensive and is the primary cause of the revenue decline forecast for this year. The audio chip forecast is characterized by overall growth, but not this year. 1998 should snap back as PCI-based products grow as a percentage of unit shipments. These products necessarily carry a higher price but offer distinct advantages that make them worth the extra money.

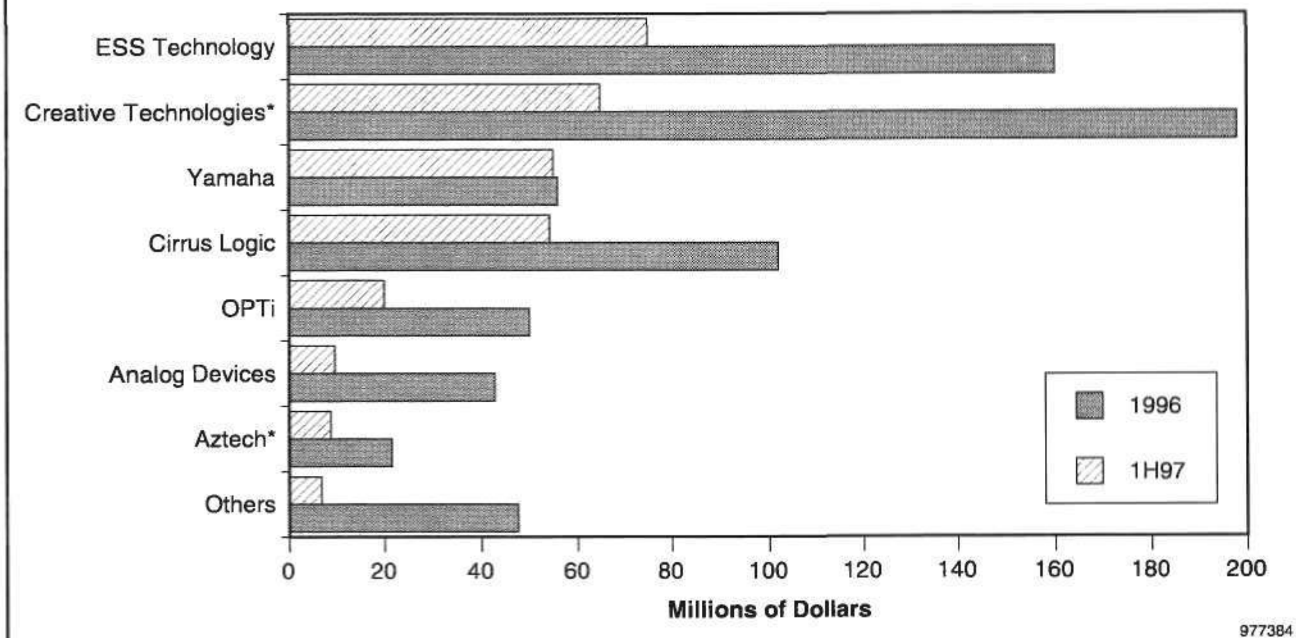
Unit shipments continue to grow much faster than PCs because the attach rate of audio chips to new PCs continues to increase. Dataquest expects audio to become a standard feature on all PCs by the year 2000. As price pressure eases in 1998, Dataquest expects a revenue growth rate of 20 percent. Growth will be slower near the end of the forecast because the attach rate will saturate at 100 percent.

Table 3-1
First-Half 1997 PC Audio Chip Market Share

	Standalone Codecs (K) 1H97	Chipsets Shipped on Board-Level Products (K) 1H97	Chipsets Sold as Chips (K) 1H97	Total Units (K) 1H97	Chip Revenue ($M) 1H97	Chip Revenue ($M) 1996	Revenue Market Share 1H97	Revenue Market Share 1996	Change in Share
ESS Technology	-	-	9,100	9,100	75.0	160.0	25.5	23.6	1.9
Creative Technologies	-	5,000	2,200	7,200	64.8	198.0	22.0	29.2	-7.2
Yamaha	-	-	6,500	6,500	55.0	56.0	18.7	8.3	10.5
Cirrus Logic	1,709	-	4,900	6,609	54.3	102.0	18.5	15.0	3.4
OPTi	-	-	3,000	3,000	20.0	50.0	6.8	7.4	-0.6
Analog Devices	7,834	-	0	7,834	9.5	42.8	3.2	6.3	-3.1
Aztech	-	1,750	25	1,775	8.6	21.6	2.9	3.2	-0.2
Others	-	-	500	500	6.7	47.6	2.3	7.0	-4.8
Total	**9,543**	**6,750**	**26,225**	**42,518**	**293.9**	**678.0**	**100.0**	**100.0**	**-**

Source: Dataquest (October 1997)

Figure 3-1
First-Half 1997 PC Audio Chip Market Share



* Includes revenue for chips shipped on board-level products
Source: Dataquest (September 1997)

A second major trend centers on Intel's AC-97 initiative. AC-97 implementations use a separate codec rather than an integrated one. This puts renewed emphasis on audio quality and is helping drive the shift to PCI and wavetable synthesis at the same time.

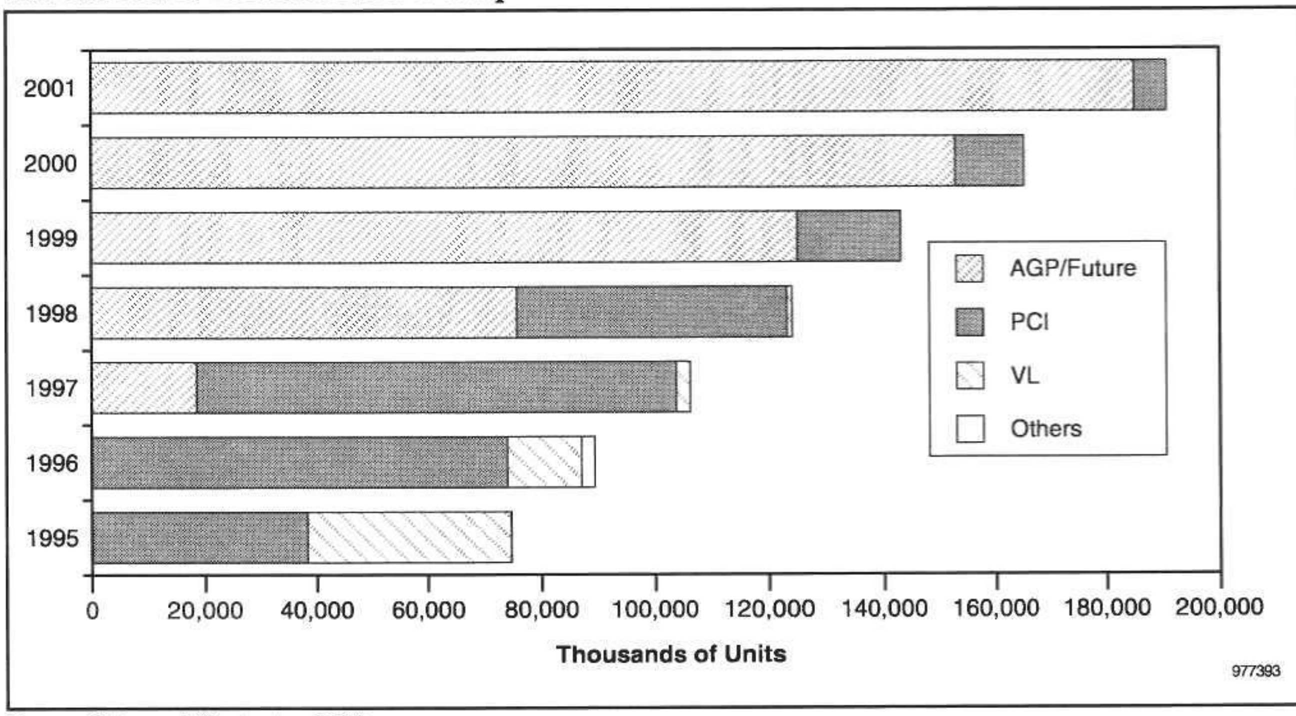
Table 3-3 and Figure 3-2 show the forecast for PC audio chip shipments and revenue, and Table 3-4 and Figure 3-3 show the revenue and unit forecast, respectively, for bus interface for PC audio chips.

Table 3-2
Features of Many Popular PC Audio Chips

Vendor	Product Name/Number	Type	Synthesis	Spatial Enhancement	True 3-D Sound	Interface	Package
Creative Technologies	Vibra	Integrated controller/codec	FM	Yes	no	ISA	TQFP-100
Cirrus Logic	CS4237B	Integrated controller/codec	FM	SRS	No	ISA	TQFP-100
	CS4238B	Integrated controller/codec	FM	Qsound	No	ISA	TQFP-100
	CS4610/11	Controller	WT,WG	None	Yes	PCI	PQFP-100
	CS4297	AC-97 codec	N/A	None	NA	AC-97	TQFP-48
ESS Technology	ES1878	Integrated controller/codec	FM	No	No	ISA	TQFP-100
	ES690	Controller	WT	No	No	MPU-401	PQFP-52
	Maestro-1	Controller	FM, WT	Yes	Yes	PCI	PQFP-208
	Maestro-2	Controller	FM, WT	Yes	Yes	PCI	TQFP-100
	ES1918	AC-97 codec	N/A	No	NA	AC-97	TQFP-48/64
Oak Technology	TelAudia, OTI-610	Controller	WT	No	Yes	PCI	PQFP-160
	OTI-612	AC-97 codec	N/A	No	NA	AC-97	Unknown
Opti	OptiSound 82C931	Integrated controller/codec	FM	None	No	ISA	PQFP-100
S3	SonicVibes	Integrated controller/codec	FM, WT	SRS	No	PCI or ISA	PQFP-160
VLSI	Songbird VL82C829	Controller	FM, WT, WG	No	Yes	PCI	PQFP-160
Yamaha	OPL3-SA	Integrated controller/codec	FM	No	No	ISA	TQFP-100
	OPL4-ML	Controller	FM, WT	No	No	ISA	TQFP-100

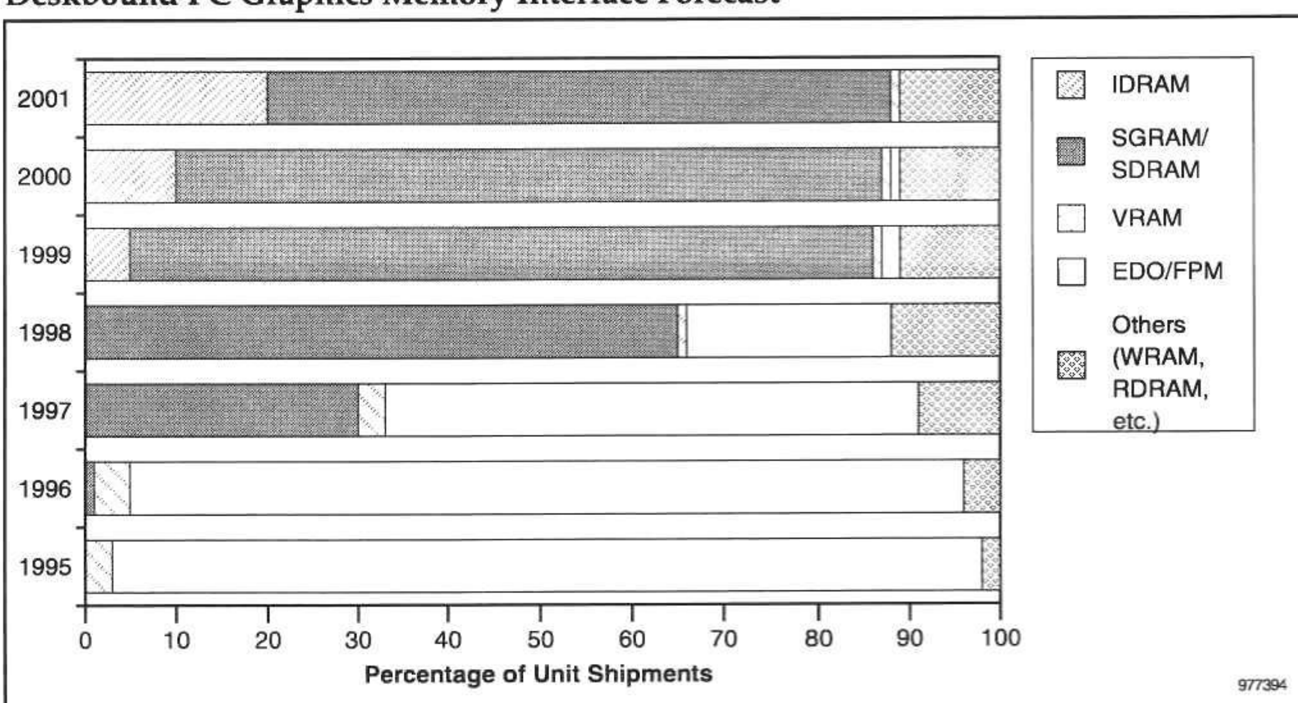
NA = Not applicable
Source: Dataquest (September 1997)

Figure 4-7
Bus Interface Forecast for PC Graphics Controllers



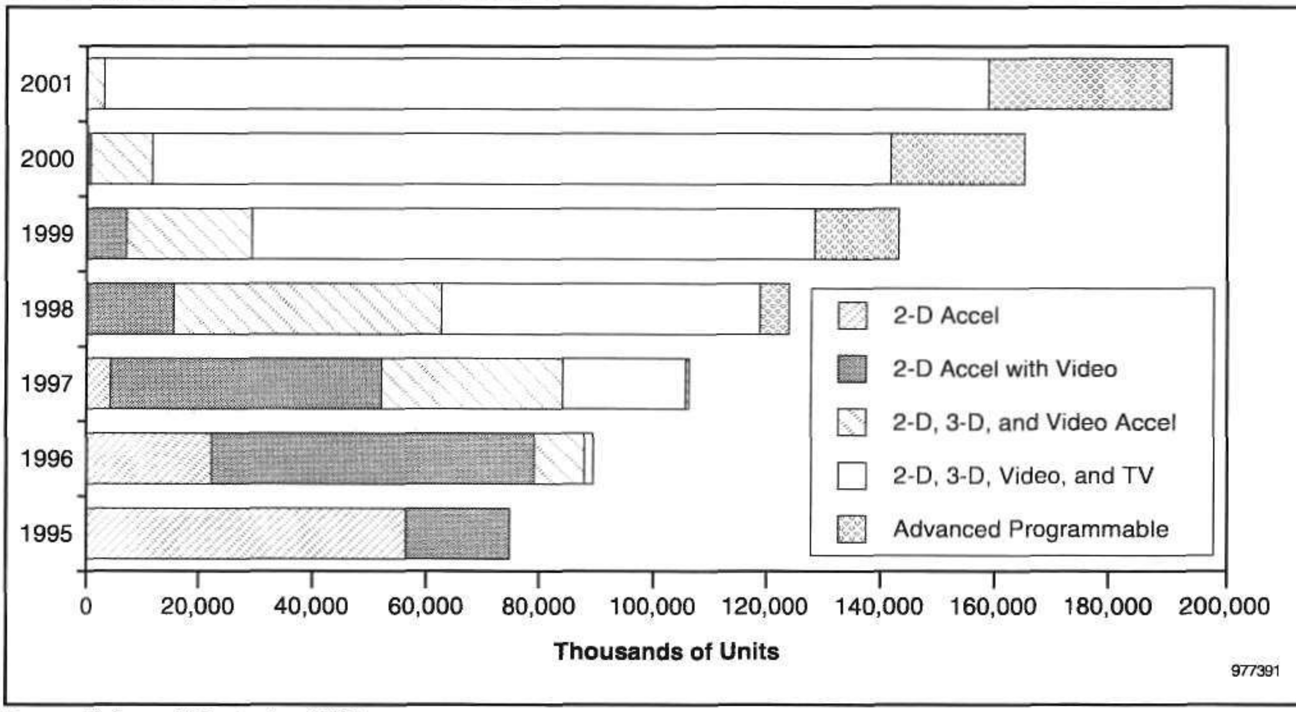
Source: Dataquest (September 1997)

Figure 4-8
Deskbound PC Graphics Memory Interface Forecast



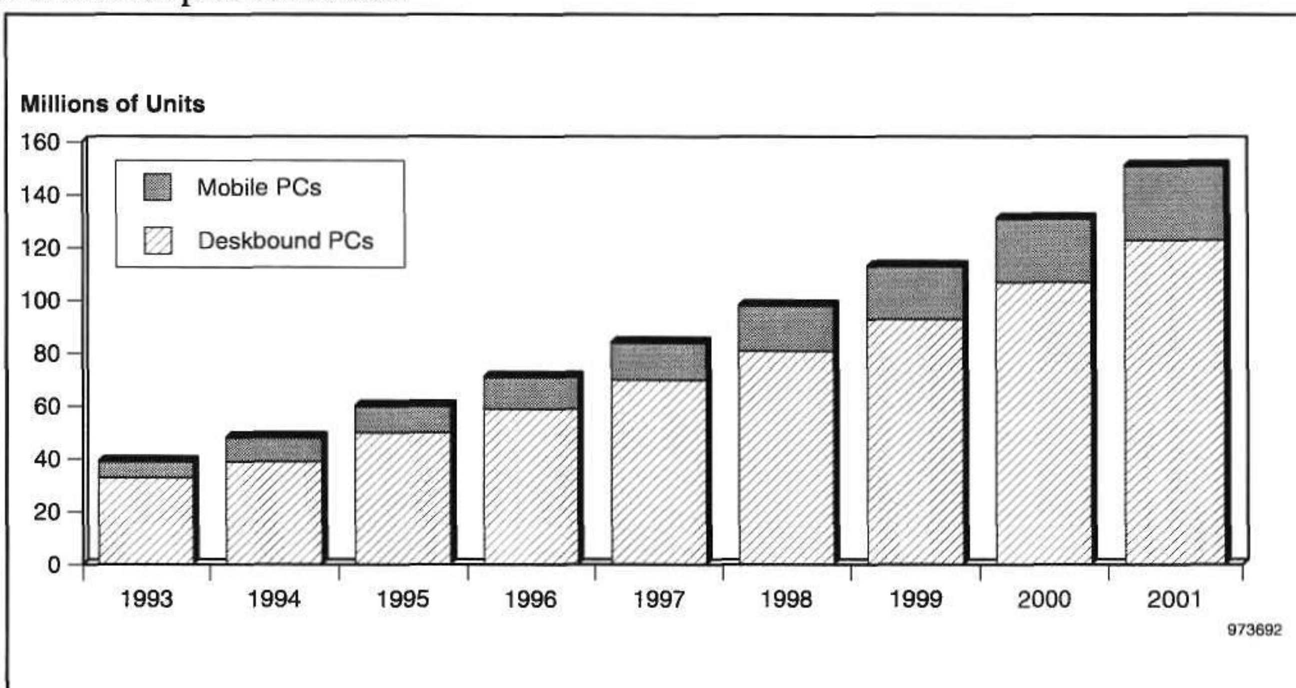
Source: Dataquest (September 1997)

Figure 4-5
PC Graphics Controller Unit Forecast



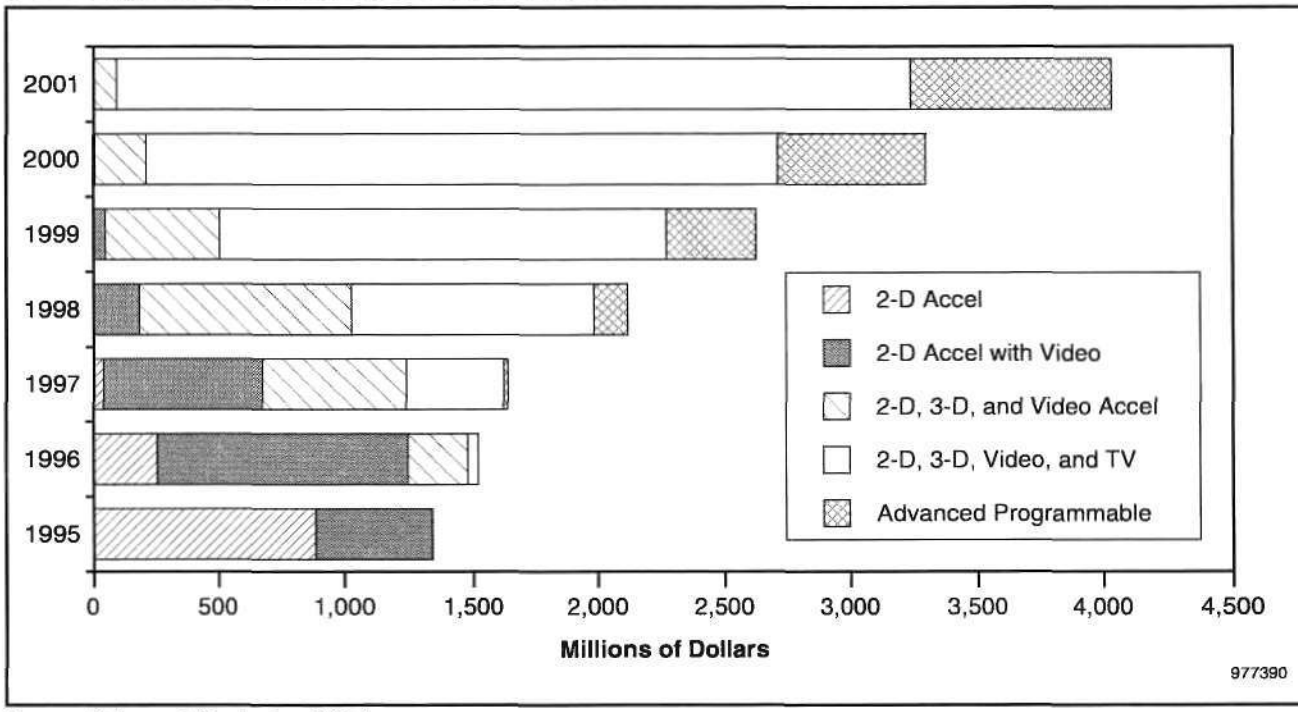
Source: Dataquest (September 1997)

Figure 4-6
PC Unit Shipment Forecast



Source: Dataquest (September 1997)

Figure 4-4
PC Graphics Controller Revenue Forecast



Source: Dataquest (September 1997)

Table 4-6
Deskbound PC Graphics Controller Unit Forecast (Thousands of Units)

		1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Desktop	2-D Accel	46,539	16,387	2,705	0	0	0	0	-100.0
	2-D Accel with Video	16,862	49,543	36,073	10,477	6,015	0	0	-100.0
	2-D, 3-D, and Video Accel	53	8,765	30,030	36,670	12,031	6,914	0	-100.0
	2-D, 3-D, Video, and TV	0	1,524	20,742	52,386	87,823	107,853	127,170	142.2
	Advanced Programmable		8	631	5,239	14,437	23,506	31,793	429.7
	Total Units	**63,453**	**76,228**	**90,181**	**104,771**	**120,306**	**138,273**	**158,963**	**15.8**
Mobile	2-D Accel	9,925	5,930	1,610	0	0	0	0	-100.0
	2-D Accel with Video	1,353	7,248	11,750	4,997	1,139	673	0	-100.0
	2-D, 3-D, and Video Accel	0	0	1,931	10,378	10,249	4,037	3,178	NA
	2-D, 3-D, Video, and TV	0	0	805	3,844	11,388	22,201	28,599	NA
	Total Units	**11,278**	**13,178**	**16,096**	**19,218**	**22,776**	**26,910**	**31,776**	**19.2**
Total	2-D Accel	56,464	22,317	4,315	0	0	0	0	-100.0
	2-D Accel with Video	18,215	56,791	47,822	15,474	7,154	673	0	-100.0
	2-D, 3-D, and Video Accel	53	8,765	31,962	47,048	22,280	10,950	3,178	-18.4
	2-D, 3-D, Video, and TV	0	1,524	21,547	56,229	99,211	130,054	155,769	152.3
	Advanced Programmable	0	8	631	5,239	14,437	23,506	31,793	429.7
	Total Units	**74,731**	**89,406**	**106,277**	**123,989**	**143,081**	**165,183**	**190,739**	**16.4**

NA = Not applicable
Source: Dataquest 1997

Competition is fierce in the graphics market and will continue through spring 1998. Almost all current vendors have introduced or announced plans to introduce 3-D graphics controllers. This contrasts 1997 from 1996 when only two major graphics vendors, S3 and ATI, were shipping single-chip 3-D controllers suitable for high-volume motherboard designs. The price war of 1996 centered around 2-D products, giving S3 and ATI a chance to reap higher margins for their 3-D product offerings. The price war of 1997 shifted to include 3-D controllers as well as 2-D controllers. Consumer multimedia PCs have been the first designs to get "motherboard" 3-D, but business PCs will increasingly get 3-D controllers as older 2-D graphics chips are discontinued. This will increase price pressure on low-end 3-D controllers because OEMs are reluctant to pay extra for 3-D for their business product lines. Graphics vendors will push 3-D chips into the business segment, but it will not help to increase ASPs until mainstream applications (for example, Microsoft Office) can make use of advanced 3-D features and require higher levels of performance. The value proposition for 3-D graphics is clear for consumer and professional applications but remains cloudy for most productivity applications.

Tables 4-5 and 4-6 show the market forecast for PC graphics controllers with specific breakouts for the deskbound and mobile market segments. Figures 4-4 and 4-5 present the same data graphically. Figure 4-6 shows the PC unit shipment forecast split by deskbound and mobile segments. Figure 4-7 shows the bus interface forecast for PC graphics controllers. Figures 4-8 and 4-9 show the memory interface forecast for the deskbound and mobile PC graphics controller segments, respectively.

Table 4-5
PC Graphics Controller Revenue Forecast (Millions of Dollars)

Segment	Product Type	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Desktop	2-D Accel	703	147	14	0	0	0	0	-100.0
	2-D Accel with Video	413	808	379	89	30	0	0	-100.0
	2-D, 3-D, and Video Accel	2	235	511	551	163	90	0	-100.0
	2-D, 3-D, Video, and TV	0	41	363	840	1,418	1,805	2,247	122.6
	Advanced Programmable	0	0	16	131	361	588	795	395.3
	Total Revenue	**1,118**	**1,232**	**1,282**	**1,611**	**1,972**	**2,483**	**3,042**	**19.8**
Mobile	2-D Accel	187	107	26	0	0	0	0	-100.0
	2-D Accel with Video	34	181	258	94	17	7	0	-100.0
	2-D, 3-D, and Video Accel	0	0	50	294	295	115	92	NA
	2-D, 3-D, Video, and TV	0	0	21	118	342	693	899	NA
	Total Revenue	**221**	**288**	**355**	**506**	**655**	**815**	**990**	**28.0**
Total	2-D Accel	889	254	39	0	0	0	0	-100.0
	2-D Accel with Video	447	989	637	183	47	7	0	-100.0
	2-D, 3-D, and Video Accel	2	235	561	845	458	205	92	-17.2
	2-D, 3-D, Video, and TV	0	41	384	958	1,760	2,498	3,146	138.0
	Advanced Programmable	0	0	16	131	361	588	795	395.3
	Total Revenue	**1,339**	**1,520**	**1,637**	**2,117**	**2,627**	**3,298**	**4,032**	**21.6**

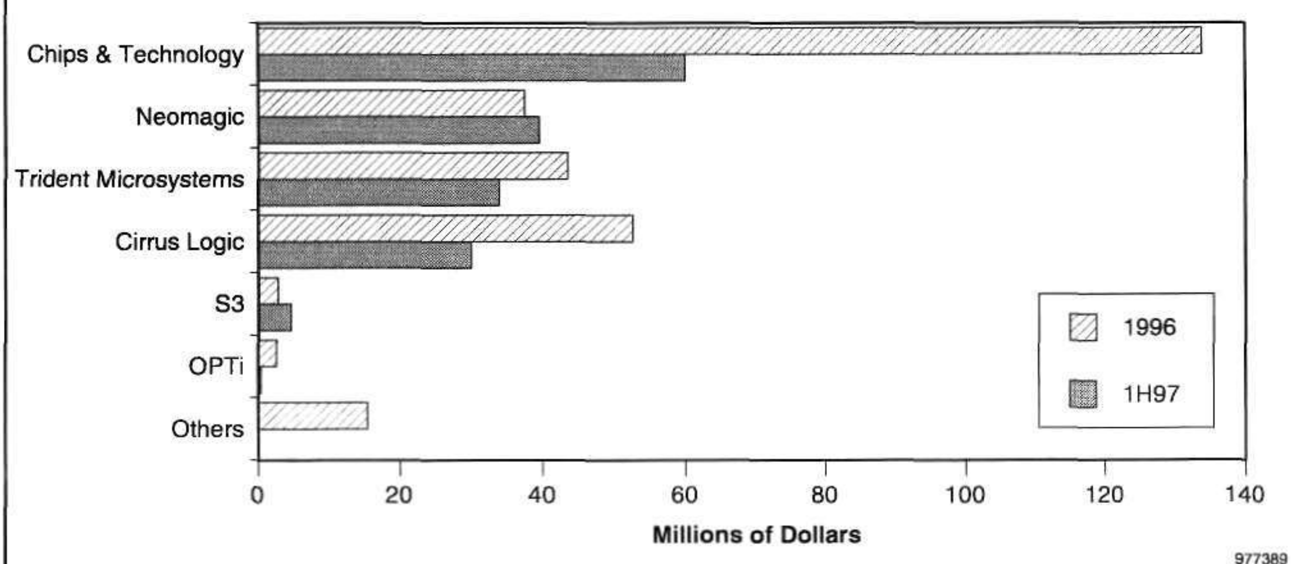
NA = Not applicable
Source: Dataquest 1997

Table 4-4
First-Half 1997 Mobile PC Graphics Controller Market Share

	Units (K) 1996	Units (K) 1H/97	Revenue ($M) 1996	Revenue ($M) 1H/97	Rank	Previous Rank
Chips & Technology	6,380	2,500	134	60	46	36
Neomagic	1,070	1,200	38	40	13	23
Trident Microsystems	2,170	1,476	43	34	15	20
Cirrus Logic	2,500	1,500	53	30	18	18
S3	128	223	3	5	1	3
OPTi	130	23	3	0	1	NR
Others	801	0	15	0	5	-
Total	**13,178**	**6,922**	**288**	**168**	**100**	**100**

NR = Not relevant
Source: Dataquest (September 1997)

Figure 4-3
First-Half 1997 Mobile PC Graphics Controller Market Share



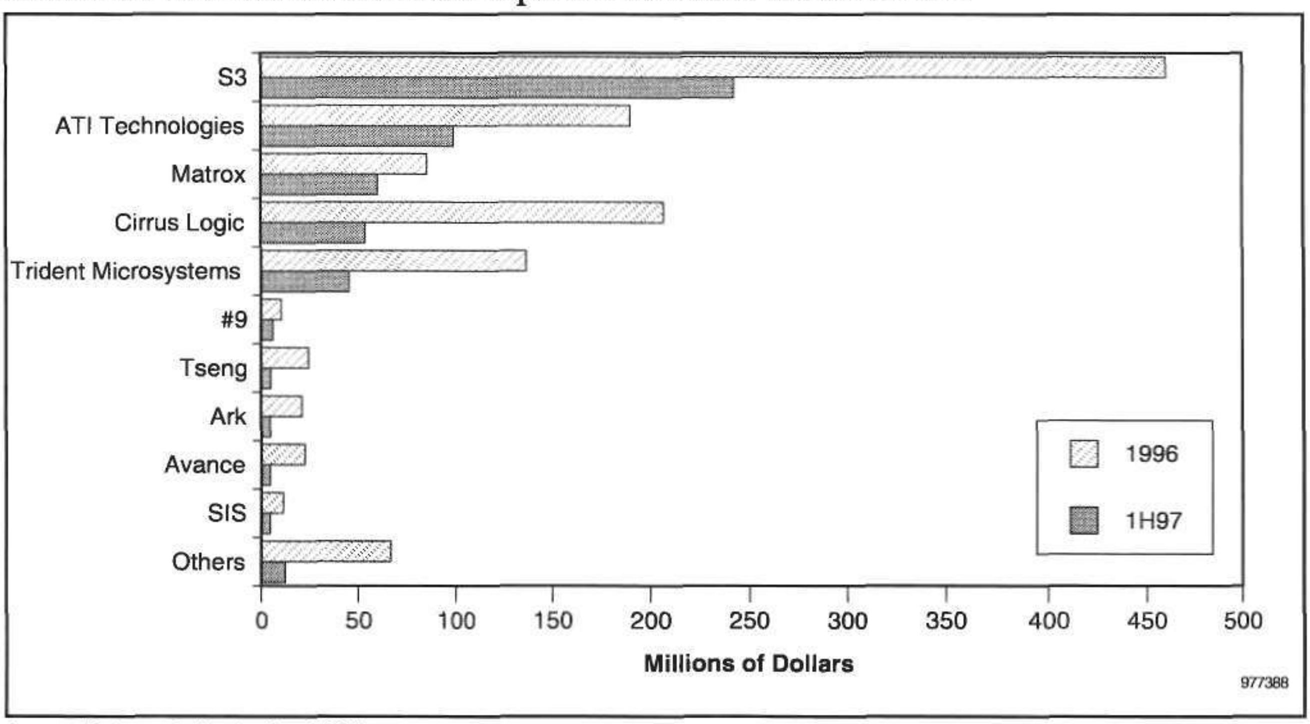
Source: Dataquest (September 1997)

Table 4-3
First-Half 1997 Deskbound PC Graphics Controller Market Share

	Units (K) 1996	Units (K) H1/97	Revenue ($M) 1996	Revenue ($M) H1/97	Rank	Previous Rank
S3	28,910	20,200	460	242	38	45
ATI Technologies	10,000	6,535	190	99	16	19
Matrox	2,950	2,400	85	60	7	11
Cirrus Logic	14,750	4,500	207	54	17	10
Trident Microsystems	10,580	4,885	137	46	11	9
#9	350	200	11	6	1	1
Tseng	1,500	500	25	5	2	1
Ark	1,800	550	22	5	2	1
Avance	1,800	400	23	5	2	1
SIS	900	450	12	5	1	1
Others	3,580	1,421	66	13	5	2
Total	**76,220**	**41,591**	**1,225**	**533**	**100**	**100**

Source: Dataquest (September 1997)

Figure 4-2
First-Half 1997 Deskbound PC Graphics Controller Market Share



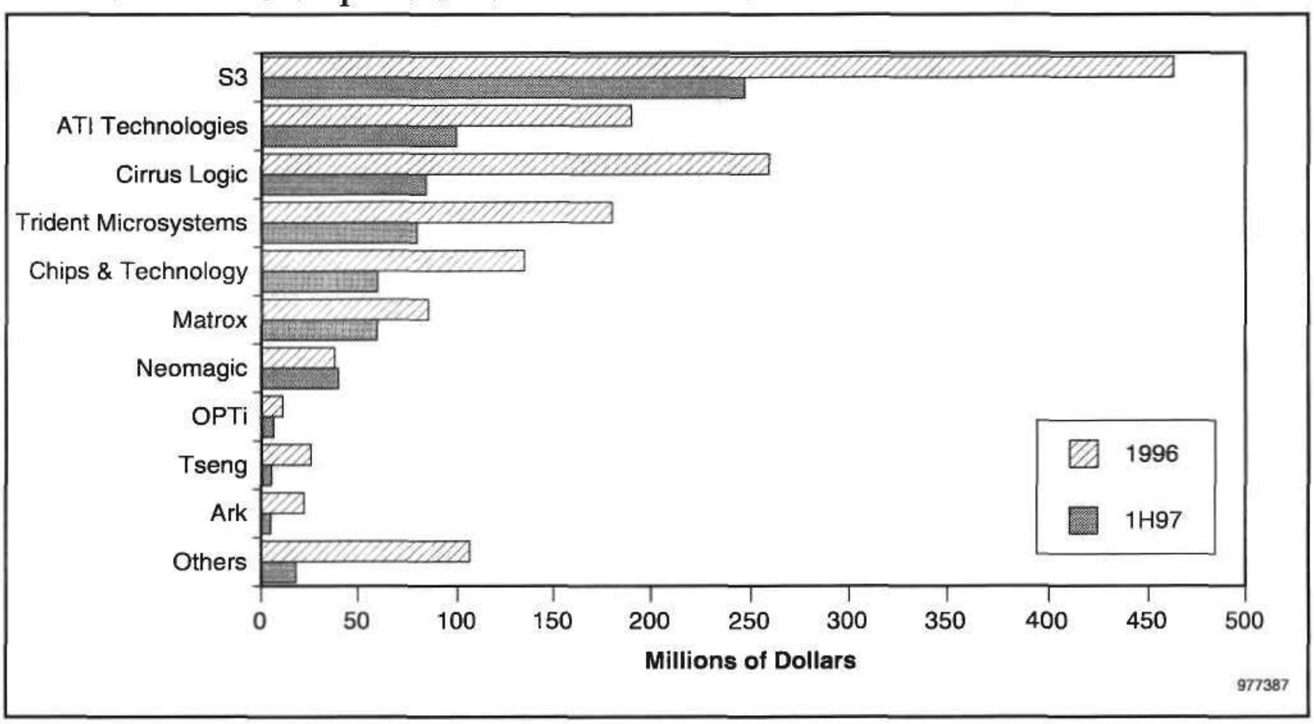
Source: Dataquest (September 1997)

Table 4-2
First-Half 1997 Graphics Controller Market Share

	Units (K) 1996	Units (K) H1/97	Revenue ($M) 1996	Revenue ($M) H1/97	Revenue Market Share (%) H1/97	Revenue Market Share (%) 1996
S3, Inc.	29,038	20,423	463	247	31	35
ATI Technologies	10,000	6,535	190	99	13	14
Cirrus Logic	17,250	6,000	259	84	17	12
Trident Microsystems	12,750	6,361	180	80	12	11
Chips & Technology	6,430	2,500	135	60	9	9
Matrox	2,950	2,400	85	60	6	9
Neomagic	1,070	1,200	38	40	2	6
#9	350	200	11	6	1	1
Tseng	1,500	500	25	5	2	1
Ark	1,800	550	22	5	1	1
Others	6,261	1,844	106	17	7	2
Total	**89,398**	**48,513**	**1,513**	**702**	**100**	**100**

NR = Not relevant
Source: Dataquest (September 1997)

Figure 4-1
First-Half 1997 PC Graphics Controller Market Share



Source: Dataquest (September 1997)

Table 4-1 (Continued)
Comparison of PC Graphics Controller Products

Company	Product Name	Product Number	Target Platform	2-D+ Video	3-D	TV Features	MPEG-2 Motion Compensation	Bus Interface	Package	Memory Type
S3, Inc	ViRGE/VX		Deskbound	Yes	Yes	No	No	PCI	BGA-256	VRAM
	ViRGE/DX		Deskbound	Yes	Yes	No	No	PCI	PQFP-208	EDO
	ViRGE/GX		Deskbound	Yes	Yes	No	No	PCI	PQFP-208	SGRAM
	ViRGE/GX2		Deskbound	Yes	Yes	Yes	No	PCI/AGP	BGA-328	SGRAM
	ViRGE/MX		Mobile	Yes	Yes	Yes	No	PCI/AGP	BGA-256	EDO/SGRAM
	ViRGE/MXi		Mobile	Yes	Yes	Yes	No	PCI/AGP	PQFP	Integrated
Trident	3DImage	975	Deskbound	Yes	Yes	Yes	No	PCI	PQFP-208	SGRAM
	3DImage	975DVD	Deskbound	Yes	Yes	Yes	Yes	PCI	PQFP-208	SGRAM
	3DImage	985	Deskbound	Yes	Yes	Yes	No	PCI/AGP	BGA-316	SGRAM
	3DImage	985DVD	Deskbound	Yes	Yes	Yes	Yes	PCI/AGP	BGA-316	SGRAM
	Cyber	9385	Mobile	Yes	No	No	No	PCI	T/PQFP, BGA-256	SGRAM
	Cyber	9388	Mobile	Yes	No	Yes	No	PCI	BGA-316	Integrated
	3D Cyber	9397	Mobile	Yes	Yes	Yes	No	PCI	BGA-316	SGRAM

Source: Dataquest (September 1997)

Table 4-1
Comparison of PC Graphics Controller Products

Company	Product Name	Product Number	Target Platform	2-D+ Video	3-D	TV Features	MPEG-2 Motion Compensation	Bus Interface	Package	Memory Type
3Dfx	Voodoo Graphics		Deskbound	No	Yes	No	No	PCI	PQFP	EDO
	Voodoo Rush		Deskbound	No	Yes	No	No	PCI	PQFP	EDO
	Banshee (Q1 98)		Deskbound	Yes	Yes	No	No	PCI/AGP	Unknown	Unknown
3DLabs	Permedia2		Deskbound	Yes	Yes	No	No	PCI/AGP	BGA-256	SGRAM
Alliance	ProMotion	AT3D	Deskbound	Yes	Yes	No	No	PCI	PQFP-208	EDO
ATI	3D RAGE II		Deskbound	Yes	Yes	Yes	No	PCI	PQFP-208	EDO
	3D RAGE II+DVD		Deskbound	Yes	Yes	Yes	Yes	PCI	PQFP-208	SGRAM
	3D RAGE PRO		Deskbound	Yes	Yes	Yes	Yes	AGP/PCI	BGA-256	SGRAM
	3D RAGE LT		Mobile	Yes	Yes	Yes	No	PCI	BGA-256	EDO/SGRAM
Avance		ALG25128	Deskbound	Yes	No	No	No	PCI	PQFP	EDO
Chips&Tech	HiQVideo	65550	Mobile	Yes	No	No	No	PCI/VL	T/PQFP-208,BGA-256	EDO
	HiQVideo	65554	Mobile	Yes	No	No	No	PCI	BGA-256	EDO
Chromatic	Mpact2 (3DVD)	3600	Deskbound	Yes	Yes	Yes	Yes	PCI	BGA-352	RDRAM
Cirrus Logic	VisualMedia	GD-5480	Deskbound	Yes	No	No	No	PCI	PQFP-208	SGRAM
	Laguna	GD-5460	Deskbound	Yes	No	No	No	PCI	PQFP-208	RDRAM
	Laguna3D	GD-5464	Deskbound	Yes	Yes	No	No	PCI	PQFP-208	RDRAM
	Laguna3D/AGP	GD-5465	Deskbound	Yes	Yes	No	No	AGP/PCI	PQFP-208	RDRAM
	VisualMedia	GD-7555	Mobile	Yes	No	No	No	PCI	BGA,PQFP-256	EDO
	VisualMedia	GD-7556	Mobile	Yes	No	Yes	No	PCI	BGA,PQFP-256	EDO
Intel	Auburn		Deskbound	Yes	Yes	No	No	PCI/AGP	Unknown	SGRAM
NeoMagic	MagicGraph	128ZV	Mobile	Yes	No	No	No	PCI	PQFP-176	Integrated
	MagicGraph	128XD	Mobile	Yes	No	No	No	PCI	PQFP-176	Integrated
nVidia	Riva 128		Deskbound	Yes	Yes	Yes	No	PCI/AGP	BGA	SGRAM
Oak Technology	Warp5		Deskbound	Yes	Yes	No	No	PCI/AGP	BGA	EDO, SGRAM
Rendition	Verite	R1000	Deskbound	Yes	Yes	No	No	PCI	PQFP	EDO
		R2200	Deskbound	Yes	Yes	Yes	Yes	PCI/AGP	BGA?	SGRAM

Chapter 4
PC Graphics Competitive Trends

PC graphics are a highly visible and volatile part of the PC semiconductor market. Price pressure appears to have eased a bit for the fall but is likely to return for the spring 1998 design cycle. Overall, this price competition will speed the adoption of new features that consumers will use and corporate buyers will get for free.

Dataquest believes that 1997 and 1998 will be highly competitive years for PC graphics chip companies. Consolidation is expected among the second- and third-tier vendors as they scramble for design-wins. The current market leaders are strong and are likely to remain high-volume suppliers for several years. Dozens of companies view the transition to 3-D graphics as an opportunity to enter the PC graphics chip market, and, as a result, the market is more crowded than it has been for years. Many of them will exit this market if they fail to secure good design-wins in 1998. Small players will fail or get bought for their intellectual property; larger players may choose simply to cancel product lines. In the meantime, commodity graphics vendors will face lower margins as those companies that are desperate for sales fuel the price war. Exceptions will exist when companies have a product that is ahead of the curve, such as Neomagic's current advantage in embedded memories, which the company refers to as integrated DRAM or IDRAM. The transition to accelerated graphics port (AGP) could produce additional exceptions as some vendors beat others to market.

Current Product Offerings

Table 4-1 compares the features of a variety of graphics controllers shipping this year. Chapter 5 contains a profile of every vendor listed in Table 4-1.

Market Share

Tables 4-2, 4-3, and 4-4 show the vendor market share for the PC graphics controller market with breakouts for deskbound and mobile PC graphics markets. Figures 4-1, 4-2, and 4-3 present that same data graphically.

Market Forecast

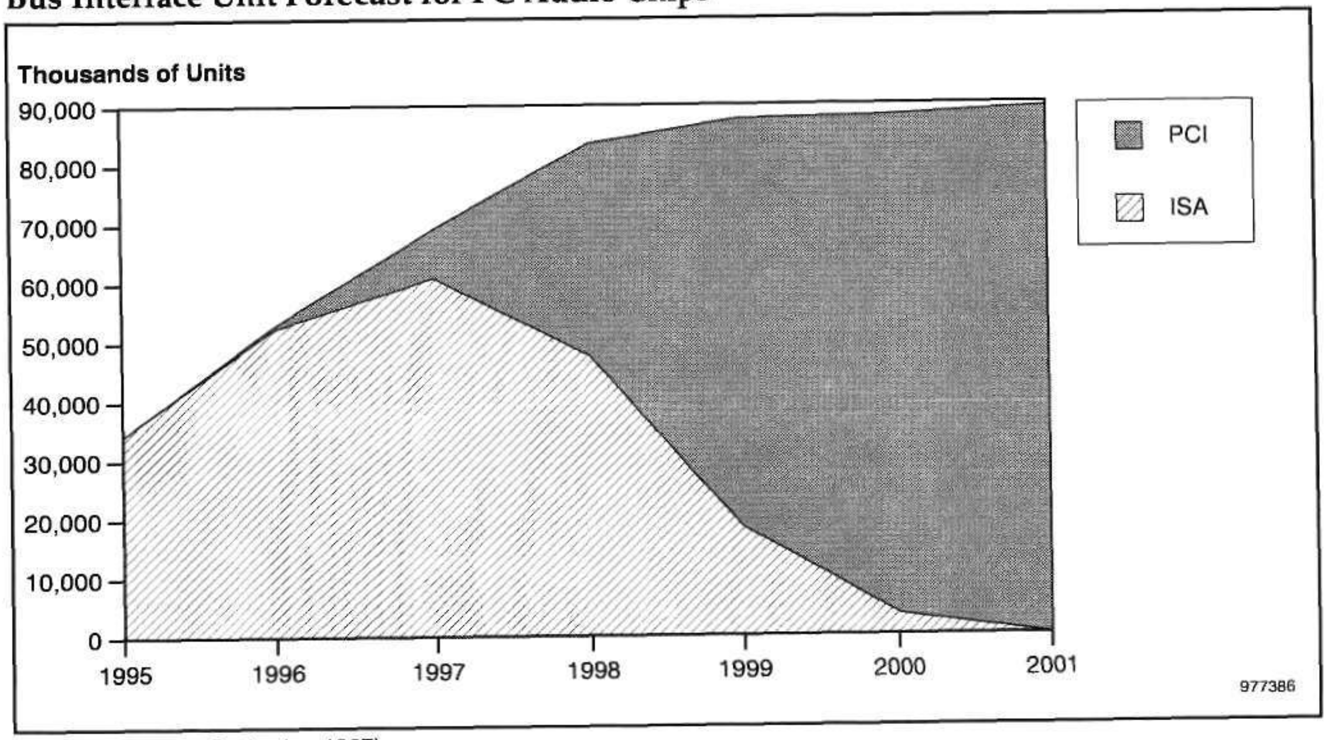
The market forecast for PC graphics controllers reflects two defining trends in the market. First, high levels of competition will limit revenue growth for 1997. Greater use of IDRAM is the second major trend. Stronger revenue growth will follow the sluggish growth for 1997, fueled by rising average selling prices (ASPs)—particularly for the mobile segment of the graphics controller market—and greater unit shipments resulting from PC market growth.

Table 3-4
Bus Interface Revenue Forecast for PC Audio Chips (Millions of Dollars)

	1995	1996	1997	1998	1999	2000	2001
ISA	100	99	88	57	21	4	0
PCI	0	1	12	43	79	96	100

Source: Dataquest (September 1997)

Figure 3-3
Bus Interface Unit Forecast for PC Audio Chips



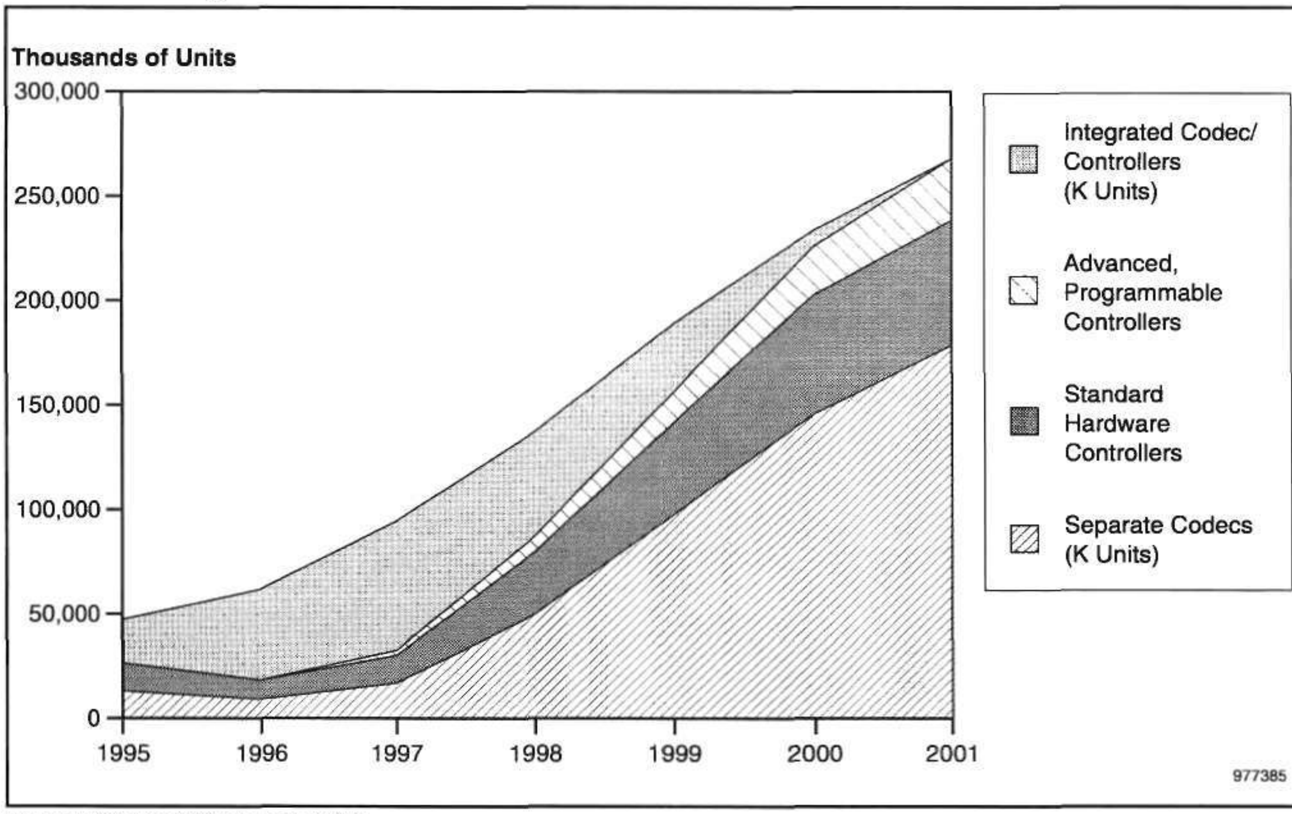
Source: Dataquest (September 1997)

Table 3-3
PC Audio Chip Forecast

	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
PC Audio Chips (K Units)	47,392	62,017	94,724	137,431	189,020	234,048	267,852	34.0
Growth Year-to-Year	-	30.9	52.7	45.1	37.5	23.8	14.4	-
PC Audio Chip Revenue ($M)	484.6	676.5	646.3	725.1	863.5	993.8	1,105.1	10.3
Growth Year-to-Year	-	39.6	-4.5	12.2	19.1	15.1	11.2	-
Controller/Codec Bundles	34,141	52,767	79,200	99,950	130,359	153,726	178,568	27.6
Separate Codecs (K Units)	13,251	9,250	17,107	49,975	97,769	146,040	178,568	80.8
Separate Hardware Controllers (K Units)	13,251	9,250	15,523	37,481	58,662	80,322	89,284	57.4
Software Controllers Using CPU (K Units)	0	0	1,584	12,494	39,108	65,718	89,284	NA
Integrated Codec/Controllers (K Units)	20,890	43,517	62,093	49,975	32,590	7,686	0	-100.0

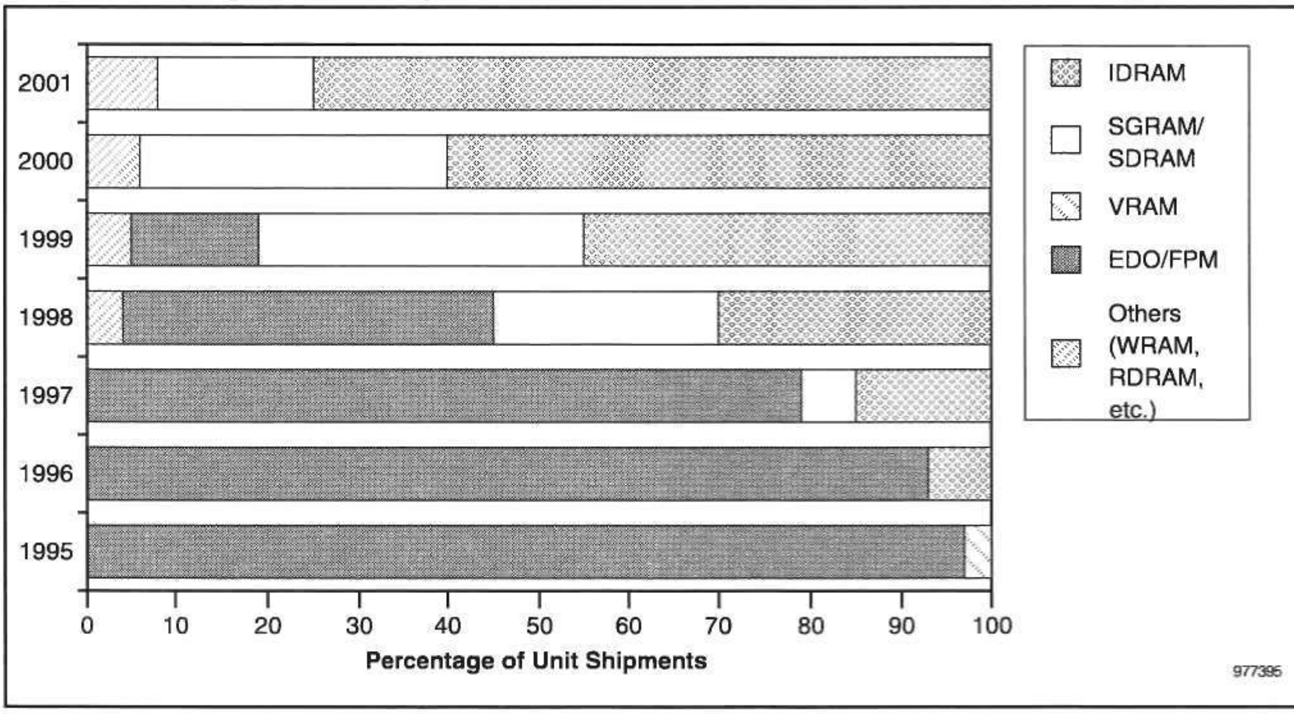
NA = Not available
Source: Dataquest (September 1997)

Figure 3-2
PC Audio Chip Forecast



Source: Dataquest (September 1997)

Figure 4-9
Mobile PC Graphics Memory Interface Forecast



Source: Dataquest (September 1997)

Chapter 5
Who's Who

The following company briefs describe the key players in the PC audio and graphics chip markets. Vendors are listed alphabetically.

3Dfx

3Dfx Interactive set records for 3-D graphics performance with its Voodoo Graphics chipset and is synonymous with high-performance graphics for PC gaming. The company's vision from the start included PC graphics products as well as opportunities to use the PC platform for arcade games. The benefits of this model include a single application programming interface (API) for arcade versions and PC versions of games, as well as significantly reduced costs of the arcade game platforms by using high-volume standard products instead of custom chips. 3Dfx's vision has proceeded with 3Dfx chips being used in the arcade driving game titled "San Francisco Rush" and the spin-off of a company called Quantum3D. Quantum3D is pursuing the arcade platform business with a family of board-level products while 3Dfx continues to focus on chip sales and development.

The Voodoo Graphics chipset consists of two chips and is a 3-D graphics product only. 2-D and video functions required a separate graphics controller and memory. Voodoo Rush was introduced to address those issues. The Voodoo Rush chip combined the two Voodoo Graphics chips into one and was designed to share a single memory array with select 2-D graphics controllers. The next chip, called Banshee, will integrate the 2-D functions for a single-chip design. Banshee is scheduled for first quarter 1998 and will be a critical indicator of 3Dfx's competitiveness for 1998.

3Dlabs

3Dlabs Inc. pioneered the merchant chip market for 3-D graphics accelerators for PC workstation applications. The company formed as a group of Du Pont Pixel in the United Kingdom and emerged as 3Dlabs, a Bermuda corporation, in 1994. 3Dlabs is the largest vendor of chips for professional-class 3-D graphics acceleration. The company created a less-expensive 3-D graphics chip last year called PerMedia in order to reach a broader share of the graphics market. The second version of this chip, called PerMedia2, was introduced this year and has significantly increased 3Dlabs shipment volume. 3Dlabs has two manufacturing partners, IBM Corporation and Texas Instruments Inc. The relationship with TI extends beyond manufacturing and includes cross-licensing of technology between the two companies. 3Dlabs gained access to TI's RAMDAC technology, and this sped the development of PerMedia and PerMedia2, both of which feature an integrated RAMDAC. TI has rights to sell many (all) of the chips that 3Dlabs sells, as well as rights to develop unique products based upon 3Dlabs' 3-D graphics technology. The company went public in November 1996 and is traded on the Nasdaq exchange as TDDDF.

ATI Technologies

ATI Technologies Inc. evolved from a graphics board company to a powerhouse graphics vendor selling chips as well as boards. This strategy mirrors Matrox Graphics Inc., but ATI outpaces its fellow Canadian company in unit volume if not revenue. ATI's revenue for the quarter ending May 1997 was $135 million compared to Dataquest's estimate of $150 million for Matrox in the same period. Unit sales for ATI each of the past two years have moved the vendor up to No. 4 in the market share rankings for the first half of 1997.

3D RAGE, an entry-level 3-D graphics chip, boosted ATI's sales in 1996 and broadened the company's customer base. ATI maintains a blistering pace of product development and added three new products to the RAGE family over the past 12 months. Potentially the most significant of those new parts is the RAGE PRO chip. RAGE PRO is the first 2x AGP graphics chip. Competing products operate at only 1x AGP, or 66 MHz. That feature, and the performance benefits stemming from it, has generated lots of design activity for RAGE PRO for fall product announcements.

ATI made the transition successfully to customer-owned tooling (COT) during the first half of this year. Higher margins resulted from the change and ATI posted an increase in gross margin for its third fiscal quarter of this year compared to the previous year. Most of ATI's competitors posted a decline in gross margin for the same period because of pricing volatility.

One of ATI's challenges is continued unit growth. ATI sells boards and chips, but the company will not sell chips to any of its add-in board competitors. This makes complete sense and protects ATI's board-level revenue, but it does push a lot of high-volume design opportunities out of reach. Competitors S3 Inc. and Trident Microsystems Inc. sell to multiple add-in board vendors because they do not sell any board-level products. ATI gets more dollars per unit from a board-level sale rather than a chip-level sale, but margins are better at the chip level. PC OEMs who prefer to use add-in cards for graphics and have forged strong relationships with add-in board vendors are difficult for ATI to reach from a sales point of view.

Analog Devices

Analog Devices Inc. (ADI) is well-known for its analog, mixed-signal, and digital signal processing (DSP) technologies and was a leading supplier of codecs to the PC audio market. The company leveraged its mixed-signal expertise by integrating other PC audio components with its audio codecs just as Cirrus Logic (Crystal Semiconductor) did, but ADI did not find the same degree of success. The transition to AC-97-style implementations is an opportunity for the company to at least sell codecs into the PC audio market if not more integrated products. ADI's participation in the modem chip market could give the company a leg up in the market for integrated audio and communication products.

The 1821 SoundComm solution from ADI combines audio and modem features, leveraging the host microprocessor for most of the modem signal processing requirements. The 1821 is an audio controller integrated with an audio codec and a modem codec. Host-based signal processing (HSP) technology from Smartlink Ltd., based in Israel, enables the software modem features.

Aureal Semiconductor

Aureal Semiconductor (AURL: OTC Bulletin Board) rose like a phoenix from the ashes of MediaVision. The company reorganized itself as Aureal in 1995 and the following year purchased Crystal River Engineering (CRE), a 3-D audio pioneer. (Aureal is short for audio realism.) CRE developed high-end, positional 3-D audio technology for NASA and sold audio subsystems for location-based entertainment (LBE) such as virtual-reality simulators and theme park rides. Aureal is based in Fremont, California, as was MediaVision.

Aureal's crown jewel is its audio processing technology for positional 3-D audio effects. Aureal markets its technology under the trademark A3D Interactive, short for Aureal 3D (A3D). A wide variety of game developers and multimedia chip suppliers have licensed A3D. The level of support speaks volumes about the quality and importance of A3D and paves the road for future success.

License fees drive Aureal's revenue stream today but the business model will change as the company brings its Vortex PC audio chip to market later this year. The Vortex is currently sampling and will reach volume production this fall. The company is operating at a substantial loss because of the start-up expenses for the Vortex. Revenue for the first half of 1997 topped $1.1 million, but expenses outpaced revenue by a factor of eight. Aureal is funding its operations through sale of stock as well as a line of credit. Aureal sold 1.9 million shares of stock this summer for $3.8 million and restructured its line of credit, increasing it to $11.5 million.

Chips & Technologies

Chips & Technologies Inc. (Chips), based in San Jose, California, is the market share leader in graphics controllers for mobile PCs. The company is also involved with desktop graphics products and is working with Intel and Lockheed Martin on Intel's i740 graphics chip. Chips' role in that project is providing 2-D graphics and video acceleration technology.

The relationship between Chips and Intel changed dramatically last July when the two announced that Intel had tendered an offer to buy all outstanding Chips shares. This offer was extended to October 17 after the FTC requested additional information from both vendors.

Chips has a tremendous number of design-wins from its existing products, but faces greater competition for new design-wins. Delays in the new products, particularly embedded memory and 3-D graphics products, have reduced Chips' competitiveness in winning new designs. Toshiba, Chips' biggest account, recently announced that its flagship product, the Tecra, would have S3's ViRGE MXi chip that features embedded memory and 3-D acceleration.

Cirrus Logic

Cirrus Logic Inc. is often thought of as a PC multimedia chip vendor, but Cirrus' graphics revenue has declined so much that the mass storage group now brings in more revenue than the PC products group. Cirrus invested heavily in manufacturing over the past few years and participates in two joint venture fabs. MiCRUS is a joint venture with IBM Microelectronics, and Cirent is a joint venture with Lucent Technologies. The company re-inked its agreement with Lucent to reduce its wafer purchase obligations from the Cirent fab and license a number of additional technologies from Lucent. The new agreement is much more in line with Cirrus' near-term capacity requirements and ensures that Cirrus will have access to critical technologies for future products. Cirrus sells both audio and graphics products. Each is discussed separately here.

Cirrus Audio

Cirrus Logic sells a variety of audio chips through its subsidiary Crystal Semiconductor. Until the spring of 1997, Cirrus's PC audio products were marketed under the Crystal brand name, but now these products carry the Cirrus Logic brand. Other consumer and professional audio products still carry the Crystal Semiconductor name.

One of the PC audio leaders, Cirrus Logic built its market share on the quality of its codecs and was a dominant supplier of standalone codecs before those functions were integrated with the digital controller. The company continues to differentiate its integrated codec/controller products on the basis of its audio quality, but it endorses the transition to PCI- and AC-97-type implementations, too. The transition to AC-97 implementations brings new opportunity to Cirrus because of the emphasis on audio quality and the existence of a standalone codec. Cirrus lost a lot of codec business as audio chip vendors integrated the codec with the digital controller. The company created its own integrated products, too, but the company had little competition for the standalone codec sales and has stiff competition for sales of the integrated products.

Cirrus Logic's product line includes ISA-based integrated codec/controller products, AC-97 codecs, and a PCI-based audio controller called the CS4610. The ISA-based products will remain in Cirrus' product line but are not likely to be enhanced.

Cirrus Graphics

Cirrus Logic dominated the PC graphics market in the mid-1990s but has lost significant market share since the end of 1995. The company made a number of false starts in the 3-D graphics arena, including investments in Microsoft's Talisman architecture, 3DO's M2 technology, and an internally designed product. The product Cirrus did bring to market for 3-D graphics is Laguna3D. The Laguna family uses Rambus DRAM (RDRAM) and includes 2-D accelerators as well as 3-D accelerators. Laguna3D refers to the 3-D chips in the Laguna product family. Cirrus is still one of the top five graphics chip vendors, but is a long way from its former glory as No. 1.

Creative Technology

Creative Technology Ltd. is a leading supplier of audio chips and has dominated the market for sound board shipments. In the 1980s, Creative built a strong brand name by selling PC sound boards through retail outlets. Creative's SoundBlaster family of sound boards is the de facto standard for PC audio feature sets and software compatibility because of its strength in the retail market. Software developers have largely depended on SoundBlaster standards to ensure software compatibility and this mountain of legacy applications gives Creative additional market momentum. Through the early 1990s, Creative successfully managed the transition from a retail board supplier to a retail and OEM board supplier as PC OEMs began adding multimedia features to their product lines. The company managed another transition from 1994 to 1995 and as it began selling PC audio chips in addition to its board-level offerings. Creative is the largest sound board supplier, holding 67 percent unit market share for 1995, and it is the third-largest supplier of PC audio chips, with 15 percent unit market share for the same year.

Looking forward, Creative faces increasing competition in the PC audio market as the demand for audio chips heats up and PC OEMs increasingly favor buying chips rather than boards. Two of Creative's strengths are its brand name and its ability to deliver software compatibility at the chip or board level. The positive impact of these will gradually erode as technology shifts to wavetable synthesis (see Chapter 2) and implementation trends shift to greater use of motherboards and daughterboards rather than ISA cards (see Chapter 3).

ViBRA is the name Creative chose for its family of integrated codec/controller chips. Three versions of the ViBRA chip are available today, the ViBRA 16S, ViBRA 16C, and ViBRA 16CL. Both the 16C and 16CL have integrated FM synthesis, but the 16S does not. Dataquest expects Creative to bring another version to market this fall that includes integrated spatial enhancement.

ESS Technology

The rapid rise of audio features in mobile PCs was fueled by ESS Technology Inc.'s ability to deliver volume quantities of highly integrated audio chips. ESS took the PC audio chip market by storm in late 1994 by integrating the controller and codec functions into a single chip. Other companies introduced similar products at roughly the same time, but ESS was ready for volume production months before those competitors. In 1995, ESS beat its competition to the punch again by integrating the FM synthesis functions. Almost all other vendors were using Yamaha's OPL-3 FM synthesis chips because of Yamaha's patent protection for that technology. ESS took the bold step of creating its own FM synthesis technology, named ESFM, instead of using Yamaha's patented technology. This led to a lawsuit for alleged patent infringement, but the suit was settled this year. Details of the settlement were sealed, but company announcements indicate the settlement did not have a significant impact on the financial results of either company.

ESS purchased Platform Technologies last spring to buttress its internal development of PCI audio products. ESS is selling the Agogo PCI audio product designed at Platform as well as the Maestro family, which was created by the unified design team following the acquisition. The Maestro family incorporates audio features as well as modem and telephony features. ESS introduced a modem chipset last year, but has been much more successful with its audio and MPEG-1 products than with its communications products.

The company reported a loss for the second calendar quarter of 1997 with net revenue of $45 million, down 7 percent from the same quarter of 1996. Revenue was negatively impacted by a $22 million charge for the Platform Technologies acquisition and by a decision to defer the recognition of $13 million revenue from MPEG-1 products shipped to distributors in China. Management decided to defer that revenue until those units ship from the distributor to OEMs because of price volatility in the MPEG-1 market and the likelihood of inventory write-downs. The company's two major markets, MPEG-1 decoders and PC audio chips, are volatile markets for pricing even though unit shipments are growing nicely overall. The company has made equity investments in a joint venture fab in Taiwan.

Intel

Intel Corporation's activity in the graphics market gets a lot of attention. The company overwhelmingly dominates the microprocessor market and wields tremendous influence over the trends and technologies of the PC platform. For these reasons, combined with the company's wealth and manufacturing strength, Intel is simultaneously respected and feared as a graphics competitor. Some folks have compared Intel's current foray into the graphics business with its entry into the core logic business a few years back. Dataquest believes the graphics business will be much tougher for Intel than the core logic business for a number of reasons. The two most significant reasons are the high level of competition in the graphics business today and the fact that core logic has much greater synergy with Intel's core product line, microprocessors, than graphics has.

Key events to watch that will dramatically affect Intel's success in the graphics market include the FTC's approval (or disapproval) of Intel's purchase of Chips & Technologies and the trend toward AGP add-in cards versus AGP graphics chips on the motherboard. The purchase of Chips bulldozes a number of barriers to entry and will make Intel much more formidable in the graphics arena. The AGP issue is more complex. Dataquest believes that Intel graphics products could have considerable appeal when sold as part of an Intel motherboard but will be less effective competing for add-in card designs. The market trends of AGP graphics down versus up will therefore affect Intel's graphics opportunities.

NEC

NEC Corporation entered the graphics chip business with a product line called PowerVR. Like 3Dfx's Voodoo Graphics, the original PowerVR chipset was multiple chips and did not include 2-D or video functions. The second product in the PowerVR family is called PCX2 and is a single chip, but it still does not include 2-D or video features. The limited design and sales activity for PowerVR products last year prompted NEC to get much more serious about working with independent software vendors (ISVs) and generating acceptance of PowerVR's alternative methods of processing 3-D graphics.

NEC scored a big win this summer with Matrox and that company's new m3D product. Success of the PowerVR product line remains to be seen, but NEC is much more active today to ensure that leading titles run (and look good doing it) on the PowerVR architecture.

Matrox

Matrox is the largest graphics board vendor on a revenue basis. The company differentiates its products by designing its own chips and targeting the high end of the corporate PC market and low end of the professional graphics market. One exception to this trend is the recent announcement of m3D, a consumer-targeted add-in card that uses NEC's PowerVR technology instead of internally designed chips.

Matrox dominates the market for graphics cards in the $200 to $500 range, but the company faces new levels of competition from a host of board-level products based on 3Dlab's PerMedia2 chip. The Matrox Millenium series is the company's flagship product line and has won acclaim for its 2-D graphics performance. Success of the Millenium product line can be attributed to the combination of 2-D performance and robust support for Windows NT applications. The Millenium II brings more 3-D features and higher performance to the Millenium family, but it doesn't have the breadth of 3-D features offered by the PerMedia2-based products. Millenium II has strong appeal for multimedia content creators that require all-around performance for 2-D, 3-D, and video functions but is less attractive for users of 3-D CAD and scientific applications.

Oak Technology

Oak Technology Inc. ranks No. 1 in market share for CD-ROM drive controllers and has worked to broaden its product line to other PC chip products. Oak re-entered the graphics market last year with a product name Eon, but met with little success. The Sunnyvale, California, company has a new product called Warp5 that is high-performance and targeted right at the PC gaming crowd. The major risk for Oak as it markets Warp5 are not that the chip will not be competitive on a price/performance basis, but that the company's innovative architecture will have minor incompatibilities or performance issues running Direct3D titles.

OPTi

OPTi Inc.'s audio products represent half of its revenue, and the company suffered from the severe price erosion in the audio market. The company's announcement of second quarter 1997 results included plans to restructure the company. OPTi continues to sell millions of audio chips but doesn't command the front line for pricing. Sales of the company's PCI audio product, MachOne, could provide some relief from the price erosion of ISA-based products.

Rendition

Rendition Inc. is a graphics chip start-up based in Mountain View, California. The company's first product, the Verite 1000, was the first low-cost graphics chip to include a hardware setup engine. A programmable RISC core made the product even more unique. Verite 1000 met marginal success despite its strong 3-D performance. Game programmers, including John Carmack of Doom fame, raved about the chip's 3-D capabilities, but that did not translate into high-volume sales. Demand may have been limited by the Verite's 2-D performance.

S3 Inc.

S3 is the largest graphics chip vendor in the world and recently expanded its product lines to include standard audio products. A new logo and tagline symbolize the company's broader goals. The words "Sight. Sound. Speed." appear under the new "S" logo, and S3 refers to itself as a multimedia accelerator company. Often considered a fabless company, S3 actually owns 25 percent of a Taiwanese foundry joint venture with UMC and Alliance Semiconductor.

S3 built market share with tremendous growth in 1995 and 1996 for desktop graphics chips. The key to success was leading the transition from 32-bit graphics engines to 64-bit designs. S3 developed a reputation for superb execution and quality products. Cirrus Logic was late with its 64-bit products and subsequently with its 3-D products, and S3 made the most of those opportunities to win new, high-volume designs at Cirrus' expense. Mobile graphics controllers appeared in S3's product line last year with marginal success. The first mobile graphics products were named Aurora; the newer mobile products include 3-D acceleration and are part of the ViRGE family. S3 already announced a design-win for the ViRGE Mxi in the Toshiba Tecra.

The company inked a deal last spring with Faroudja to gain exclusive rights to some of that company's video processing technology for PC applications. Faroudja is a household name in high-end video equipment such as line-doublers.

S3 introduced SonicVibes, a PCI audio chip, last year and has announced two add-in board design-wins so far. The chip is compatible with the ISA bus, too, but ISA implementations require additional memory devices. The company purchased Floreat, a communications software company two years ago, so future announcements of communications products would not be a surprise.

Trident Microsystems

Trident Microsystems Inc. has been one of the top graphics chip vendors for years. It is one of the few vendors that has maintained it rank among the top vendors for an extended period of time. Although Trident was a very large graphics vendor, it had difficulty penetrating tier one accounts until the middle of 1996. Trident has significantly enhanced its image over the past 12 months with a more competitive product line and a list of top-tier design-wins in notebooks as well as desktop PCs.

Revenue growth for Trident stems from higher ASPs and higher units sales. The company was able to increase its own ASPs even though industry ASPs are declining. This remarkable feat was achieved by greater sales of mobile graphics products, which carry a higher ASP compared to their desktop counterparts, and a more competitive product line that is bringing Trident closer to the ASPs of other top graphics chip vendors.

The company made a couple of false starts in the 3-D graphics arena with a couple of product designs that never made it to the product introduction phase. Trident introduced its 3DImage product line this year. The 975 and 985 products offer competitive performance for mainstream consumer and business markets' desktop markets; the Cyber 9397 is a 3-D accelerator for notebooks. Trident also made an equity investment in a Taiwan-based joint venture fab.

Yamaha

Yamaha Corporation and audio technology go hand in hand with products ranging from musical instruments, professional audio equipment, consumer electronics, and audio chip products. The PC audio chip products are sold through a division called Yamaha Systems Technology Inc. in and through Yamaha in Japan.

Until 1995, Yamaha was the sole supplier of FM synthesis chips to the PC audio market. The company had patent rights to FM synthesis and benefited greatly from the proliferation of the Sound Blaster standard because it included Yamaha's patented technology. Yamaha's FM synthesis revenue stream lost momentum when ESS Technology created its own FM synthesis logic and won the patent infringement suits that Yamaha pursued. The courtroom battles weakened Yamaha's grip on FM synthesis technology, and other chip vendors soon introduced products with their own integrated FM synthesis technology through 1995 and 1996. Today, Yamaha still sells millions of FM synthesis chips, but the company is not the sole supplier as it was in the past. Yamaha sells a variety of other PC audio products including integrated codec controller products such as the OPL-SA chip, wavetable synthesizers, and wavetable ROMs. The company experienced a surge in sales volume with design-wins in many Toshiba notebooks and Intel motherboards over the past year.

Yamaha licensed the original FM synthesis technology from Stanford University and continues to work with audio researchers there. A recent product from that collaboration is wave-guide synthesis, a technology that is more advanced than both FM and wavetable synthesis. Yamaha and Stanford are licensing a suite of patented technologies and software applications under the trademark Sondius-XG. Dataquest listened to a demo of the Sondius-XG wave guide synthesis and was truly impressed. It is hard to make synthesized music sound as good a a CD recording, but Yamaha has done it.

Chapter 6

Dataquest Perspective

Rapid change and technology shifts are hallmarks of the PC audio and graphics chip markets. Successful vendors must balance technical issues with the realities of software compatibility, software availability, and actual demand for certain features. Each of these issues can mean the difference between success and failure.

Graphics chip vendors are advised to target their products at specific segments of the market such as consumer, business, professional, and mobile computing. 3-D performance is largely tied to die size, so vendors need to have access to leading-edge process technology. Small vendors need to establish good foundry contacts or partner with fab owners. Larger vendors should examine investing in a foundry or a joint venture. Bear in mind that great chips do not sell themselves without software compatibility. Chips targeted at consumers need to have a list of top software titles that run—and run well—on the chip. There is a world of difference between saying that a chip supports Direct3D and having Direct3D applications run well on that chip. OEMs want to buy solutions, not problems with a long list of features.

Audio chip vendors are advised to look hard at new features to integrate. Home theater is fine for a living room PC, but how many PCs are in the living room? Vendors should deliver features that count. Business and mobile PCs need basic audio, so integrated codec and controller chips will be fine for a while. Consumer PCs need the bells and whistles because positional 3-D and wavetable quality will provide differentiation. Prices are so low now, it is hard to compensate for deficient features by cutting the price. Vendors taking the higher ground with respect to features may not make great margins today, but they should get the sale! Watch for integration of communications products such as analog modems.

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