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November 30, 1995

Errata

In Dataquest's *1994 Stepper Market: Reflection of the Growing Strength in Semiconductor Production,* dated November 13, 1995 (SEMM-WW-MA-9505), Figure 1 contains an error in the data given for Asia/Pacific and Europe. The correct data is as follows:

Europe	14%
Asia Pacific	24%

Please file this notice with the original document in your Semiconductor Equipment, Manufacturing, and Materials Worldwide binder. Dataquest regrets the error and apologizes for any inconvenience.

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December 1994

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Jeffrey A. Byrne
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- Optical Disk Drives *Europe*
- Rigid Disk Drives *Worldwide*
- Rigid Disk Drives *Europe*
- Tape Drives *Worldwide*
- Tape Drives *Europe*

Graphics
- Graphics and Displays *Worldwide*

Online, Multimedia, and Software

Emerging Technologies
- Multimedia *Worldwide*
- Online Strategies *Worldwide*

Business Productivity
- Client/Server Software *Worldwide*
- Personal Computing Software *Worldwide*
- *European* Personal Computing Software
- *European* Personal Operating Systems
- Workgroup Computing *Worldwide*
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- AEC and GIS Applications *Worldwide*
- Electronic Design Automation *Worldwide*
- Mechanical CAD/CAM/CAE *Worldwide*
- CAD/CAM/CAE/GIS *Europe*
- CAD/CAM/CAE/GIS *Asia/Pacific*

Services

Customer Services
- Customer ServiceTrends *North America*
- *European* Customer Services

Professional Services
- Professional ServiceTrends *North America*
  - Systems Integration and Applications Development
  - Consulting and Education
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Sector Programs
- System Services *North America*
- *European* Desktop Support Services
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Emerging Technologies
- Digital Documents *North America*
- Colour Products *Europe*

Copiers
- Copiers *North America*
- Copiers *Europe*

Facsimile
- Facsimile *North America*

Printers
- Printers *North America*
- Printers *Europe*
- Printer Distribution Channels *Europe*
- Printer Tracking Services *Asia/Pacific*

Semiconductors

Regional Markets
- Semiconductors *Worldwide*
  - Semiconductor Industry Snapshot
- Semiconductors *Europe*
- Semiconductors *Asia/Pacific*
- Semiconductors *Japan*
- Strategic Tracking Services
  - China/Hong Kong
  - Taiwan
  - Korea
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Products
- ASICs *Worldwide*
- ASICs Product Planning *Europe*
- Memories *Worldwide*
- Memory Product Planning *Europe*
- Microcomponents *Worldwide*
- Microcomponent Product Planning *Europe*
- Discretes Product Planning *Europe*

Application Markets
- Semiconductor Application Markets *Worldwide*
- Semiconductor Application Markets *Europe*
- Semiconductor Application Markets *Asia/Pacific*
- Communications Semiconductors & Applications
- PC Semiconductors and Applications
- PC Teardown Analysis
- PC Watch *Europe*
- Electronic Equipment Production Monitor *Europe*

Manufacturing
- Semiconductor Equipment, Manufacturing, and Materials *Worldwide*
- LCD Multi-client Study

Pricing Trends
- Semiconductor Procurement *Worldwide*

Telecommunications

Networking
- Networking *North America*
  - Local Area Networks *North America*
  - Digital WANs *North America*
  - Modems *North America*
- Networking *Europe*
  - Asynchronous Transfer Mode (ATM) *Europe*
  - ISDN *Europe*
  - Modems *Europe*
  - Local Area Networks *Europe*
  - Private Digital WAN *Europe*
- Networking Market Watch—Intelligent Hubs
- Network Distribution Channels *Europe*

Voice
- Voice Communications *North America*
  - Voice Processing *North America*
  - Integrated Calls Centers *North America*
  - Premise Switching Systems *North America*
- Voice Communications *Europe*
  - Voice Processing *Europe*
  - Call Centres *Europe*
  - Telephones *Europe*
  - PBX/KTS Systems *Europe*

Public
- Public Network Equipment & Services *Worldwide*
- Public Network Equipment & Services *North America*
  - Public Network Equipment *North America*
  - Public Network Services *North America*
- Public Network Equipment & Services *Europe*
  - Public Network Equipment *Europe*
  - Public Network Services *Europe*

Personal
- Personal Communications *North America*
- Personal Communications *Europe*
  - Infrastructure and Services *Europe*
  - Terminals *Europe*
- Wireless Communications *Europe*

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Wafer Fabrication Equipment Market Share: Market share by company by region for 150 companies that participate in 40 different segments of front-end wafer fab equipment.

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Dataquest ALERT

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The E3 Show: Video Game Showdown in Los Angeles

The Electronic Entertainment Expo (E3) quite simply was a showcase for home video game entertainment. The show, held May 11 through 13 in Los Angeles, is advertised as encompassing everything that is electronic, entertaining, and interactive, but the focus this year was on next-generation home video game hardware and software. The Sega Saturn and Sony Playstation were the darlings of the show, with innumerable software vendors using these 32-bit systems to showcase their latest efforts. This *Dataquest Alert* is a short description of the new hardware platforms from Sega, Sony, Nintendo, Atari, and 3DO.

"Who Has the Best Game in Town?"

This was the question on everyone's lips. Unfortunately, this question is more complex than it appears to be. Having the best game in town requires a combination of advanced features built into the hardware and popular software titles. Sony, Sega, 3DO, Atari, and Nintendo were all showing advanced hardware, although Nintendo's Ultra-64 was conspicuously absent. The booths for all five of these companies featured an abundance of demonstration units in addition to press releases with technical specifications. A description of each hardware platform is provided in this *Dataquest Alert*. For more detailed information on these hardware platforms, see Dataquest's upcoming game hardware report titled *Video Game Hardware: Technology at the Next Level*, to be available in July. This report includes complete bills of materials for the Sega Saturn and Sony Playstation, in addition to detailed market analysis focusing on the semiconductor technologies and market opportunities.

Sega Saturn

Sega wowed the crowd by announcing that the Saturn was now available in limited quantities at three national retailers: Toys R Us, Electronics Boutique, and Neostar (the last of which is a holding company for Software Etc. and Babbages). This statement confirmed pre-E3 rumors of a release before the previously announced September 1995 date. Sega has been selling the Saturn in Japan since the Christmas 1994 season. Estimates of total sales hover at about 500,000 units. The Saturn is a CD-ROM-based game unit with a 32-bit architecture. The announcement included a target price of $399 that includes a software title called Virtua Fighter. Dataquest believes this price to be aggressive, based on our own teardown analysis of this system, including a costed bill of materials. The Sega Saturn features eight processors, more than 4MB of RAM, advanced sound processing including MIDI capabilities, a 320-KB/sec CD-ROM drive, and expansion options.

Sony Playstation

Just after the announcement by Sega, Sony Computer Entertainment announced that its Playstation platform would sell for $299 when it arrives in stores on September 9, 1995. Dataquest believes this system, like the Sega Saturn, is priced aggressively, based on a teardown analysis of these units. The Playstation is CD-ROM-based and has a highly integrated design. In contrast to the Sega Saturn, the Playstation has the control electronics for the CD-ROM drive on the main board, which makes the unit very compact. The small size of the case is misleading, however, because the Playstation has lots of processing power with a MIPS R3000 core for the main processor, in addition to a graphics processor, a geometry engine, a sound processor, and a data decompression engine for JPEG decoding. Other specifications include 2.5MB of DRAM, 1MB of VRAM, and an array of video output options.

Table 1 compares the Sega Saturn and the Sony Playstation.

Nintendo Virtual Boy

Nintendo's Virtual Boy game unit breaks the mold of the console-attached-to-your-TV standard. It is difficult to classify this product as either a handheld device like the Game Boy or a console device like the Super NES because it delivers an extremely different experience. Virtual Boy provides a visually immersive, three-dimensional gaming experience using a self-contained display. The unit looks like a pair of large goggles wired to a handheld controller. In the exhibit hall, Nintendo showed the Virtual Boy mounted on a small stand. To understand how the Virtual Boy was displayed, imagine a pair of large goggles mounted on a stand so that a user can lean forward and look into the goggles. Virtual Boy is portable, but is designed to be used in a stationary position. Walking around with the goggles on would be dangerous. The unit is deceptively lightweight. Although the battery pack is attached to the hand controller, all of the main electronic components are contained in the goggles. A 32-bit RISC processor and a dual LED display create a smooth, three-dimensional display. The display, designed by Reflection Technology in Waltham, Massachusetts, has an LED strip and a mirror assembly for each eye. Unfortunately, the colors on the Virtual Boy are limited to a few shades of red, but the images are crisp and offer surprising depth because each eye receives a different image. Previous concerns over image flicker associated with this type of display appear to be unwarranted, based on our "test drive" of the unit. The Nintendo Virtual Boy delivers a flicker-free image with sharp definition. The 3-D nature of the titles displayed involved vertical graphic planes at different apparent distances from the viewer in addition to true three-dimensional graphics where objects move fluidly toward or away from the viewer.

Atari Jaguar VR

The Atari Jaguar VR is the Jaguar game unit with a head-mounted display and an additional unit for motion tracking. This Jaguar VR platform is visually immersive and offers a new level of virtual reality in home gaming systems. The hardware uses infrared tracking to measure real-time movement of both the head-mounted display and an optional joystick controller.

When a user plays a game with the Jaguar VR system, the display changes as the head turns. For example, a user playing a game with a first-person perspective (seeing what the character would see rather than seeing the character on the screen) can look to the right simply by turning his or her head to the right. Head motion is tracked along two degrees of freedom. (Left and right rotation is one degree of freedom; up and down rotation is the second degree of freedom.) The optional joystick is also tracked in two degrees of freedom, but the specific degrees of freedom can vary from one software title to the next. The head-mounted display uses a single, 104,000-pixel LCD display and then splits the image for each eye, so the effect is immersive, but not truly three-dimensional. For safety reasons, the head-mounted display will shut itself off if the player tries to walk around. The game must be played while sitting or standing in one spot.

Table 1
Hardware Comparison of the Sega Saturn and Sony Playstation

Feature	Sega Saturn	Sony Playstation
Number of Processors	Eight	Five
Main CPU	Hitachi SH-2 (two)	MIPS R3000 core from LSI Logic
CPU Clock Frequency (MHz)	28.6	33
Memory	2MB main 1.5MB video 540KB audio 540KB CD-ROM cache 32KB nonvolatile	2MB main 1MB video 512KB audio
Graphics	Two processors 200,000 texture-mapped polygons/sec 500,000 flat, shaded polygons/sec 16 million colors 720x576 max resolution	Two processors 180,000 texture-mapped polygons/sec 360,000 flat, shaded polygons/sec 16 million colors 640x480 max resolution
Sound	Yamaha FH1 DSP Motorola 68EC000 processor 32 PCM channels 8 FM channels 44.1-KHz sampling	Sound processor Built-in digital effects such as reverb and envelope 24 PCM channels 44.1-KHz sampling
Decompression Standards	Proprietary	JPEG
CD-ROM Drive	2x speed	2x speed
Video Output	Composite video standard Optional NTSC, S-video, RGB, and HDTV	Composite video S-video RGB output 5V power for external RF converter

Source: Dataquest (June 1995)

3DO M2

3DO used the show to announce many of the specifications of its next hardware offering, which is called M2. 3DO was the first company to produce a 32-bit, CD-ROM-based game platform, and the M2 is its next step. Although 3DO was not showing M2 hardware on the show floor, it did share many technical details. The core of the M2 technology is a 66-MHz PowerPC 602 CPU with 10 custom coprocessors. Other specifications include a 64-bit memory bus with 6MB (48Mb) of memory including synchronous DRAM and ROM, an MPEG engine supporting both MPEG-1 and JPEG decompression, alpha-channel graphics processing, a 66-MHz DSP for audio processing (including MPEG audio decompression), and backward compatibility with existing 3DO software titles.

Dataquest Perspective

Video game units are becoming fixed-function PCs in terms of both processing power and industry-standard features. The number and complexity of semiconductor devices in each unit are overwhelming, and those devices represent the cutting edge of consumer technology. All of these units also are targeted to the price-sensitive and highly competitive consumer electronics market, which makes the video game hardware market a low-margin business where high volumes are required to recover start-up costs. Based on a teardown analysis of two game units, Dataquest believes the hardware platforms are sold at very low margins and possibly sold at a loss to capture early market share in the emerging 32-bit game market. The profits appear to be tied to software sales.

The market dynamics and pricing policies for video game hardware make this a high-reward and high-risk market for semiconductor manufacturers. Custom ICs are the rule rather than the exception inside these boxes, because each must have cutting-edge features in a highly integrated design. Standard chip products with these features are either not available or are not as integrated as they need to be to meet aggressive cost goals. Hardware designs for these game units are a mix of technologies from different vendors, but most of the technologies are integrated in ASICs rather than purchased as standard components. However, Sega, Nintendo, Atari, 3DO, and Sony are not defining the compression standards and sampling rates for multimedia technology; they are picking and choosing among the standards to deliver the greatest punch at the lowest price. For these reasons, semiconductor companies that want their core processor, MPEG decoder, or audio synthesizer in these units must work with the game developers from the beginning. The high level of integration required to make these game platforms profitable does not allow substitution of semiconductor technologies in the middle of the design process.

The high product volumes for successful home video game platforms make this market irresistible for many semiconductor companies, in spite of the risks. A critical step for a semiconductor manufacturer is to work on reducing the risk once a decision to pursue this market has been reached. Silicon Graphics is working to reduce the market risk of its Magic Carpet architecture by targeting multiple markets with the same core technology. For example, a proprietary version of the Magic Carpet architecture is the core technology for Nintendo's Ultra-64 video game platform, but Silicon Graphics is also releasing an "open systems" version of the architecture for the interactive set-top box market. In other words, Silicon Graphics has leveraged its design efforts to create opportunities in two different markets. Three alliance partners (AT&T Network Systems, Samsung Electronics, and Philips Electronics N.V) already have announced plans to use the Magic Carpet architecture in set-top box products. Silicon Graphics has successfully reduced the market risk of this architecture by pursuing both of these growing opportunities, and it plans to promote the Magic Carpet architecture for additional consumer products.

Summary

Overall, the home video game market provides a tremendous opportunity for semiconductor companies to enjoy high volumes and high profits. There is a high risk of choosing the "wrong" platform, however. For these reasons, it is important to leverage design efforts into more than one specific electronic system. The example given in this document is Silicon Graphics' foray into both home video games and set-top boxes with the Magic Carpet architecture, but opportunities also exist in the PC multimedia market. Success in any one of these markets will quickly lead to the million-unit volumes that every semiconductor company craves.
By Geoff Ballew

Perspective

Semiconductor Application Markets Worldwide

Dataquest Predicts

Electronics Industry Works into a Groove for Major League Growth

Abstract: *In the latest semiannual forecast of electronics equipment production, Dataquest predicts worldwide revenue will grow by 11.8 percent in 1995 to reach $791 billion. A strong growth rate is projected to carry the industry to $1.2 trillion by 2000, an upward revision from Dataquest's spring forecast. This report also provides details on forecast production revenue and growth rates for equipment subcategories and for geographic regions. Details of this forecast are presented in Dataquest's Semiannual Worldwide and North American Electronic Equipment Production Forecast (SAMM-WW-MS-9504), which will be published in October. Please see this publication for complete details of this forecast.*
By Dale Ford

Dataquest Predicts

The electronics industry moved onto a significantly higher revenue growth curve beginning with the 1993 recovery. In the latest semiannual forecast of electronics equipment production, Dataquest predicts revenue from worldwide electronics equipment production will grow by 11.8 percent in 1995 to reach $791 billion. This growth follows a 10.6 percent revenue increase in 1994, according to revised statistics.

Dataquest predicts electronics equipment revenue will grow at a 9.0 percent compound annual growth rate (CAGR) for the next five years, driving overall revenue to $1.2 trillion by the year 2000. Worldwide industry revenue will top the $1 trillion mark in 1998, two years earlier than previously forecast. This growth in electronics equipment production will drive a semiconductor market that Dataquest forecasts will climb to $331 billion by 2000. The new growth path of the electronics industry is best illustrated in

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(For Cross-Industry, file in the Semiconductors, Volume 3 of 3 binder behind the **Semiconductor Application Markets Worldwide** name)

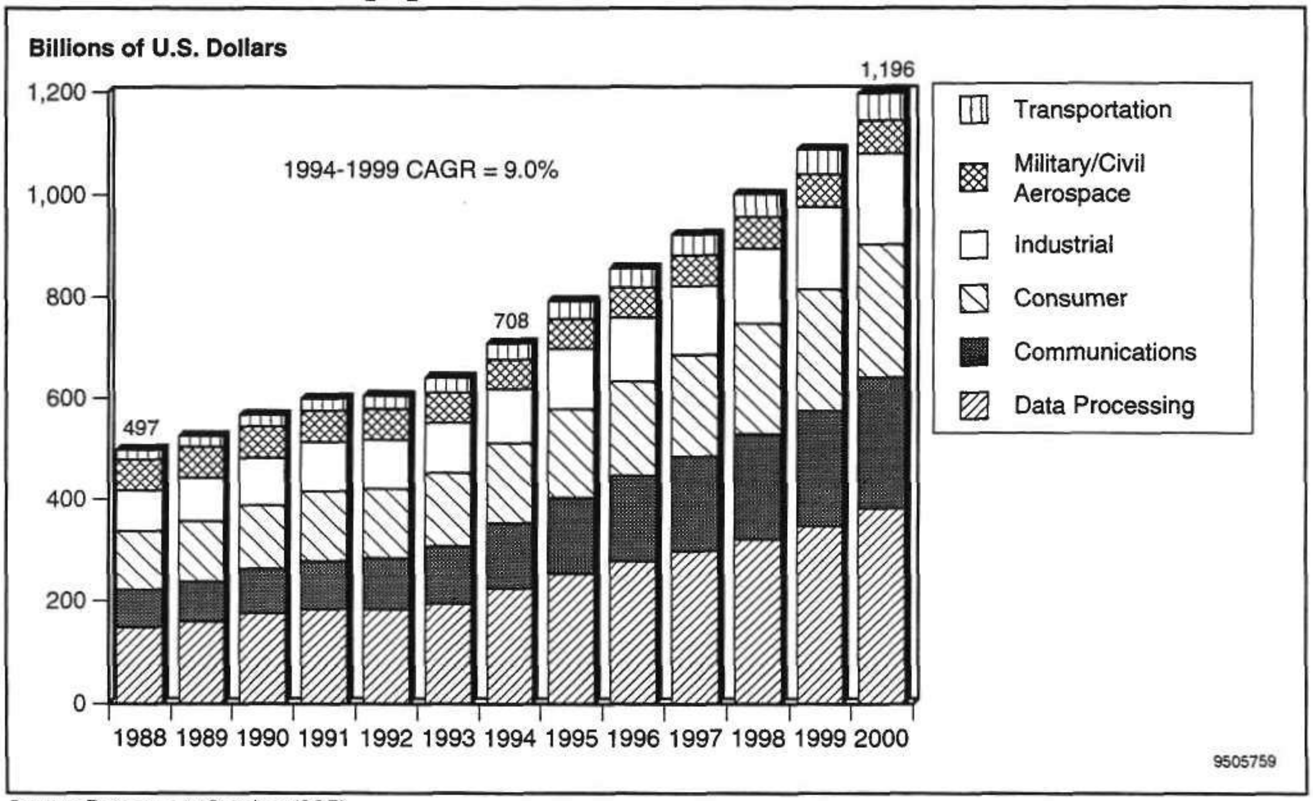
Figure 1. From 1988 to 1993, electronics equipment industry revenue grew at a rate of 5.1 percent CAGR. A clear inflection point is seen between 1993 and 1994 as the industry moved to a much higher level of growth, now forecast to be 9.3 percent CAGR from 1993 to 2000.

If the electronics industry were compared to a professional baseball pitcher, it could be said the pitcher began the game throwing a combination of fastballs, change-ups, spitballs, sinkers, sliders, and even some curves. Now in the last two innings (years), he has moved into "a zone" and begun throwing blazing fastballs. Naturally his manager is pleased, but he is also concerned that the pitcher's arm will soon tire. Dataquest predicts this kid is a champ with staying power and the right stuff to keep throwing smoking fastballs for at least the next five innings (years).

Who's Hot, Who's Big

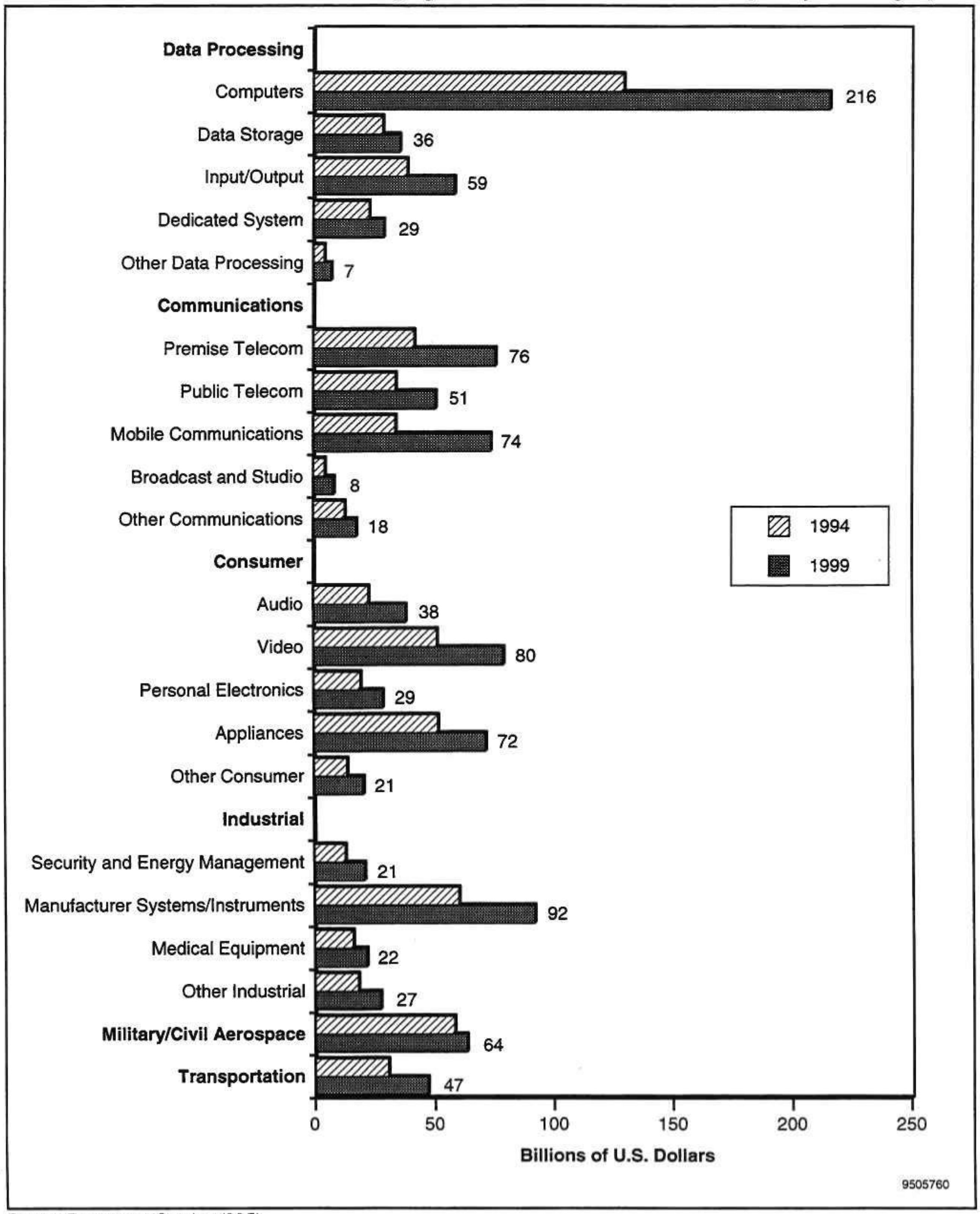
Dataquest's new forecast shows major upward revisions in the forecast revenue growth for computers, premise telecommunications equipment, mobile communications equipment, video consumer products, and appliances. The revenue forecast for each of the major equipment categories is presented in Figure 2. As expected, the PC market plays a dominant role in shaping the growth of industry revenue. In 1994, PCs accounted for 11.3 percent of total electronic equipment industry revenue with $80 billion in factory revenue. By 1999, the PC market is forecast to account for 15.2 percent of total industry revenue and generate $165 billion in sales. It should be noted that this revenue does not include standard peripherals

Figure 1
Worldwide Electronic Equipment Production Revenue Forecast



Source: Dataquest (October 1995)

Figure 2
Worldwide Growth of Electronic Equipment Production Revenue by Major Category



Source: Dataquest (October 1995)

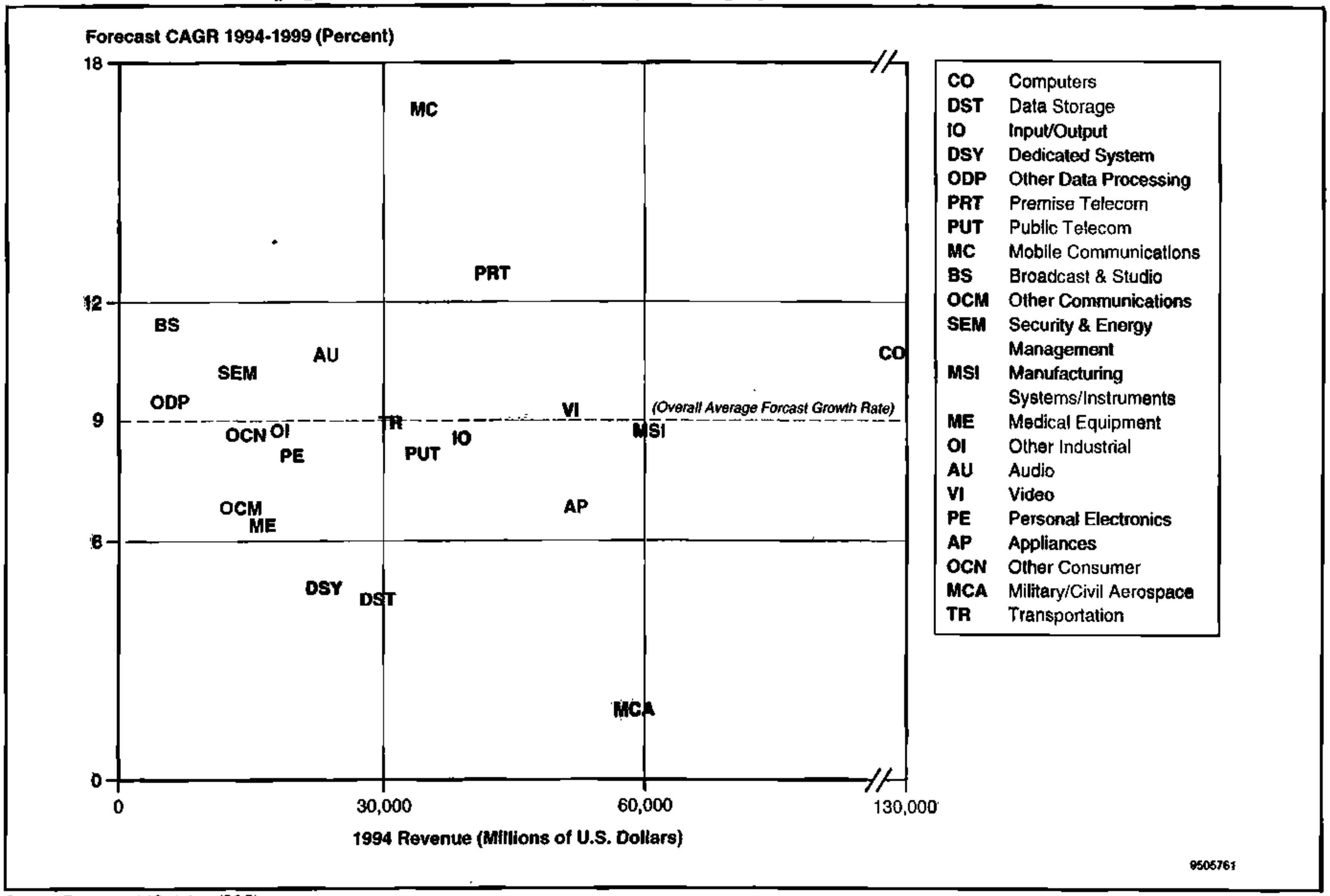
such as rigid disk drives and CD-ROM drives, among others, but it does include memory SIMMs sold through aftermarket channels into the PC market. As seen in Figure 3, other data processing categories such as data storage are forecast to experience comparatively slower growth rates due to severe price erosion. However, the price decline in these categories is a key factor in enabling complete, cost-competitive PC packages to stimulate the growth of both business and consumer PC markets. Overall, the data processing category is forecast to grow at a 9.0 percent CAGR during the next five years, the highest growth rate next to the communications category.

The communications category is expected to experience the highest revenue growth during the next five years with a forecast revenue growth of 12.2 percent CAGR. Mobile communications and premise communications are projected to lead the way with increases of 16.8 percent and 12.7 percent CAGR, respectively. Revenue from mobile communications equipment should more than double from $34.1 billion worldwide in 1994 to $74.3 billion in 1999.

The Asia/Pacific region continues on its path to replace North America as the leading producer of electronic equipment by 1999. Figure 4 shows that in 1995 North America is expected to generate 31 percent of the worldwide electronic equipment revenue, followed by Japan with 27 percent, Europe with 22 percent, and Asia/Pacific with 20 percent. However, by 1999 Asia/Pacific is forecast to produce 27.4 percent of worldwide electronic equipment revenue with $297 billion, while North America is forecast to account for 26.6 percent of the revenue with $289 billion. It is also notable that revenue growth in the Asia/Pacific region is not driven by PCs, data storage, and consumer products alone. Communications, particularly mobile communications, will add momentum to the regional growth in production as the local markets experience dramatic expansion.

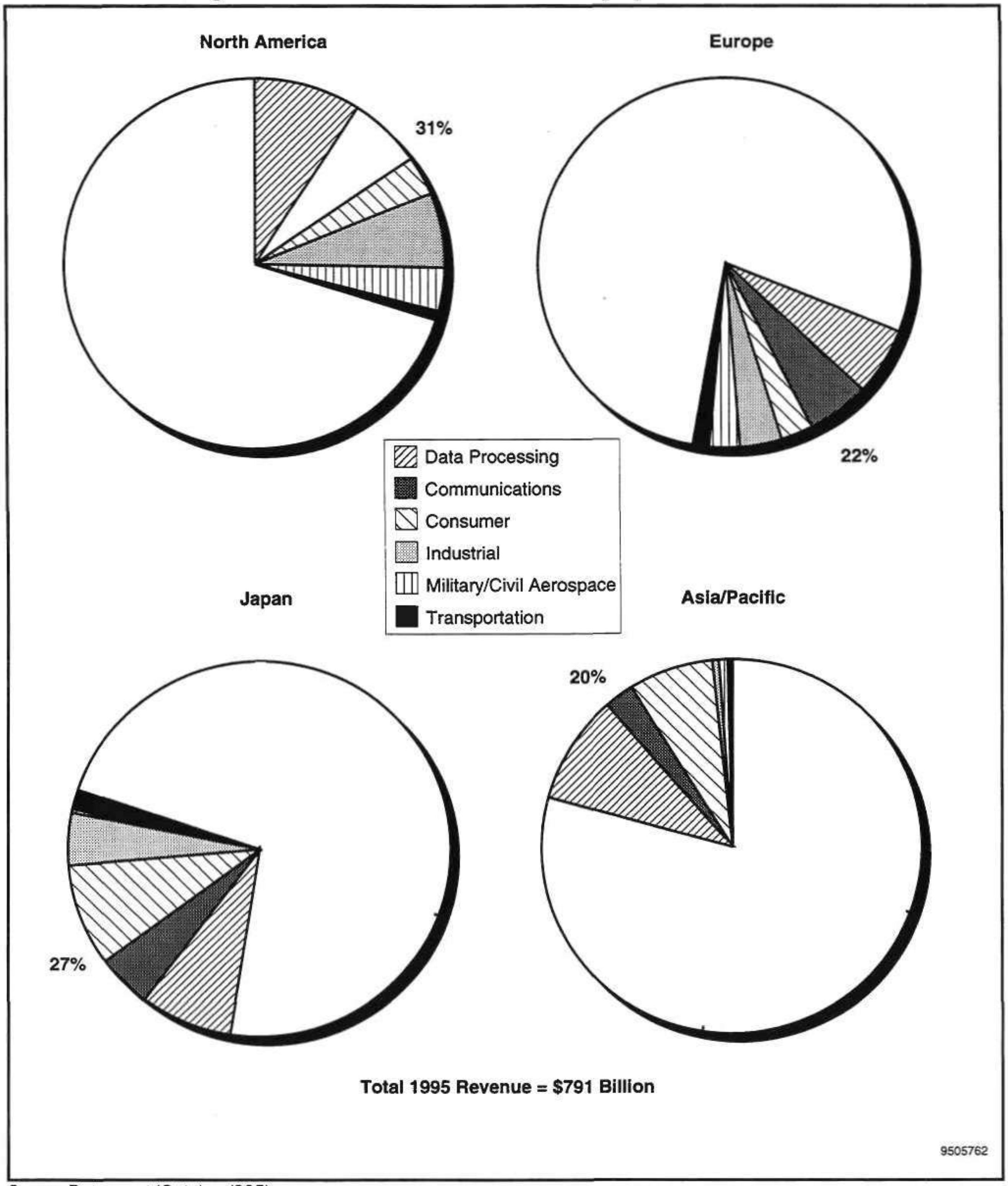
Dataquest's semiannual forecast of worldwide and regional electronic equipment production draws on extensive databases that cover a range of areas from data processing to transportation. Information for these databases is developed by Dataquest analysts in North America, Europe, Japan, and the Asia/Pacific region. Through a coordinated effort, this information is compiled and analyzed to develop a comprehensive view of the worldwide electronics industry. Details of this forecast are presented in Dataquest's Semiannual *Worldwide and North American Electronic Equipment Production Forecast* (SAMM-WW-MS-9504), which will be published in October. Please see this publication for complete details of this forecast.

Figure 3
Worldwide Electronic Equipment Growth Forecast by Major Category



Source: Dataquest (October 1995)

Figure 4
Estimated 1995 Regional Production of Electronics Equipment



Source: Dataquest (October 1995)

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Perspective

Semiconductor Application Markets Worldwide

Dataquest Predicts

The Worldwide Electronics Industry: On Target for $1 Trillion by 2000

Abstract: *Building on momentum that began in 1993, the worldwide electronics industry surged ahead 9.0 percent to nearly reach $690 billion in 1994. Dataquest's most recent electronic equipment forecast predicts continued strong growth of 6.5 percent during 1995, which will push production to $734 billion. This same forecast projects the worldwide electronics industry to have a compound annual growth rate of 7.0 percent during the next five years to drive the industry to $967 billion in 1999. If this same growth is sustained an additional year, the worldwide production of electronic equipment will top $1 trillion in the year 2000. This report provides a summary of the global and regional forecasts for the data processing, communications, consumer, industrial, military/civil aerospace, and transportation electronics industries. The information presented highlights important regional and market trends and identifies significant economic factors influencing these trends. Also, an updated strategic planning guide plots product opportunities in each of the major industry segments and explains the implications of future product developments for semiconductor products.*
By Dale Ford

Electronics Production Experiences Solid, Broad-Based Growth

The dramatic 9.0 percent growth of the worldwide electronics industry during 1994 was driven by solid production increases in all regions and all but one of the major industry segments. The electronics industry nearly reached $690 billion in 1994 and is expected to hit $734 billion in 1995.

Dataquest Predicts

Dataquest predicts that worldwide electronics industry will have a compound annual growth rate (CAGR) of 7.0 percent in the next five years, driving the industry to $967 billion in 1999. Sustained growth for an additional year at the same rate will put worldwide production of electronic equipment over $1 trillion by the year 2000.

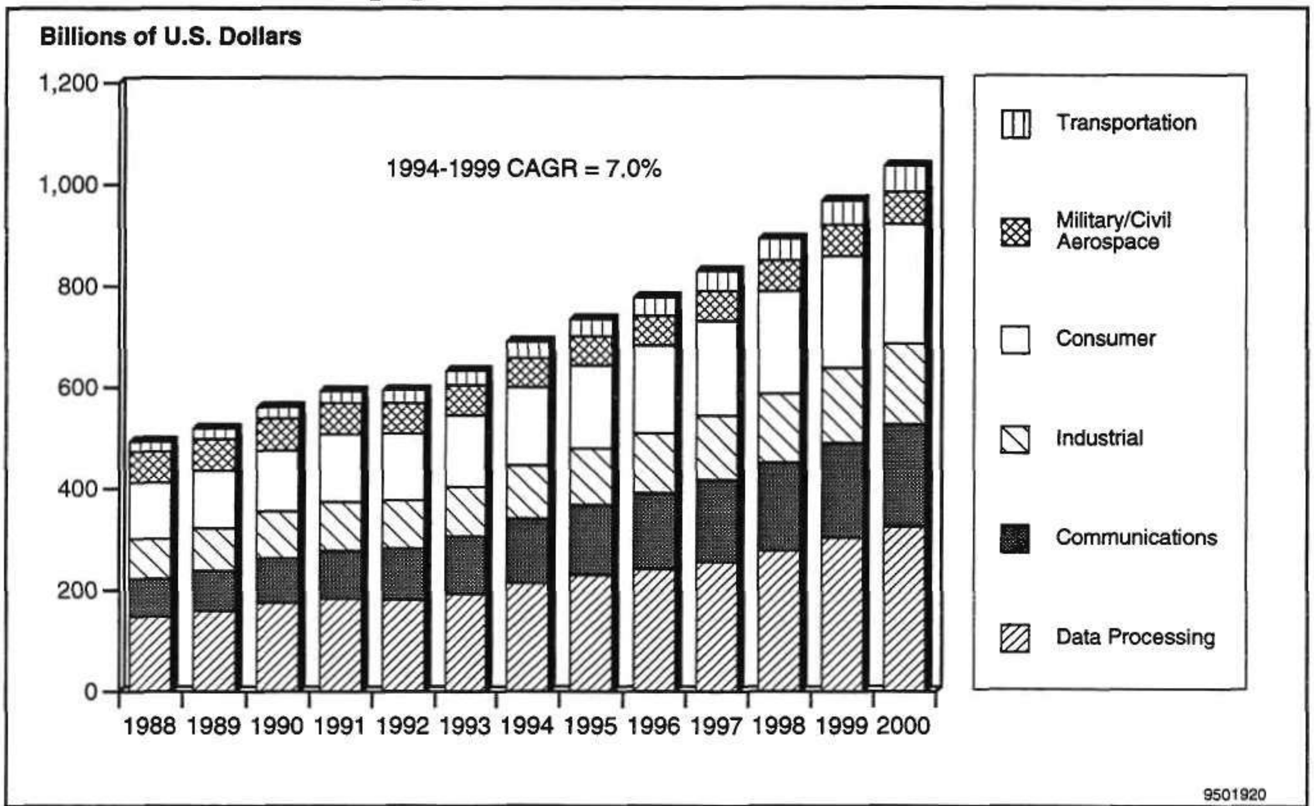
Dataquest

Program: Semiconductor Application Markets Worldwide
Product Code: SAMM-WW-PD-9501
Publication Date: May 8, 1995
Filing: Perspective

The communications and data processing industries led all industries with amazing growth of 11.4 percent and 11.3 percent, respectively. Mobile communications continued to fuel growth in the communications segment, while the surprisingly strong growth of personal computers boosted the data processing industry to new heights. The only industry that failed to show major growth was the military/civil aerospace industry, which contracted 2.6 percent in 1994 because of continued cuts in defense spending. Figures 1 and 2 summarize Dataquest's worldwide electronics industry forecast. The Asia/Pacific region continued its robust growth as production grew 17.6 percent in 1994 to $135 billion. Rebounding from a severe recession, Japan's growth rate surpassed North America and Europe in 1994 as its production grew 9.0 percent to $190 billion. The soaring yen has also boosted the dollar-based growth of Japanese production in 1994. This article includes figures that show the continuing shift in global production patterns.

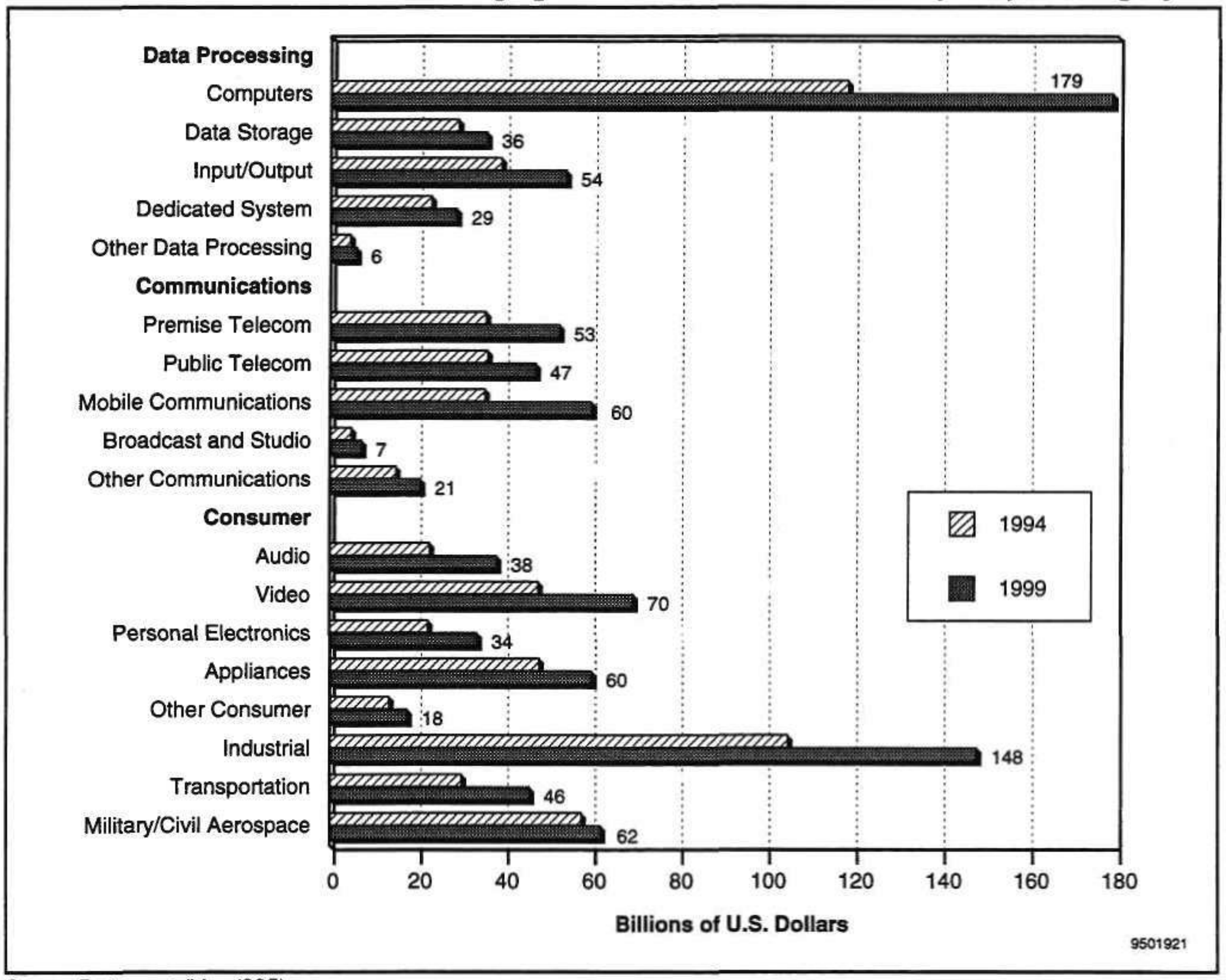
The combination of a dynamic electronics industry and shifting global and regional economic conditions creates tremendous challenges for projecting the development of the global electronics industry. Dataquest's recent forecast of worldwide and regional electronic equipment production draws on extensive databases covering data processing to transportation. Information for these databases is developed by Dataquest analysts in North America, Europe, Japan, and the Asia/Pacific region. Through a coordinated effort, this information is compiled and analyzed to develop a comprehensive view of the worldwide electronics industry. Detailed results of this project are presented in Dataquest's *Worldwide and North American Electronic Equipment Production Forecast*, dated April 24, 1995 (SAMM-WW-MS-9501). Please see this publication for complete details of this forecast.

Figure 1
Worldwide Electronic Equipment Production Revenue Forecast



Source: Dataquest (May 1995)

Figure 2
Worldwide Growth of Electronic Equipment Production Revenue by Major Category



Source: Dataquest (May 1995)

Global Economics: Continued Strength, Moderate Growth Expected

Current and expected worldwide macroeconomic conditions are assessed and forecast in developing Dataquest's electronic equipment production forecast. Information from The Dun & Bradstreet Corporation, including gross domestic product (GDP) forecasts listed in this section, is used to develop a macroeconomic forecast for the world's major economies. This forecast identifies trends in the economic health of the world's leading consumers and producers of electronic equipment and provides a foundation for projecting electronic equipment production on a regional basis.

Worldwide business optimism for first-quarter 1995 sales edged higher, while expectations for higher prices and profits moved toward six-year peaks, according to The Dun & Bradstreet Corporation's latest quarterly survey of more than 11,000 business executives in 16 countries. Although there has been recent volatility in some markets in response to proposed U.S. trade sanctions against China and the recent depreciation of the

Mexican peso, the strength of the survey responses indicates that the current global economic expansion will be able to overcome setbacks without a broad negative impact. Specific trends and assumptions for the major regions in this forecast are outlined in the following sections.

North America

Table 1 shows actual gross domestic product (GDP) growth in 1994, and 1995 to 1996 projections.

Table 1
North American Gross Domestic Product Growth Percentages

	1994	1995	1996
United States	4.0	2.9	3.0
Canada	4.2	3.7	3.2
Mexico	2.8	2.0	2.5

Source: The Dun & Bradstreet Corporation

Assumptions for the North American region include the following:

- The first-quarter 1995 survey suggests that executives in North America and Europe believe their economies' respective expansions are nearing their peaks, and that inflationary pressures will grow stronger as idle production capacity is exhausted. As the second quarter approaches, prices will merit closer inspection in order to gauge the impact of recent interest rate hikes in the United States.
- Rising interest rates are also expected to moderate growth in the consumer electronics, home PC, and automobile markets during 1995. Higher interest rates have already slowed the housing market, which will reduce sales of consumer electronics into new homes.
- Prior to the sharp decline in the value of the peso, executives in Mexico had reported expectations for record growth in sales, prices, profits, and inventories as businesses in the region prepared for unprecedented expansion under the North American Free Trade Agreement (NAFTA). Unfortunately, the recession that has gripped Mexico in the wake of the collapsing peso changes everything. Although there is still tremendous promise in the region, little of the previously expected growth will be realized until the peso stabilizes. As one of the United States' largest trading partners, and also as a critical export market for Canada, Mexico's volatility will doubtless have some damping impact on expected growth across North America.
- Uncertainty surrounding government rules and regulations for the information superhighway continues to present roadblocks to corporate development efforts. Expansion of investment has been delayed by many companies because of poor results in many trials across country.

Japan

Assumptions for the Japanese region include the following:

- Japan's real GDP is forecast to grow 2.0 percent in 1995, up from 0.8 percent growth in 1994, and to accelerate to 3.5 percent in 1996.
- Japan experienced steady economic growth during the last three quarters of 1994. However, Japanese executives predicted that business conditions would only improve marginally during the first quarter of 1995. Strong

gains in expected sales and employment levels were offset by slightly lower expectations for net profits. The yen's appreciation against Western currencies proved a hindrance to exports and has frustrated Japan's nascent recovery, at least for the first quarter of 1995.

- Industrial electronics should benefit from a resumption of capital spending by Japan's manufacturing industries, in keeping with Japan's overall economic recovery. Industrial electronics growth is being particularly spurred by record investment spending in the semiconductor industry on manufacturing equipment, and on test and measurement equipment.
- Production for domestic consumption and export will continue to shift out of Japan. The further strengthening of the yen will reinforce this shift.
- Japan will continue leadership in significant high-growth electronics equipment areas such as notebook PCs, personal digital assistants, digital cellular telephones, video games, video cameras, and optical disk drives.

Europe

Table 2 shows actual GDP growth in 1994 and 1995 to 1996 projections.

Table 2
European Gross Domestic Product Growth Percentages

	1994	1995	1996
Germany	2.8	3.1	3.5
United Kingdom	4.0	3.2	3.0
France	2.4	3.2	2.9
Italy	2.3	2.9	3.2

Source: The Dun & Bradstreet Corporation

Assumptions for the European region include the following:

- Europe is enjoying the benefits of a mature economic expansion, and most indexes are positive for the duration of the first quarter of 1995. The region has expanded continuously from the first quarter of 1993. European manufacturers made significant productivity gains in 1994, but continued expansion could increase pressure on central banks in the region to raise interest rates.
- Although growth in various segments of the European telecommunications market is mixed, European telecommunications manufacturing companies are benefiting from a significant presence in the global market and rising exports to the fast-growing Asia/Pacific market. In the mobile arena, GSM cellular telephones will drive a huge market in Europe as penetration rates approach those in the United States. The continued success of GSM in non-European countries also will bolster production in the near term until it shifts closer to the regions of consumption.
- Strong rates of growth are anticipated throughout Europe as overall expectations for sales and profits continue to be optimistic.
- With a strengthened economy, household spending on consumer electronics will continue in 1995.

Asia/Pacific

Table 3 shows actual GDP growth in 1994 and 1995 to 1996 projections.

Table 3
Asia/Pacific Gross Domestic Product Growth Percentages

	1994	1995	1996
Taiwan	6.3	6.3	6.5
South Korea	8.2	7.5	7.5
Singapore	10.0	8.0	8.0
Hong Kong	5.5	5.5	5.0

Source: The Dun & Bradstreet Corporation

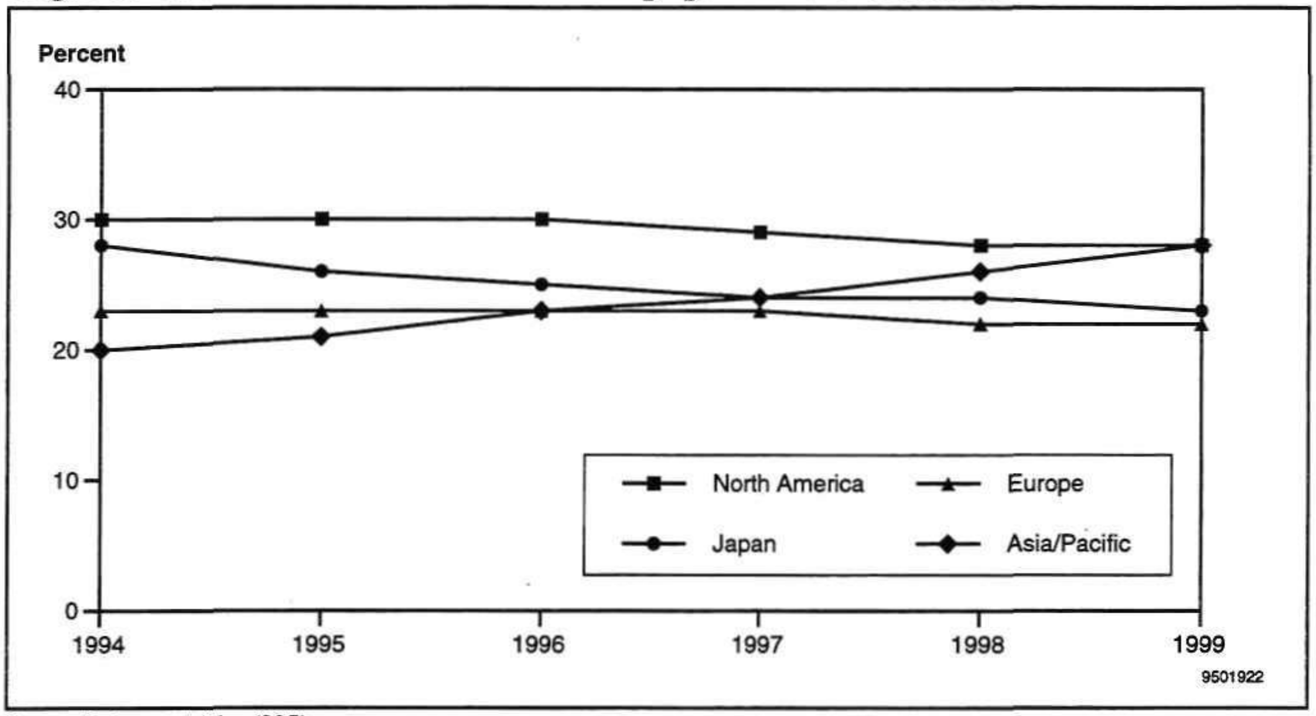
Assumptions for the Asia/Pacific region include the following:

- The Dynamic Asian Economies (DAE)—Korea, Taiwan, Thailand, Hong Kong, Singapore, and Malaysia—have attracted growing attention for their strong economic performance. The strong growth patterns of 1993 and 1994 are projected to continue into 1995 and 1996. Significant increases in local regional consumption and liberal trade policies that fuel exports persist as key drivers in these economies.
- Because of the continued importance of exports to the world's mature economies for the Asia/Pacific region, the economic performance of Asia/Pacific countries is influenced strongly by economic activity in areas such as the United States and Europe. The impact of decelerating growth in the United States is expected to be partially offset by accelerating growth in western Europe in 1995. Also, the currencies of major economies in this region are tied to the U.S. dollar, so their exports are becoming cheaper (in some cases) as the dollar depreciates against the yen and deutsche mark. Conditions in these export markets paint a bright picture for the Asia/Pacific region in 1995.
- Low-cost production opportunities will continue to generate growing captive and contract manufacturing operations in Asia/Pacific countries such as Indonesia, Malaysia, Thailand, and The People's Republic of China.
- Investment in consumer electronics production, particularly from Japan, will follow an upward trend. Local demand for consumer products in many countries in the region is just beginning to grow.
- The booming telecommunications growth in China and the Asia/Pacific region will expand. The industry has leapfrogged from low-end telephones and answering machines to include high-end equipment plants. Major telecommunications players have been encouraged to invest in local manufacturing in exchange for market access.

Regional Production Trends: Shifting to Asia/Pacific Region

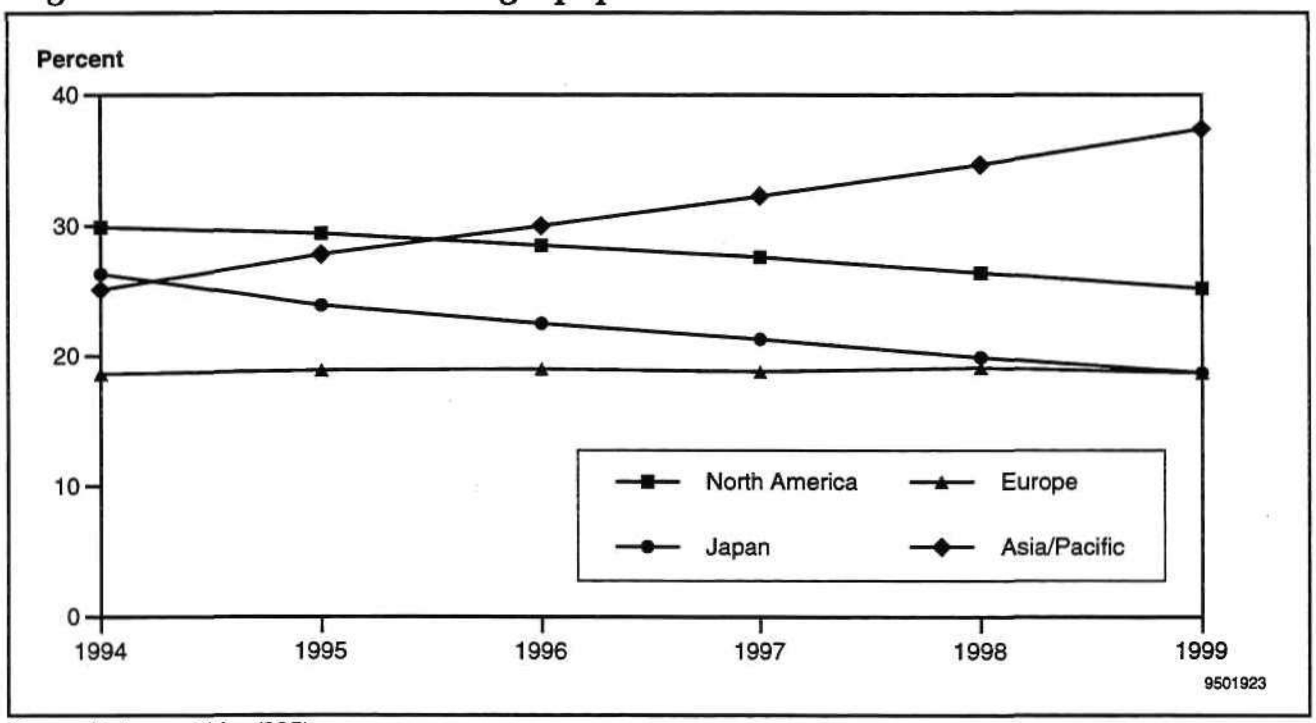
The influence of the economic factors described is seen in the shifting global production trends in the electronics industry. Although overall production in all regions will grow, the Asia/Pacific region is predicted to continue its dramatic ascendancy in electronic production as it serves growing markets in its own region and provides cost-effective manufacturing solutions for export markets. As a result, the Asia/Pacific region will edge out North America as the leader in revenue from electronic equipment production by 1999. Figure 3 shows the clear pattern of shifting production to the Asia/Pacific region. The major underlying trends in data processing, communications, and consumer equipment that sum to this overall movement are shown in Figures 4, 5, and 6.

Figure 3
Regional Share of Worldwide Electronic Equipment Production Revenue



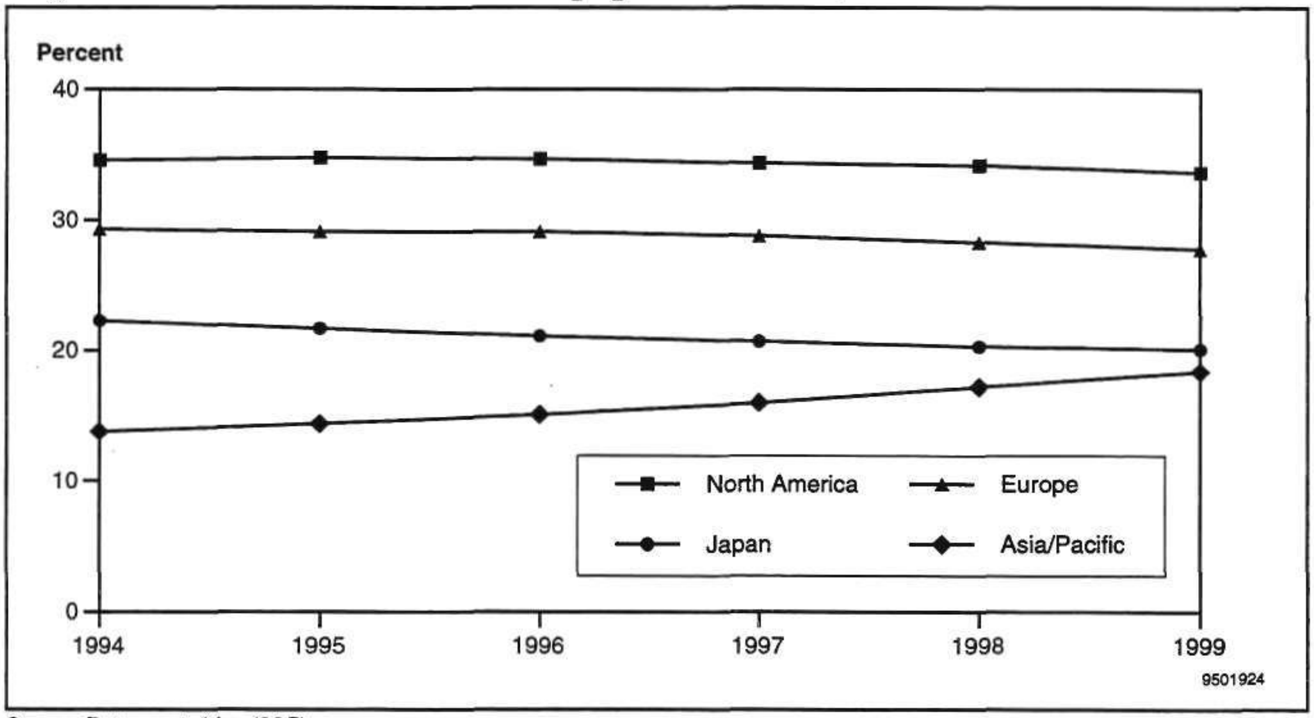
Source: Dataquest (May 1995)

Figure 4
Regional Share of Data Processing Equipment Production



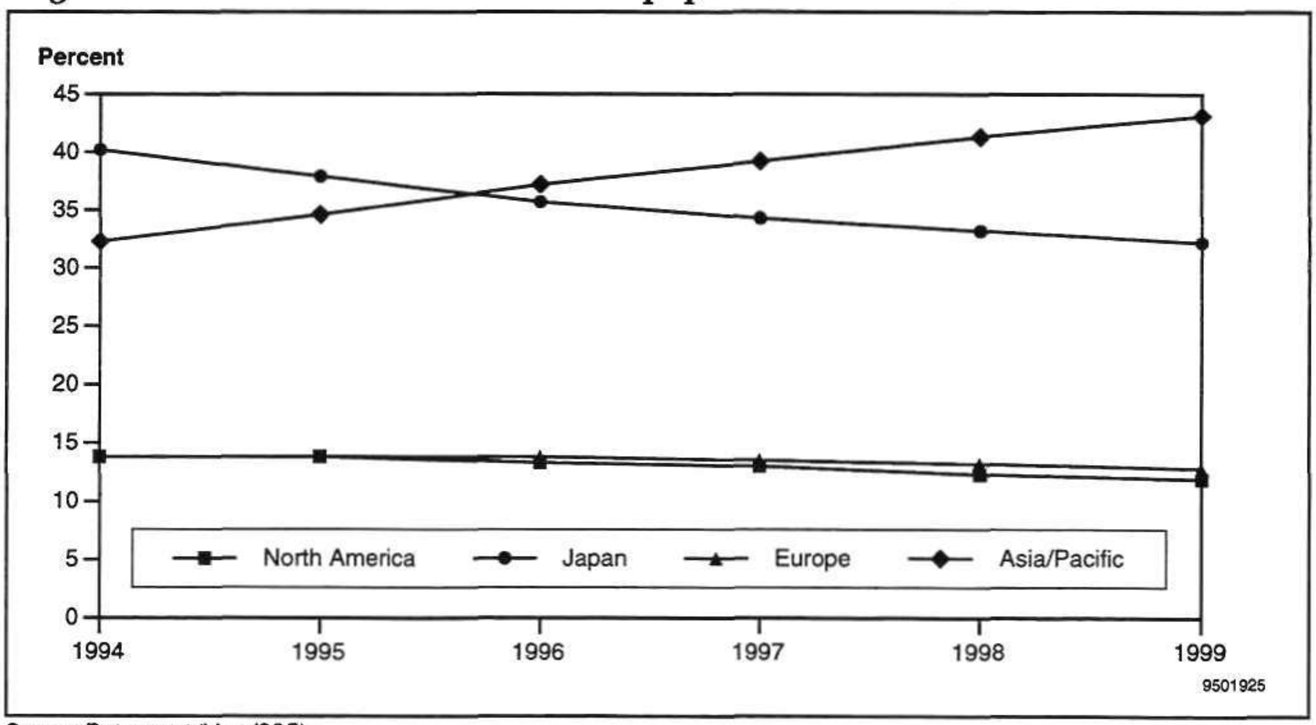
Source: Dataquest (May 1995)

Figure 5
Regional Share of Communications Equipment Production



Source: Dataquest (May 1995)

Figure 6
Regional Share of Consumer Electronics Equipment Production



Source: Dataquest (May 1995)

Market Opportunities in the 1990s

Mergers, alliances, trial markets, and multifunctional products have developed at a quickened pace as companies pursue market opportunities created by overlapping industries in computers, communications, and consumer products. Indeed, there are few product segments that will not be impacted by the growing overlap of technologies and markets. The following figures and highlighted trends provide an overall perspective on the anticipated growth of major segments in the data processing, communications, and consumer industries. Key trends are also listed for the industrial, military/civil aerospace, and transportation industries.

Data Processing Equipment Market Trends

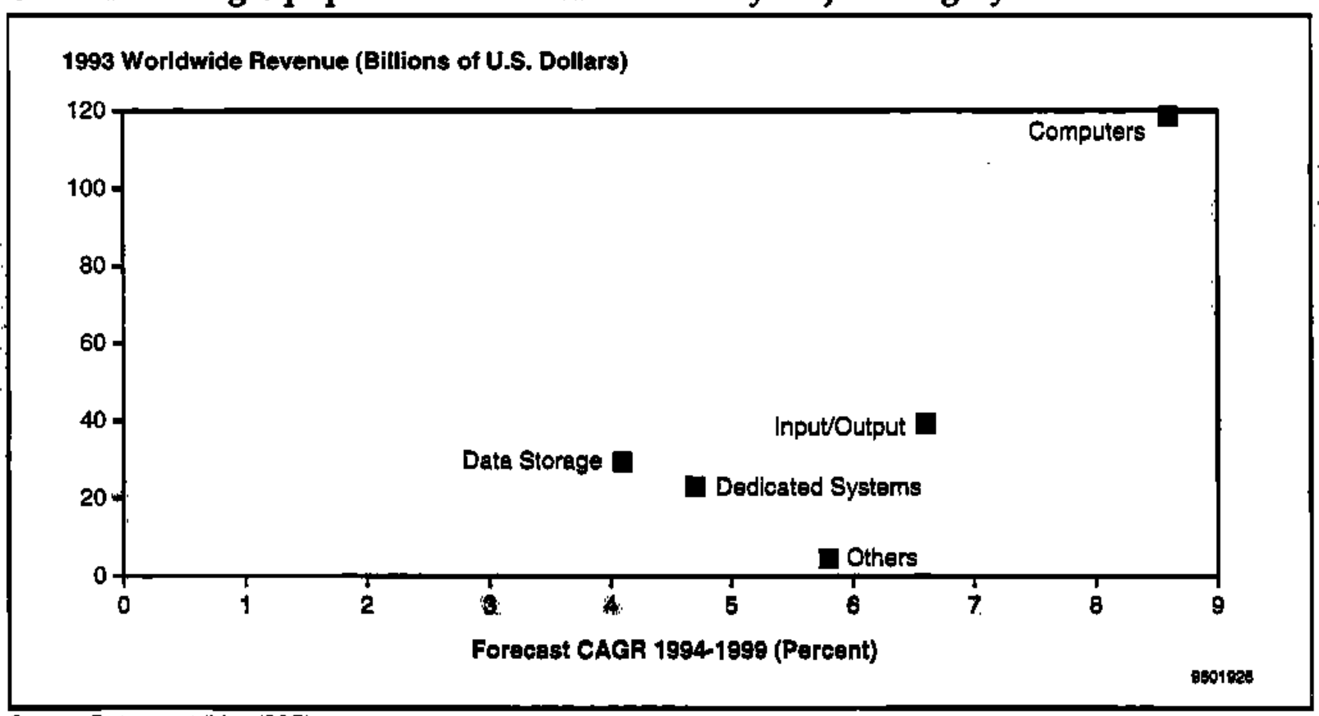
The worldwide data processing equipment market is forecast to grow at a 7.2 percent CAGR from $214 billion in 1994 to $304 billion in 1999. Figure 7 shows the forecast growth and size of major segments within this market.

Key Trends

Key trends are as follows:

- Competitive forces among the Pentium, PowerPC, and the other RISC processor camps continue to drive the price, performance, and pace of product development in the PC and workstation markets. As a result, businesses and consumers are gaining access to soaring computing power at stable price points.

Figure 7
Data Processing Equipment Production Forecast by Major Category



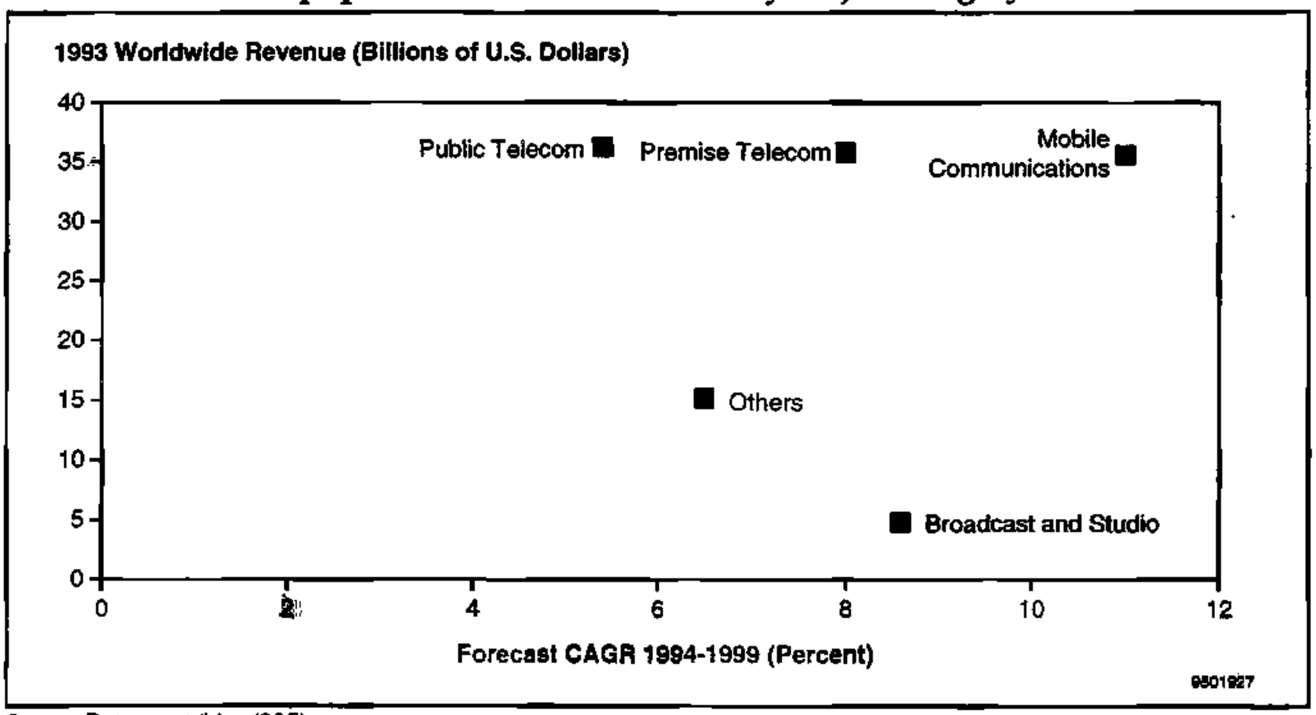
Source: Dataquest (May 1995)

- Mobile products such as notebook, subnotebook, and palmtop PCs are leading the growth of the PC market. Continued sluggishness and a conversion to less-expensive systems based on multiprocessing technology in the mainframe and midrange markets is offsetting strong growth by PCs in the computer market. Also, the success of the PC is eroding the potential workstation market.
- The expansion of the home PC market and multimedia PCs has provided added momentum to the PC market. Both of these factors lead to a significant increase in growth of the personal computer market during 1994. These drivers will continue to play a fundamental role in market growth over the forecast period. The rapid expansion of interest in multimedia is also bolstering growth in the storage, display, and add-in board segments such as sound, graphics, and video boards.
- Increasingly powerful operating systems and applications programs are pushing the appetite for storage capacity. Together with multimedia products, they are creating demands for higher storage capacity in rigid and optical disk drives. However, major price erosion has kept revenue flat or declining in all major storage categories. This trend will depress future revenue growth.

Communications Equipment Market Trends

The worldwide communications equipment market is forecast to grow at an 8.1 percent CAGR from $127 billion in 1994 to $188 billion in 1999. Figure 8 shows the forecast growth and size of major segments within this market.

Figure 8
Communications Equipment Production Forecast by Major Category



Source: Dataquest (May 1995)

Key Trends

Key trends are as follows:

- A continued surge in demand for wireless voice and data communications products including cellular phones, wireless modems, and repopularized pagers is propelling the mobile communications markets to high growth rates.
- The growth of mobile communications markets throughout the world exceeded even the most optimistic forecast for 1994. For example, the number of cellular subscribers in the United States grew by more than 40 percent in 1994. Dataquest is very optimistic about the continued growth of wireless markets in North America and around the world. In the United States, the creation of a new personal communications services (PCS) market that will increase competition with existing wireless communications services is expected to fuel even greater growth. The GSM system in Europe is driving strong growth in that region, and the Personal Handy Phone (PHP) and Pacific Digital Cellular system is showing great promise in Japan. However, PCS/personal communication network (PCN) is a very cost-conscious market and there will be significant price pressure on end-user equipment. This pressure will be reflected to the factory, where significant average selling price (ASP) erosion is expected over the forecast period. Even with these price pressures, strong growth is forecast for mobile equipment revenue.
- The strong subscriber growth in the mobile communications market will act as a driver for new infrastructure equipment and mobile base stations. In addition to serving the needs of their local markets, the United States and Europe are major exporters of mobile communications equipment to other developing regions of the world. For this reason, the growth of base station production will outpace even the growth of the local markets in these areas.
- A trend toward digital cordless phones, smart phones, and answering machines is developing.
- Digital radio and TV studio upgrades are stimulating higher growth in broadcast and studio equipment.
- Increased capital spending is stimulating premise networking equipment production. Near-term demand is for higher-speed networking products such as switched Ethernet and FDDI. Intermediate and long-term production will be carried on for 100-Mb/sec and ATM technologies.
- The modem market is being propelled by record subscriptions to online services and Internet. ISDN and T Carrier equipment production is increasing because of higher-speed WAN requirements.
- Public telecom and cable infrastructure equipment companies (for example, SONET) are receiving record orders to support the rollout of high-bandwidth interactive video services to the residential market.
- Fiber-optic-based synchronous digital hierarchy (SDH)/SONET transmission systems are being installed worldwide. Asynchronous transfer mode (ATM) and asymmetric digital subscriber loop (ADSL) are representative of new technologies under evaluation.
- Networking and internetworking equipment continues strong growth as network systems are deemed an integral part of computer hardware additions and upgrades driving purchases of hubs, routers, and bridges.

- Call processing equipment continues in popularity in North America and expansion in other regions.

Consumer Electronic Equipment Market Trends

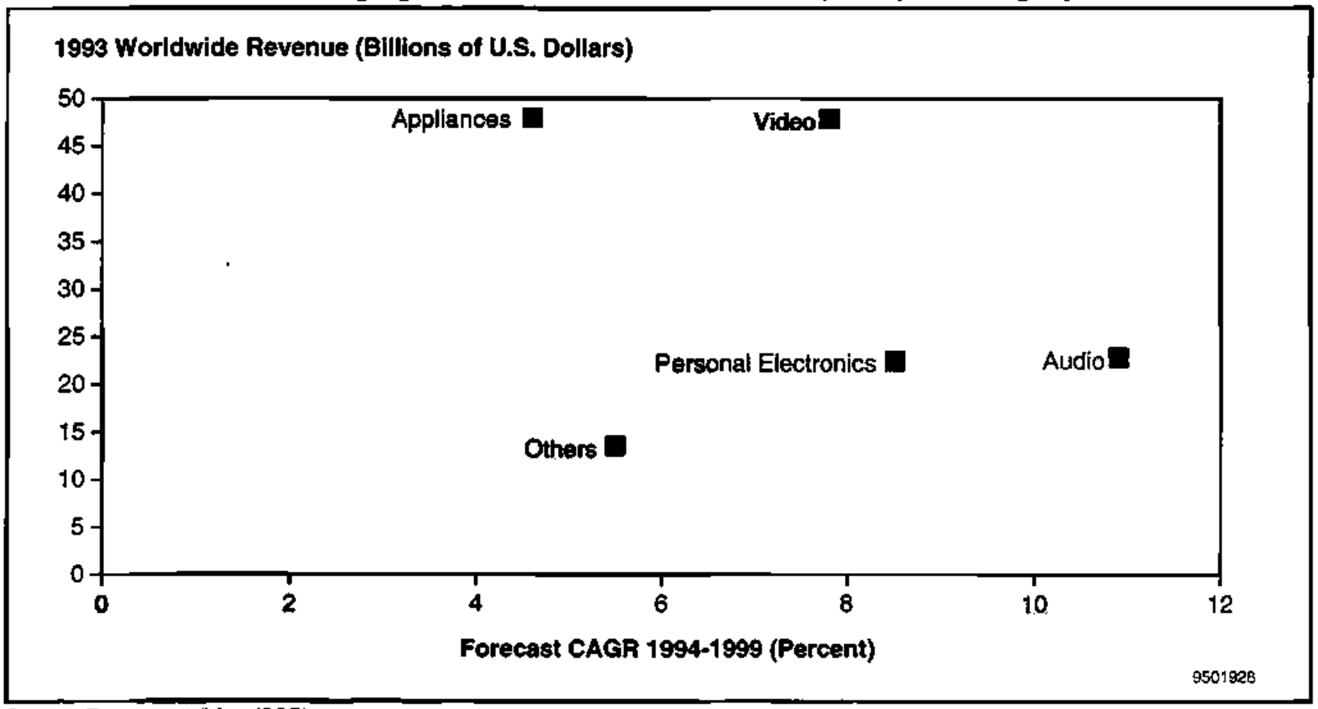
The worldwide consumer electronic equipment market is forecast to grow at a 7.3 percent CAGR from $155 billion in 1994 to $220 billion in 1999. Figure 9 shows the forecast growth and size of major segments within this market.

Key Trends

Key trends are as follows:

- Much of the consumer electronics market has entered "replacement" mode in Group of Seven (G7) countries. Growth in consumer electronics sales in newly industrialized countries is adding strength to this market.
- A seemingly insatiable appetite for entertainment is driving growing purchases of items such as VCRs and video game players. Digital video and audio products are replacing past-generation analog systems. DSP-based TVs, VCRs, camcorders, and audio products including Digital Compact Cassette (DCC) and Mini Disc (MD) are emerging. The DCC and MD products have enjoyed early success in Japan, and their promoters believe this growth will spread to other regions as more supporting "software" is introduced. Also, a new genre of interactive consumer devices such as CD-ROM "infotainment" systems and digital videodisk (DVD) is emerging.

Figure 9
Consumer Electronic Equipment Production Forecast by Major Category



Source: Dataquest (May 1995)

- The competition over the set-top decoder box market is heating up as companies vie for the opportunity to bring the information superhighway into the living room with their hardware. Sales of direct broadcast satellite systems soared in 1994. Sales of cable TV set-top boxes are expected to ramp up also. Very strong growth is forecast for this network.
- Appliances continue solid growth with strengthening economies and new household formation.

Industrial, Aerospace, and Transportation Electronics Equipment Market Trends

The worldwide industrial electronics equipment market is forecast to grow at a 7.1 percent CAGR from $105 billion in 1994 to $148 billion in 1999. Highlights are as follows:

- Industrial electronics production has been fueled by broad-based growth of business spending on capital equipment. The continuing trend of downsizing has driven companies to seek implementation of more efficient processes. Recent increases in interest rates have lowered the current outlook for growth in industrial equipment production slightly below what it otherwise would have been.
- There is a growing trend toward the use of standard computing equipment in industrial control applications.
- Increased pressure from managed health care providers and insurance companies has had a major impact on the medical electronics markets. Major equipment manufacturers are revising their product development strategies to provide more cost-effective solutions for an extremely cost-conscious market. In a period of major cost-cutting in the health care industry, medical equipment providers are working to position their products as a "solution" to the problem of spiraling costs. This environment will moderate revenue growth in this segment over the forecast period.

The worldwide transportation electronics equipment market is predicted to grow at an 8.6 percent CAGR from $30 billion in 1994 to $45 billion in 1999. Highlights are as follows:

- Automotive production in the United States and Europe is expected to slow over the next two years as higher interest rates impact the market. The Asia/Pacific market for automobiles is booming.
- Automotive electronics content is rising. Products enabling compliance with more rigorous antipollution regulations and fuel-efficiency standards, antilock brakes, air bags, navigation systems, and security systems are leading the way. Comprehensive driver information systems will add to the growth in the long term.

The military/civil aerospace electronics market is expected to grow at a modest 1.5 percent CAGR from $58 billion in 1994 to $62 billion in 1999 for the following reason:

- Military spending cuts are expected to level out after several years of deep cuts. A cyclical upturn is expected in civil aviation avionics production. Civilian space electronic production is expected to remain robust amid a flurry of orders for low-earth-orbit satellite telephone and direct broadcast satellites.

A Spectrum of Opportunities

Tables 4 through 9 show updated planning guides with the 1994 to 1999 outlook for selected worldwide electronic products. In general, the declining stage indicates that the product or function is being replaced by another. Slow growth of zero to 6 percent indicates that a mature product is on the way to decline or is in a replacement/saturated market mode. Emerging growth of greater than 12 percent and moderate growth of 7 to 12 percent represent the market behavior of products going through introduction and maturity.

Projected semiconductor trends for computer systems are as follows:

- Memory
  - PCs with 7MB average DRAM in 1994 will move to 20MB DRAM in 1999. The preferred configuration will be x16.
  - Increased opportunities will emerge for fast/synchronous DRAMs as MPU speeds outstrip conventional memory architectures.
  - Bursting, MPU-specific SRAM will be used for cache design. Average size will move from 256KB to 1MB by 1999.
- MPU/MCU
  - New generations of Pentium, PowerPC, Alpha, PA-RISC, SPARC, and MIPS processors will drive future PCs, workstations, and servers.
  - Proprietary processors such as ARM and Dragon will continue to be used in palmtop devices.
- ASIC/ASSP
  - New chipsets to support new MPU generations will continue to emerge.
  - The PCI bus standard will dominate with Card Bus emerging.
  - The PCMCIA interface will dominate in the mobile market.

Table 4
Computers: 1994 to 1999 Unit Growth

Declining (Negative)	Slow (0 to 6%)	Moderate (7 to 12%)	Emerging (More than 12%)
386 PC	486 PC		Multimedia PCs and workstations
Proprietary midrange		Open workstation/server	Power PC—PCs/workstations/servers
Proprietary workstations			Pentium (P6, P7)—PCs/servers
Proprietary mainframe		RISC mainframe	Alpha, PA-RISC, SPARC; MIPS—PCs/workstations/servers
Proprietary supercomputer		RISC supercomputer	Notebook/subnotebook PCs
			Palmtop computers (for example, PDAs)
			Pen-based organizers
			Board computers

Source: Dataquest (May 1995)

- ❑ Mixed-signal graphics on a single chip (with RAMDAC) will implement high-resolution, surpassing 1 million pixels with 24-bit color, 3-D graphics, and digital video.
- ❑ Mixed-signal I/O chips will support high-speed storage and peripherals communications (enhanced IDE, SCSI, P1394/Fiber Channel, SSA).
- ❑ Sound and video codecs and I/O functions will be used in multimedia systems.

Projected semiconductor trends for computer peripherals and boards are as follows:

- Memory
  - ❑ Storage systems (RDD/tape) will move from SRAM to DRAM.
  - ❑ 20MB SRAM/DRAM memory cards and 100MB flash memory cards will be used for storage.
  - ❑ Graphics cards will move from average 0.5MB to 2MB DRAM/VRAM.
- MPU/MCU
  - ❑ Storage systems will move from 8-bit to more sophisticated 16- and 32-bit processors with digital signal processing (DSP) capability.

Table 5
Computer Peripherals, Boards, and Functions: 1994 to 1999 Unit Growth

Declining (Negative)	Slow (0 to 6%)	Moderate (7 to 12%)	Emerging (More than 12%)
Storage			
More than 5.25-inch RDD	More than 5.25-inch optical drive		3.5-inch RDD (greater than 400MB)
			2.5-inch, 1.8-inch RDD
			CD-ROM/R/XA/I
			Magneto-optical drives
			Disk arrays (RAID)
			Solid-state drives/PCMCIA memory cards
			1/4-inch cartridge/4mm helical scan tape drives
Multimedia/graphics (boards or functions)			
CGA/EGA/standard VGA	Analog video		Windows graphics accelerators
			Accelerated digital video
	Sound (8 bit)		Sound (16 bit)
			Speech processing
Terminals			
Alphanumeric graphics			X windows

Source: Dataquest (May 1995)

- ASIC/ASSP
  - Mixed-signal, highly integrated storage controller chipsets increasingly will be used for controls and data path. PRML, Fiber Channel, and SSA are emerging technologies.
  - Single-chip graphics controllers that integrate RAMDAC, digital video, and timing, among others, will predominate in mainstream applications.

Projected semiconductor trends for other data processing equipment are as follows:

- Memory
  - High-end printer/copiers will move to 4MB to 8MB memory.
  - Flash will replace ROM/EPROM in systems (4MB or greater).
- MPU/MCU
  - Single-chip controllers will be used in low-end printers and handheld terminals.
- ASIC/ASSP
  - Mixed-signal chipsets will be used in most systems.

Table 6
Other Data Processing Equipment: 1994 to 1999 Unit Growth

Declining (Negative)	Slow (0 to 6%)	Moderate (7 to 10%)	Emerging (More than 12%)
Word processors	Dot matrix printers	Laser printers (1 to 10 ppm)	Laser printers (more than 10 ppm)
	Plain paper printers	Ink jet printers	Color printers
	Point-of-sale terminals		Host-based printers
	Bank/teller systems		Personal PPCs
			Color/digital copiers
			Scanners
			Handheld terminals
			Smart cards
			Smart/crypto cards

Source: Dataquest (May 1995)

Projected semiconductor trends for communications equipment are as follows:

- Memory
  - LAN systems increasingly will employ flash (1MB or greater) and DRAM/SRAM (4MB or greater) memory.
  - Public/WAN systems will use denser and higher-speed DRAM/SRAM and special function memory.
  - Low-power flash memory increasingly will be used in mobile devices.

Table 7
Communications Equipment: 1994 to 1999 Unit Growth

Declining (Negative)	Slow (0 to 6%)	Moderate (7 to 12%)	Emerging (More than 12%)
Networking/Image Communications			
Previous LAN standards (NICs)		Ethernet/token-ring cards	Fast Ethernet/AnyLAN NICs FDDI NICs, ATM NICs
			Wireless LAN, NICs, and hubs
			Switched and 100-Mbps hubs
Bridges	Traditional hubs	Routers, T/E carrier systems	ATM switches Frame Relay systems
			ISDN adapters
Previous modems		Standalone fax	Fax/modem cards/PCMCIA
		V.32/bis modem	V.34 modem
			Videoconferencing
			Video phones
Mobile communications			
Corded phones	Analog cellular	Analog cordless	Digital cordless
			Base stations
			PCN/PCS/digital cellular terminals
			Satellite phones
		One-way pagers	Wireless data communication
			Two-way pagers (narrowband PCS)
Transmission/broadcast			
	Digital microwave	Digital local loop systems	SONET/SDH transmission
	VSAT		Digital cable/DBS transmission
			ADSL/HDSL transmission
			HDTV upgrade
Switching and call processing			
Analog line cards	PBX/CO switch	Voice response systems	Wireless PBX
		Automatic call distribution systems	N-ISDN, ATM
		Voice mail systems	

Source: Dataquest (May 1995)

- MPU/MCU
  - 32-bit MPUs will proliferate in LAN internetworking systems such as hubs.
  - Mobile systems will move from 8- to 32-bit MPUs and DSPs.
- ASIC/ASSP
  - PC and workstation connectivity increasingly will be implemented with single-chip, mixed-signal ICs. Each standard will command its own dedicated versions (Ethernet, including 100-Mbps versions; Token Ring; FDDI; AnyLAN; ATM).
  - Advanced transceiver technology will be used for high-speed LANs (more than 100 Mbps).
  - CMOS/BiCMOS technology and advanced macro cell libraries will be used for public/WAN devices.
  - More highly integrated mixed-signal baseband chipsets will be used in mobile applications to implement various standards such as GSM, TDMA, and CDMA.
- Other
  - Mobile devices will employ a new generation of integrated, low-power, radio frequency/infrared transceivers.
  - GaAs will find some use in transmit/receive functions.
  - Many passive devices such as filters and active discretes will be incorporated into more integrated ICs.

Projected semiconductor trends for consumer equipment are as follows:

- Memory
  - SRAM/DRAM memory will be used for the first time in many systems.
- MPU/MCU
  - Processors ranging from 4 to 32 bits and DSP MPUs increasingly will be used in systems.
- ASIC/ASSP
  - New designs will employ digital/mixed-signal chipsets.
  - There is an overall trend from analog to digital technology.

Table 8
Consumer Equipment: 1994 to 1999 Unit Growth

Declining (Negative)	Slow (0 to 6%)	Moderate (7 to 12%)	Emerging (More than 12%)
Video			
B/W TV	Less than 30-inch color TV	More than 30-inch color TV	Digital/HDTV
	VCR	Laser disc	Digital/HDTV VCR
	Camcorder		Digital/HDTV camcorder
			HDTV laser disc
			Digital Video Disc (DVD) systems
			Video karaoke
	Analog cable and satellite converters		Digital cable and satellite codec/converters
Audio			
	Systems/components	Embedded CD personal stereo	Mini Disc (MD) digital audio
		Digital Compact Cassette (DCC)	
		Musical instruments	
Personal			
8-bit video game			16-bit video game
	Calculators		32/64-bit interactive players
	Watches		CD-based interactive players
Miscellaneous			
	White goods	HVAC systems	Mobile GPS terminals
	Microwave ovens	Security systems	Smart appliances

Source: Dataquest (May 1995)

Projected semiconductor trends for automotive equipment are as follows:

- Memory
  - EPROM memory will be displaced by flash memory.
- MPU/MCU
  - 32-bit processors increasingly will be used in drive-train systems. 8- and 16-bit MCUs with integrated analog interfaces and power controls will be increasingly popular.
- ASIC/ASSP
  - Systems will incorporate mixed-signal/power ASICs.
- Others
  - Solid-state sensors will be used in systems.

Table 9
Automotive Equipment: 1994 to 1999 Unit Growth

Declining (Negative)	Slow (0 to 6%)	Moderate (7 to 12%)	Emerging (More than 12%)
Discrete engine controls	8/16-bit engine controls	Solid-state switches	32-bit power train controls
		Motor controls	Solid-state sensors
			Air bags
			Four-wheel antilock braking systems
		Temperature controls	Active suspension
			Electronic steering
	AM/FM cassette stereo	CD embedded stereo	Mini Disk DCC
		Security controls	Navigation/GPS
			Intelligent Vehicle Highway System
			Electric-powered vehicle systems

Source: Dataquest (May 1995)

Dataquest Perspective

This updated summary of Dataquest's worldwide electronics equipment production forecast has highlighted major regional and market segment trends. As the market grows toward the $1 trillion mark, major opportunities and obstacles await competitors in the various market segments. As before, focus will be critical for semiconductor players in this dynamic and rapid-paced industry. The skills and resources required to successfully compete in growing markets will require concentrated attention on specific products and applications. As the challenges associated with converging markets continue to increase, more companies are entering into strategic alliances and partnerships that allow them to access new skills and technologies while leveraging their current core competencies. When executed properly, this approach will enable manufacturers to compete more successfully in bringing differentiated products to the market and realize profitable returns on their investment.

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Perspective

Semiconductor Application Markets Worldwide

Research Brief

Low-Cost, High-Performance Connections: Is 1394 a Serial Killer?

Abstract: *IEEE bus standard 1394 is nearing market rollout. It appears that advanced digital consumer electronics will be the early adopter of this high-speed peripherals interconnect technology.*
By Greg Sheppard

IEEE Bus Standard 1394

As computer and consumer systems migrate to the high-speed world of digital multimedia, a new opportunity has arisen for silicon suppliers to reduce system costs. IEEE bus standard 1394 (also known as High-Performance Serial Bus) is proposed as a method of cost-effective high-speed interconnection between various systems, including PCs and accompanying storage and input/output (I/O) peripherals, as well as advanced consumer audio, video, and interactive systems.

The standard is near final balloting and approval by the IEEE constituency. It is expected to be finalized this June or at the latest this September. At this time it is believed to be in its final form thus making a stable specification for developing semiconductor products.

An All-in-One Connector

1394 transmits data at rates of 100, 200, or 400 Mbps over a flexible six-conductor wire. There are two signal pairs and one power pair; the latter can support power-down situations. The specification supports "live" insertion and can support up to 63 nodes by daisy chaining (up to 16 hops) and

Dataquest

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branching. Because of the high data rates and relative simplicity and economy, 1394 has the potential to become a universal interface for all types of office and consumer equipment.

1394 is positioned to compete with entrenched standards like SCSI (and its serial version) but is also doing battle in certain applications with new technologies like SSA and Fiber Channel.

Serial Players

Texas Instruments (TI), Apple Computer (Apple's implementation is known as FireWire), and IBM have taken most of the initiative from a market development standpoint to get 1394 going. TI has a two-chip set on the market that implements the physical/transceiver functions and the link-layer function. Molex is on board as a supplier of connectors and cables.

A group known as the 1394 Trade Association has been formed to perpetuate the standard into multiple markets. Additional participants include Adaptec, AMD, Cypress Semiconductor, Fuji Film Microdevices, Lexmark, Maxtor, Microsoft, NCR Microelectronics, National Semiconductor, Philips, Seagate, Sony, and Toshiba.

Advantages: Plug-and-Play on the Cheap

Table 1 presents an overview of the different potential applications and our assessment of 1394's chance of use in each. This is based on a poll of different Dataquest analysts and industry players. Other uses could also emerge as connection prices come down. Key patrons already committed to this technology include Sony, for an emerging digital camera line for desktop videoconferencing; Fuji Film, for digital cameras; and the European Digital Video Broadcast (DVB) group. DVB is Europe's response to the U.S. HDTV program, and based on initial support, it has a good chance of defining much of the world's consumer digital TV standards. There is a good probability that future digital camcorders/cameras, digital VCRs, and the emerging digital video disk will all have a 1394 interface. These groups were attracted to the low cost and universal connector concept advantages of 1394. A lesser-known advantage is that, unlike SCSI, 1394 does not require an active terminator.

Legacy Means Lethargy

Unlike digital consumer equipment where there is a chance for a fresh start, computers—and their storage and document management (such as printers and scanners) interfaces—are bound greatly by backward compatibility. To change a standard here, both the host (embedded or adapter card) and peripheral must have 1394 interfaces. Unless a few key players decide to break away, penetration of 1394 into these areas remains unlikely. The storage community is going with enhanced IDE and SCSI for now, while Fiber Channel and SSA are on the horizon in some projects. The document management industry has given no indication that it will be implementing 1394, and no PC makers have committed to 1394.

When desktop videoconferencing grows in importance, the camera interface could stimulate broader use in PCs and workstations.

Table 1
Chances of 1394's Success in Various Applications

System	Chance of 20 Percent Penetration by 1999 (%)	Alternatives
RDD/Optical Storage	10	Enhanced IDE, SCSIx, SSA, Fiber Channel
Printer	10	Centronics, high-speed parallel
Scanner	10	Enhanced IDE, SCSIx
Audio Systems	20	Proprietary
Advanced/HDTV	100	Proprietary
Digital VCR/Video Disk	100	Proprietary
Video Game/Video CD	50	Analog
Camcorder/Still Camera	100	PCM, Analog
Advanced Set-Top Box	100	Proprietary

Source: Dataquest (February 1995)

Dataquest Perspective

There appears to be significant momentum behind 1394, and the chance of broad deployment in the digital consumer electronics community in particular is good. Computer industry usage remains uncertain but could change dramatically if segment leaders in storage and document management change their position. The net of it is that the chip opportunity for 1394 could hit 1 million units by 1996 and 15 million units by 1999 in consumer systems alone. We expect the chipset average selling prices to drop into the $7 range by 1999, driving an annual worldwide market of over $100 million.

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SEMICONDUCTOREQUIPMENT, MANUFACTURING, AND MATERIALS WORLDWIDE 1995

TABLE OF CONTENTS

PERSPECTIVES

MARKET ANALYSIS

Dataquest *ALERT*

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Wafer Fab Equipment Forecast Update: The More Things Change, the More They Remain the Same

In this interim update, we have modified the April 1995 forecast for front-end wafer fab equipment in light of the recently announced revision of Dataquest's semiconductor forecast. In short, the strength in the semiconductor market has translated into a strong average growth trend in equipment. We have kept the assumption that the equipment market has a cyclical nature, anticipating the migration to the 16Mb DRAM.

This *Dataquest Alert* presents the top-level regional update as a reference for our clients in advance of the next regularly scheduled forecast update in December.

The Forecast

Table 1 shows the top-line regional forecast. The compound average growth rate (CAGR) for 1994 to 2000 calls for a 20.5 percent growth rate. This is slightly higher than the semiconductor growth rate for the same period. In the semiconductor forecast, we estimated stable growth in every region to the end of the decade. However, the dynamics of supply and demand in production capacity play an important role in the equipment market and modulate the year-to-year growth rates.

The globalization of production, particularly in the DRAM market, calls for relatively uniform swings in the equipment market across all regions. This holds true even for the Asia/Pacific market, as both DRAM spending and semiconductor contract manufacturing (SCM), also known as foundry, have been responsible for the hypergrowth in this region. However, amplitude variations in the growth rates for equipment spending in Asia/Pacific and Europe will be more volatile than in the more mature markets of North America and Japan.

Currently the Dataquest fab database contains well over 100 announcements for new fabs (or major expansions and upgrades) to come on line between 1995 and 1998. The current growth in capacity began in 1993 and has been responsible for building the backlogs of equipment suppliers. For some equipment segments, such as lithography steppers, the backlogs stretch into 1997. Equipment suppliers, in turn, have built up their capacity to respond to this strong demand. In 1996, suppliers will continue not only to supply fabs, but also to build capacity to contain and manage their backlogs. This shipment momentum should carry into 1997, the turning point in our forecast.

By 1997, we estimate that DRAM suppliers will be shifting most of their "convertible" capacity from 4Mb to 16Mb production, when device shrinks and process improvements have driven up yields. Therefore, strong DRAM demand will be met by a larger supply of 16Mb devices. This will drive the price per bit down and, in turn, slow capital spending. The forecast shows this softening in the market in 1998 as a slightly negative growth rate. We have also studied the supply-demand scenario in the SCM arena, with a strong emphasis on its impact in the Asia/Pacific region. In short, until the latter part of 1997, we see tight supply of foundry capacity. With the new fabs coming on line in 1997, we expect growth in capacity of this type to slow by the end of 1998.

With sub-0.3 micron DRAM and logic devices ramping up in 1999, growth rates should turn to the positive side again. The forecast period ends with a strong growth rate predicted for 2000. The equipment market will consume about 10 percent of overall semiconductor revenue in 2000, nearly $33 billion.

Table 1

Wafer Fab Equipment Forecast, 1994-2000 (Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
Total Wafer Fab Equipment	10,756	16,672	23,109	25,430	23,851	26,247	32,956	20.5
Growth (%)	49.8	55.0	38.6	10.0	-6.2	10.0	25.6	
North America	3,141	4,553	5,748	6,330	6,347	7,073	8,555	18.2
Growth (%)	49.8	45.0	26.2	10.1	0.3	11.4	21.0	
Japan	3,668	4,995	6,742	7,194	7,151	7,850	9,587	17.4
Growth (%)	45.1	36.2	35.0	6.7	-0.6	9.8	22.1	
Europe	1,385	2,391	3,031	3,422	3,268	3,508	4,185	20.2
Growth (%)	23.9	72.6	26.8	12.9	-4.5	7.4	19.3	
Asia/Pacific-ROW	2,562	4,733	7,588	8,483	7,087	7,816	10,629	26.8
Growth (%)	87.6	84.7	60.3	11.8	-16.5	10.3	36.0	

Source: Dataquest (October 1995)

We will provide updated segment forecasts relative to the above adjustments when we have completed our year-end survey of equipment suppliers. Until our December forecast is released, we recommend that clients simply ratio the values above to the segment forecasts presented in July.

By Näder Pakdaman, Calvin Chang, Clark Fuhs, and Yasumoto Shimizu

Dataquest ALERT

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Can the $10.8 Billion Wafer Fab Equipment Market in 1994 Grow to Nearly $20 Billion in 1996? Believe It!

We knew a few months ago that the 1995 market would surprise us with its strength. A monthly leading indicator we have been developing went crazy in April and has not rested since. Our May capital spending survey confirmed our indicator--that 1995 is basically 1994 all over again.

This *Dataquest Alert* will be followed by publication of the Semiconductor Equipment, Manufacturing, and Materials Worldwide services 1995 Midyear Forecast, which SEMM clients should receive within the next few weeks. *We will also review this subject in an upcoming Dataquest Teleconference briefing on July 7, 1995, at 8:30 a.m. PDT. Please contact Jenny Williams at 408-437-8263 by July 6 if you would like to be included in the teleconference.*

Still Booming in 1995... and into 1996

Our capital spending survey just completed shows 60 percent growth over 1994 levels, but not all of this growth will trickle immediately into equipment in 1995. Several new projects in Taiwan are under way, which will place the bulk of equipment into the fabs in 1996. European companies, primarily driven by Siemens, and multinational companies make Europe the second fastest-growing region. Why the boom in Europe? With the region's economies recovering and the PC boom ongoing, Europe has attracted PC production, particularly in the United Kingdom. Semiconductor production has moved along with the PC, with Intel and DRAM producers worldwide taking part. The acceleration of telecommunications-related semiconductor production also benefits European companies such as Philips and Ericsson.

But the story behind the forecast of 52 percent wafer fab equipment growth in 1995, followed by 22 percent growth in 1996, is the continued heavy investment in DRAM capacity. The lack of availability of the critical 16Mb DRAM part at high yields, which restrains the PC market's conversion from the popular 4Mb generation parts, has forced continued investment in capacity. Persistent high prices for DRAMs has kept DRAM manufacturers profitable, which in turn has spurred strong spending.

Spending by the three largest Korean companies is expected to increase 124 percent in 1995 to a combined total of $5.6 billion. Japanese company spending will increase 44 percent as well. Three new projects in Taiwan involve new DRAM players (some with Japanese technology partners): Nan Ya Plastics, Vanguard, and PowerChip. And IBM and Siemens are back, each spending an estimated $1 billion in 1995.

What about 1997?

As we have mentioned in the past, DRAM investment will inevitably decline as capacity currently running 4Mb DRAMs converts to 16Mb parts, effectively doubling or tripling the bit capacity of the manufacturing line.

What this means is that the "pause" in the equipment will occur eventually, triggered by the conversion of the end-use market away from the 4Mb generation toward the 16Mb DRAM. This will happen only when the 1x16 configuration 16Mb DRAM becomes widely available at reasonable yields, about 60 to 65 percent, and becomes economical to produce. This is not expected to occur until well into 1996. We now look toward 1997 as being the toughest year for the equipment industry, but we do not expect it to be down significantly because PC unit shipments are expected to remain strong. PC units drive about one-third of the semiconductor market today, a strong underlying trend likely to limit the extent and duration of the slowdown.

The Forecast

Table 1 shows the regional topline wafer fab equipment forecast through the year 2000. Further details will be reviewed at the upcoming teleconference and in the forthcoming report.

Table 1

Wafer Fab Equipment Forecast, 1994-2000 (Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	2000	1994-2000 CAGR (%)
Total Wafer Fab Equipment	10,755	16,340	19,854	18,888	19,323	22,495	29,701	18.4
Percent Growth	56.4	51.9	21.5	-4.9	2.3	16.4	32.0	
North America	3,141	4,409	5,040	4,966	5,160	6,065	7,801	16.4
Percent Growth	47.5	40.4	14.3	-1.5	3.9	17.5	28.6	
Japan	3,668	5,008	5,459	4,931	4,953	5,643	7,146	11.8
Percent Growth	49.1	36.5	9.0	-9.7	0.4	13.9	26.6	
Europe	1,385	2,341	2,740	2,696	2,842	3,317	4,002	19.3
Percent Growth	41.6	69.0	17.0	-1.6	5.4	16.7	20.7	
Asia/Pacific-ROW	2,562	4,582	6,615	6,296	6,369	7,470	10,751	27.0
Percent Growth	95.7	78.8	44.4	-4.8	1.2	17.3	43.9	

Source: Dataquest (July 1995)

By Clark Fuhs

Dataquest Teleconference

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

TOPIC: CAN THE WAFER FAB EQUIPMENT MARKET EXPAND FROM $10.75B IN 1994 TO NEARLY $20B IN 1996? BELIEVE IT!

SCOPE: The session opens with comments by analysts from the Semiconductor Equipment, Manufacturing, and Materials (SEMM) Worldwide service. An interactive discussion with Dataquest clients follows.

WHO: Discussion leaders are Clark Fuhs, Näder Pakdaman, and Calvin Chang of the SEMM service. Invitees will consist of SEMM, SPSG, and Cross-Industry clients.

WHEN: Friday, July 7, 1995 at 8:30 a.m. PDT.

HOW: To confirm your attendance, call Jenny Williams (408) 437-8263, or fax Jenny at (408) 437-0292 ***no later than July 6, 1995.***

Clients who respond by July 5 will receive figures (via fax) before the teleconference.

IMPORTANT: Dataquest offices will be closed July 3 and 4. Please use attached "Fax Back" form to register early!

Dataquest ALERT

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Formosa Plastics and Komatsu Forge Alliance in Taiwan

Komatsu Electronics Corporation and the Asia-Pacific Investment Co., which is owned by the Formosa Plastics Group (FPG), this week signed a memorandum to build a silicon wafer manufacturing factory in Taiwan. The name of the new company will be Taiwan Komatsu Electronic Materials Corporation, which will have capital investment of U.S.$250 million. Ownership will be divided 51:49 in favor of Komatsu. Construction is planned to begin by the fourth quarter of 1995, and mass production is forecast to begin by 1997.

This is a technology transfer arrangement from Komatsu. The specified final capacity of 8-inch slices is about 200,000 wafers per month, but the first phase to be completed in 1997 will be for 80,000 slices. Both companies agree that a formal contract completing the joint venture will be signed by each party no later than July. FPG Director Y.C. Wang and Komatsu Director Mr. Nakanishi joined the meeting to sign the memorandum. Each director expressed his optimistic view for the future of this company and said details regarding the agreement were still being worked out.

Following the recent successes of Taiwan's semiconductor device manufacturing companies, local investors have been eyeing long-term profits and trying to move upstream into the silicon wafer manufacturing business. This is the second recent silicon wafer announcement--following Taisil Electronic Materials Corporation's entry into the field. Table 1 compares the similarities and differences between these two joint venture agreements.

Dataquest Perspective

The Taiwanese semiconductor industry has been expanding rapidly in the past three years but has outpaced supportive semiconductor industries such as silicon wafers. These recent announcements are positive signs for the local industry, which is completely dependent on imported wafers. As for long-term success, both venture companies highlighted in Table 1 will have strong technical and financial resources: FPG is the biggest privately held group in Taiwan, and the China Steel Corporation (CSC) is a government-supported company with capital of more than $2.7 billion; MEMC Electronic Materials Corporation and Komatsu are global technology leaders in wafer production. The cooperation of these companies ensures their ventures will have the capital to expand and the technology to compete. Neither will have to worry about demand.

Table 1

Comparison between Taiwan Komatsu Electronic Materials Corporation and Taisil Electronic Materials Corporation

Companies	Taiwan-Komatsu	Taisil
Investors	FPG, Komatsu	CSC (Taiwan), MEMC
Technology Source	Komatsu (Japan)	MEMC (United States)
Capital ($M)	250	191
Capacity (8-Inch Wafers/Month)	200,000	125,000
Initial Capacity (8-Inch/Month)	80,000	70,000
Pilot Time	Third quarter of 1996	Third quarter of 1996
Initial Production Time	Fourth quarter of 1996	Fourth quarter of 1996
Final Capacity Realized	To be announced	Late 1997 to early 1998
Shareholders	Komatsu (51 percent), FPG (49 percent)	MEMC (45 percent), CSC (35 percent), others (20 percent)
Location	Not available	Hsin-Chu Science Park

Source: Dataquest (May 1995)

These two plants, taken together, could appreciably supply Taiwan's production needs for 200mm wafers. However, we believe that a portion of these plants output will be exported, resulting in a continued net deficit of 200mm wafers for Taiwan. Dataquest believes Taiwan's semiconductor industry's appetite for silicon wafers will far exceed local production unless further investments are made. By 1997, when both companies' production becomes fully ramped, as planned, these facilities will be able to supply less than 50 percent of Taiwan's total wafer demand. Nevertheless, this increasing high level of interest in the semiconductor industry among Taiwan's largest conglomerates will mean Taiwan has the financial wherewithal to sustain or, quite possibly, accelerate its expansion run rate.

By Ben F.P. Lee (Taiwan) and Daniel Heyler (Hong Kong)

Dataquest ALERT

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Midterm Update: Wafer Fab Equipment Forecast--Stronger 1995 and 1996

Based on bookings levels and capital investment patterns, particularly in DRAM in Asia and Japan, we must modify our December 1994 forecast fairly dramatically in the near term. This *Dataquest Alert* presents the top-level update as a guide to our clients, in advance of the next regularly scheduled forecast update in July.

Booking Levels Strong: 1995 Shows Healthy Growth

Indications are that bookings in the first half of 1995 will finish at year-over-year growth levels of about 35 to 40 percent (below a peak of more than 50 percent growth early in 1994). These strong booking levels in the first half suggest that Dataquest's earlier projection of 16 percent growth in 1995 for wafer fab equipment is much too low. We have revised this near-term forecast to be more than 30 percent growth for 1995.

Reasons for the continued growth include the continued heavy investment in DRAM capacity, as outlined in a *Dataquest Alert* published a few weeks ago. The lack of availability of the critical 16Mb DRAM part at high yields that restrain the PC market from converting away from the popular 4Mb generation parts has forced continued investment in capacity. Persistent high prices for DRAMs have kept DRAM manufacturers profitable, which in turn has spurred strong spending.

It must be noted that our assumptions have included the end-user markets, where semiconductor consumption is increasing strongly. The continued strength in markets such as PCs and telecommunication will play an important role in how Dataquest foresees the future. However, we also believe that historical fluctuations in DRAM capacity investments have been the underlying reason for the cyclical patterns seen in capital spending. Our analysis has shown that the over- and underspending cycles correlate closely to the price per bit of DRAM devices. We believe this cyclical pattern will persist and will be coupled with the more stable growth in other segments of the industry, in particular the investments in microprocessors and logic-oriented devices.

In a recent *Dataquest Predicts* newsletter we asked the question, "What if the indicators... remain positive for the next six months?" Our answer was, "We would probably nudge up growth... for 1995, place 1996 in slightly positive territory... and bring 1997 down significantly (in growth)." This has now become reality.

Momentum in Capacity Additions Mean Positive Growth for 1996, but What about 1997?

We can no longer justify a decline year for 1996, and the current forecast here of 9 percent growth may prove on the conservative side. The growth rate is more likely to be in the low teens. However, as we mentioned in our *Dataquest Alert* last month, DRAM investment will inevitably decline as capacity now running 4Mb DRAMs converts to 16Mb parts, effectively doubling or tripling the bit capacity of the manufacturing line.

What this means is that the "pause" in the equipment *will occur* eventually and will be triggered by the conversion of the end-use market away from the 4Mb generation toward the 16Mb. This will only happen when the 1x16 configuration 16Mb DRAM becomes widely available at reasonable yields. This ramp-up, which we expected during 1995, has been pushed back some six to nine months, by our estimate. This means the current equipment boom has been extended, and the equipment slowdown delayed. We now look toward 1997 as being the toughest year for the equipment industry.

The Forecast

Table 1 shows the regional top-line wafer fab equipment forecast as we now see it, with an initial look into 1999. Our rough estimate for the year 2000, because of the cyclicality of the DRAM market and the expected capacity ramp of 16/64Mb fabs, calls for about 35 percent growth, placing the wafer fab equipment market at $26 billion to $27 billion in the year 2000.

Table 1
Wafer Fab Equipment Forecast, 1994-1999 (Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Wafer Fab Equipment	10,350	13,531	14,740	13,991	15,368	19,723	14.0
Percentage Growth	49.8	30.7	8.9	-5.1	9.8	28.3	
North America	3,105	3,800	4,228	4,409	4,754	6,056	14.3
Percentage Growth	43.1	22.4	11.3	4.3	7.9	27.4	
Japan	3,517	4,419	4,661	4,276	4,417	5,358	8.8
Percentage Growth	45.1	25.6	5.5	-8.3	3.3	21.3	
Europe	1,198	1,550	1,620	1,547	1,607	2,004	10.8
Percentage Growth	23.9	29.4	4.5	-4.5	3.9	24.7	
Asia/Pacific-ROW	2,530	3,762	4,231	3,759	4,590	6,305	20.0
Percentage Growth	87.6	48.7	12.5	-11.1	22.1	37.4	

Source: Dataquest (April 1995)

Individual Segment Forecasts

Individual segment forecasts are not yet available in this top-level forecast. We do expect to release an update for individual segments consistent with the revised forecast in a few weeks. We are wrapping up the final market share statistics for 1994 and would like to report final 1994 segments. In the meantime, we would suggest that a first-order approximation would be to use Table 3-4 from the December 26, 1994 *Market Trends* forecast report and ratio the top-line numbers in each year throughout the segments.
Clark Fuhs and Näder Pakdaman

Dataquest ALERT

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Midterm Update: Wafer Fab Equipment Forecast--Stronger 1995 and 1996

Based on bookings levels and capital investment patterns, particularly in DRAM in Asia and Japan, we must modify our December 1994 forecast fairly dramatically in the near term. This *Dataquest Alert* presents the top-level update as a guide to our clients, in advance of the next regularly scheduled forecast update in July.

Booking Levels Strong: 1995 Shows Healthy Growth

Indications are that bookings in the first half of 1995 will finish at year-over-year growth levels of about 35 to 40 percent (below a peak of more than 50 percent growth early in 1994). These strong booking levels in the first half suggest that Dataquest's earlier projection of 16 percent growth in 1995 for wafer fab equipment is much too low. We have revised this near-term forecast to be more than 30 percent growth for 1995.

Reasons for the continued growth include the continued heavy investment in DRAM capacity, as outlined in a *Dataquest Alert* published a few weeks ago. The lack of availability of the critical 16Mb DRAM part at high yields that restrain the PC market from converting away from the popular 4Mb generation parts has forced continued investment in capacity. Persistent high prices for DRAMs have kept DRAM manufacturers profitable, which in turn has spurred strong spending.

It must be noted that our assumptions have included the end-user markets, where semiconductor consumption is increasing strongly. The continued strength in markets such as PCs and telecommunication will play an important role in how Dataquest foresees the future. However, we also believe that historical fluctuations in DRAM capacity investments have been the underlying reason for the cyclical patterns seen in capital spending. Our analysis has shown that the over- and underspending cycles correlate closely to the price per bit of DRAM devices. We believe this cyclical pattern will persist and will be coupled with the more stable growth in other segments of the industry, in particular the investments in microprocessors and logic-oriented devices.

In a recent *Dataquest Predicts* newsletter we asked the question, "What if the indicators... remain positive for the next six months?" Our answer was, "We would probably nudge up growth...

for 1995, place 1996 in slightly positive territory... and bring 1997 down significantly (in growth)." This has now become reality.

Momentum in Capacity Additions Mean Positive Growth for 1996, but What about 1997?

We can no longer justify a decline year for 1996, and the current forecast here of 9 percent growth may prove on the conservative side. The growth rate is more likely to be in the low teens. However, as we mentioned in our *Dataquest Alert* last month, DRAM investment will inevitably decline as capacity now running 4Mb DRAMs converts to 16Mb parts, effectively doubling or tripling the bit capacity of the manufacturing line.

What this means is that the "pause" in the equipment *will occur* eventually and will be triggered by the conversion of the end-use market away from the 4Mb generation toward the 16Mb. This will only happen when the 1x16 configuration 16Mb DRAM becomes widely available at reasonable yields. This ramp-up, which we expected during 1995, has been pushed back some six to nine months, by our estimate. This means the current equipment boom has been extended, and the equipment slowdown delayed. We now look toward 1997 as being the toughest year for the equipment industry.

The Forecast

Table 1 shows the regional top-line wafer fab equipment forecast as we now see it, with an initial look into 1999. Our rough estimate for the year 2000, because of the cyclicality of the DRAM market and the expected capacity ramp of 16/64Mb fabs, calls for about 35 percent growth, placing the wafer fab equipment market at $26 billion to $27 billion in the year 2000.

Table 1
Wafer Fab Equipment Forecast, 1994-1999 (Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Wafer Fab Equipment	10,350	13,531	14,740	13,991	15,368	19,723	14.0
Percentage Growth	49.8	30.7	8.9	-5.1	9.8	28.3	
North America	3,105	3,800	4,228	4,409	4,754	6,056	14.3
Percentage Growth	43.1	22.4	11.3	4.3	7.9	27.4	
Japan	3,517	4,419	4,661	4,276	4,417	5,358	8.8
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Individual Segment Forecasts

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Clark Fuhs and Näder Pakdaman

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

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

Introduction

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

What is this telebriefing about?

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

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

DRAM Supply-Side

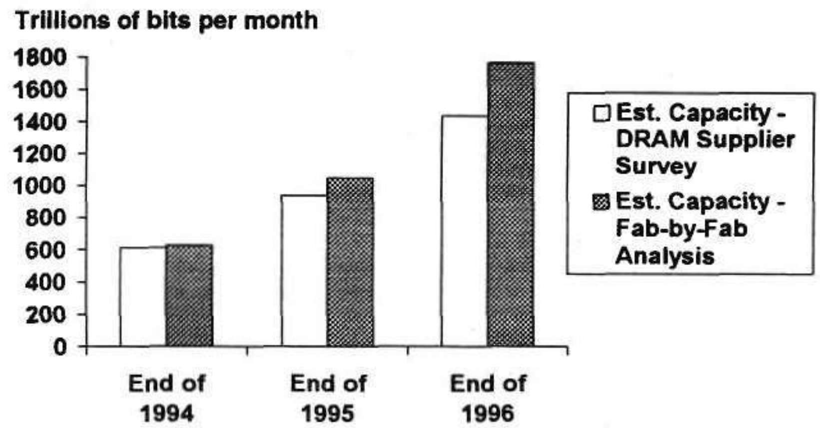
I am Clark Fuhs, a senior analyst from the SEMM group... We track most aspects of the actual manufacturing of semiconductors worldwide... Today we will briefly review the dynamic arena of DRAM capacity and supply.

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

Supply-Side Analytical Methodologies

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

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



Source: Dataquest

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

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

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

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

Three Stages of Capital Spending

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

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

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

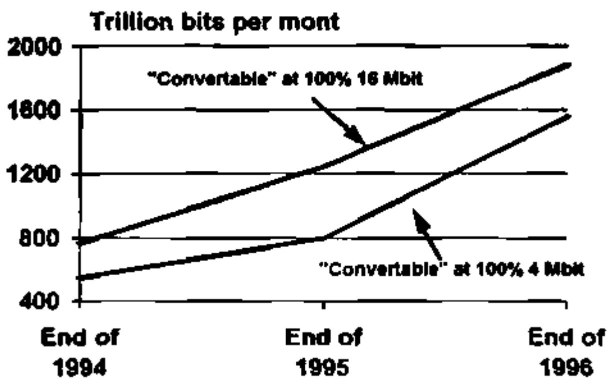
So today there are three types of capacity we must consider--capacity dedicated to 4Mb DRAMs, capacity dedicated to 16Mb DRAMs, and capacity that is "convertible" between the two. Why do suppliers like "convertible" capacity?

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

Industry's DRAM Capacity

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

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



Source: Dataquest

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

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

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

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

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

DRAM Demand-Side

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

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

DRAM Pricing Alert

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

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

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

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

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

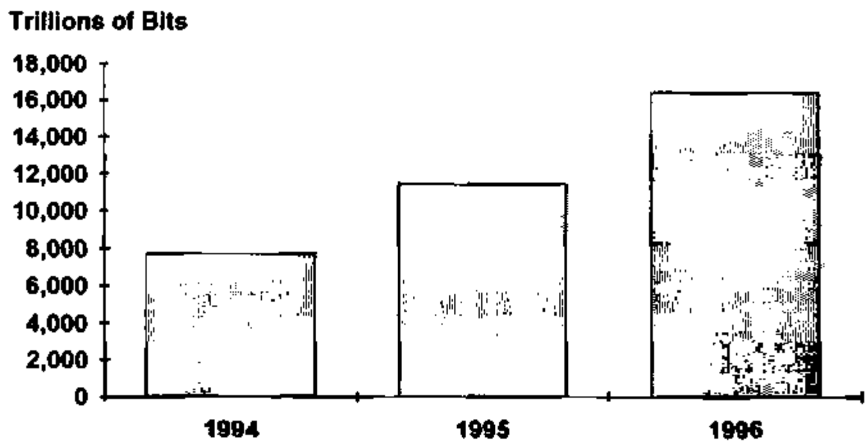
PC Forecast Revised Upward

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

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

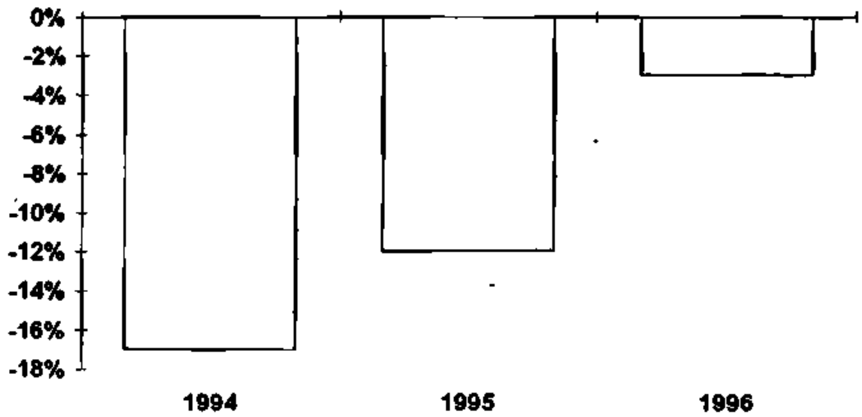
Now let's look at Figures 3 and 4. Figure 3 shows the annual bit demand of the total data processing market and other DRAM markets. We derive this number from our electronic equipment forecast, which includes PC and other data processing forecasts as well as forecasts for other DRAM applications such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

Figure 3: DRAM Demand in Bits



Source: Dataquest

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



Note: Area under 0% indicates shortage

Source: Dataquest

DRAM Shortage Will Continue

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

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

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

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

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

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

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

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

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

Conclusions

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

(This concluded the opening statement.)

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

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Earthquake in Japan: Semiconductor Producers and Fabs Survive with Minimal Impact... but Long-Term Effects Will Be Felt Because of the Human Factor

Once again, Japanese industry is shaken by a major earthquake. The Dataquest Japanese and North American Semiconductor groups have compiled a detailed summary of how the semiconductor industry has been impacted. It has been difficult to get information quickly, as telephone lines are controlled in the area from Osaka to Kobe, and it is impossible to reach anyone in the area by phone. Kyoto became accessible only yesterday.

Companies are assessing the damages they had to their facilities, but it is becoming clear that the most difficult parts of this event are the human impacts and their influence. Matsushita has dispatched several groups of people to check on about 50 employees that have not reported to the company yet, and Mitsubishi reports missing employees as well. In general there was no serious damage to semiconductor wafer fabs, as described later in this *Dataquest Alert*, and most facilities that went down should be up within 10 days. But we do suspect that back-end test and assembly facilities might have been more impacted.

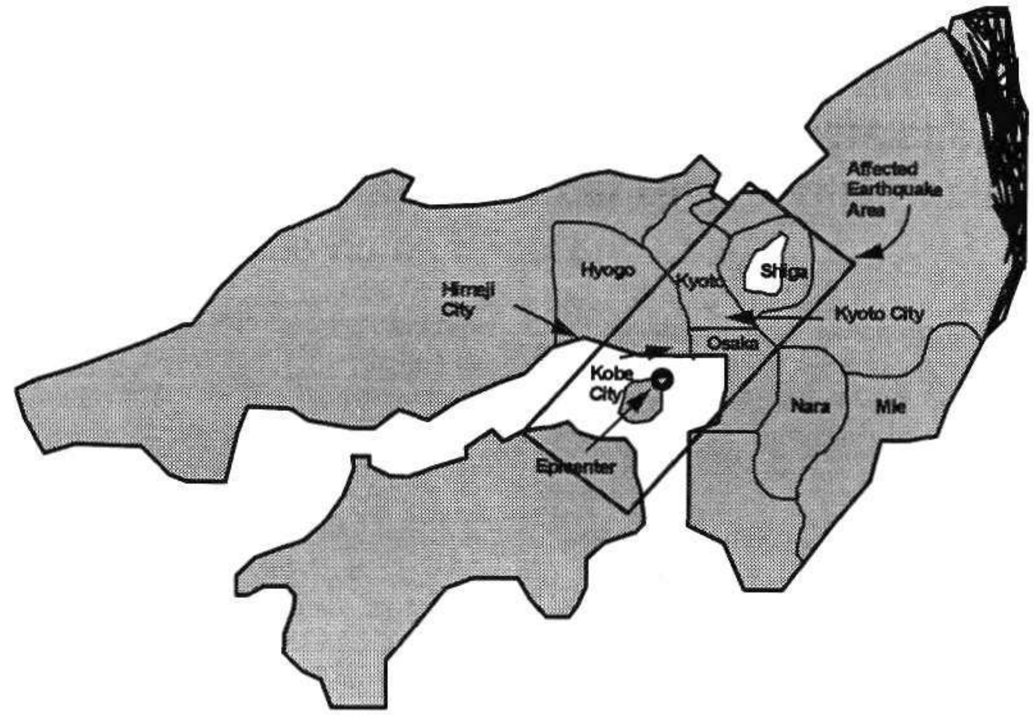
Also, it is not yet clear how serious the distribution infrastructure in the area is damaged: Water, electricity, and transportation could still delay recovery process. It is estimated that the port of Kobe handles about 20 percent of all of Japan's trade, and that port is not expected to be operational for a very long time.

Summary of the Affected Region

Figure 1 shows a representation of the area affected by the earthquake, along with approximate locations and sizes of the prefectures, or states, within Japan of interest to the semiconductor industry. The Hyogo Prefecture, where the epicenter was located, was of course hardest hit. The rectangle represents the areas most affected as the fault line runs from the islands outside of Kobe to Lake Biwa in Shiga Prefecture.

The affected area has a relatively low density of major semiconductor facilities, compared with areas just east of the region. Nara and Mie prefectures, where a high concentration of Sharp and Fujitsu plants are located, were basically unaffected, both in semiconductor and flat panel display (FPD) production.

Figure 1
Geographic Area in Japan Affected by the 1995 Quake



Source: Dataquest (January 1995)

Review of Semiconductor Manufacturers

Mitsubishi Electric

Kita Itami Works, Hyogo Prefecture, was the closest fab to the epicenter. Our contact in Tokyo happened to be on his way to the plant the morning the earthquake happened. He did reach the site, but was told to leave immediately. He could not spot any damage on the outside of the buildings, but he is not sure how the inside is damaged. Mitsubishi did release a statement today saying the plant was shut down for safety and damage assessment, with no indication of when operations could begin again. Water and electricity supply to the plant also is questioned.

This plant is more of an R&D and pilot fab, dedicated to development of next-generation devices like the 64Mb DRAM. Therefore any damage this plant had should not affect Mitsubishi's volume production.

There is some concern about Mitsubishi's assembly and test facilities in nearby Kanebo, where discretes and ICs are assembled. Although no firm reports are available, we suspect that these facilities have been affected.

KTI Semiconductor (Kobe Steel-Texas Instruments)

No damage was reported here, and Texas Instruments should be commended for quick action on the news wire services. The restart of its operation is not confirmed today, but estimating from the distance and general damages in the neighborhood (very little), it will not be long—in fact, a matter of a few days—before the equipment is requalified and operation starts again. This was the only suspect for possible decrease in DRAM supply caused by the earthquake: Now that it is safe, we could say there is almost no negative influence to DRAM supply in terms of fab capacity.

Matsushita Electronics (Semiconductor)

Matsushita has a fab in Osaka Prefecture, in Kadoma City, which is an R&D and pilot facility similar in scope to the Mitsubishi Kita Itami plant. The company admits that its buildings are damaged: Ceilings have fallen partially, and cracks are seen in the walls. But heaviest damages are seen in floors higher than the third, and the main office building has more visual damage than the fabs. No details of the impact to the fabs are known yet, but the company has stopped operation for the past two days. Recovery of operation was not determined as of Wednesday afternoon. Its newest plant in Tonami, Toyama Prefecture, which started operation in October, was far enough away and was not affected at all.

NEC

NEC has a plant with four fab lines in Otsu City in Shiga Prefecture, with main production in power, linear, and bipolar devices at design rules ranging from 0.8 to 2.0 microns. It reports that its diffusion equipment has been damaged. Some sources hold that it will take about four weeks before NEC can resume production, while others say the damage was not serious and the plant is preparing for operation already. (Resist suppliers are being told to resume delivery to the Otsu plant.) We confirmed that the plants are in operation today.

IBM

IBM's Yasu plant, in Shiga Prefecture, had no serious damage to its production facilities, but we heard that the 8mm-thick "glass-wall" (large window) of its cafeteria was shattered, so we suspect equipment could have been moved around. As with the KTI fab, we suspect that a requalification process is under way and production could start again within a week or so.

Toshiba

Toshiba has two plants in the Himeji area, about 150 to 200 miles west of Kobe: Himeji Works producing color picture tubes, LCD, and electronic parts; and Himeji Semiconductor Works producing transistors and diodes at 0.8- to 1.5-micron technology. The semiconductor plant was not heavily damaged, but operation was suspended temporarily to check on equipment that may have moved. TFT-LCD operation is in fact the joint venture with IBM, Display Technology Inc., where cracks in the ceiling are reported. We understand that this plant is back in operation today.

Toshiba's Yokkaichi plant, in Mie Prefecture, the major supply base for the 4Mb and 16Mb DRAM, was not affected at all.

Rohm

Rohm's headquarters and its main fab, located in central Kyoto City, seem to be safe from heavy damages. Rohm has three major lines that support and produce semiconductors for several fabless companies in the United States. We believe that, after a requalification process, these lines will be operational.

Ricoh

Ricoh has two fab lines in Osaka Prefecture, and is also a supply foundry to several U.S. companies in 0.8- to 1.5-micron design rule devices. We have not yet been able to contact these facilities to assess the damage, but we suspect that these plants may have been damaged more seriously than average, on the order of the Matsushita facilities nearby.

Sharp

Sharp has confirmed that it had no damage in either its Tenri plant in Nara Prefecture or Fukuyama plant in Hiroshima Prefecture (being far enough from the epicenter, about four times the distance away to the west). Fukuyama is the plant that supplies flash memory to Intel. Both plants are in operation.

Down the Food Chain: Silicon Wafer Suppliers

Sumitomo Sitix

Sumitomo Sitix has its headquarters and a major plant in Amagasaki City in the Hyogo Prefecture, in an area hit heavily by the quake. Its operations have been suspended. The company is still assessing the damage, and no plan for recovery is reported yet. This plant primarily produced 4-, 5-, and 6-inch wafers as well as ingots for all wafer sizes, including 8-inch. These ingots were then shipped to Sumitomo's plant in Imari, which was unaffected by the quake, where cutting and polishing operations are performed.

It is estimated that 3 to 4 percent of the world's silicon area goes through the Amagasaki plant. Before the earthquake, the world supply of 4-inch and 8-inch wafers was tight (the more serious is at 4-inch), while 5-inch and 6-inch supply is adequate. We believe that the end markets will experience some additional tightness in the coming months.

The Amagasaki plant also produced polysilicon, the raw material feeding the silicon wafer manufacturing industry. We estimate that the plant produced about 5 percent of the world's supply. Polysilicon capacity worldwide should be able to pick up this slack until the factory comes back online, although some immediate tight supply may be experienced as the industry readjusts to the short-term loss of the plant.

Some may be asking the question, "Is this the Sumitomo resin shortage revisited?" ***The answer is, absolutely not.*** The incident 18 months ago involved a plant representing 60 percent of the world's supply of a material (compared with 5 percent today) and was only one of two major suppliers (whereas there are six to eight suppliers of polysilicon). This situation can in no way be compared in scope to the resin issue of the past.

Mitsubishi Material Silicon

No damage is reported in Mitsubishi Material's plant in Ikuno, which is far from the epicenter.

Other Electronic Plants

Matsushita (Nonsemiconductor Plants)

Matsushita's headquarters is in the heart of Osaka City, but apparently it was not damaged. Visual damage was seen in its computer and communications plant in Kadoma City, where shattered windows were observed by people who passed the area by train.

Sanyo

Sanyo has a battery plant in Awaji Island, the small island near the epicenter, but no serious damage was reported. Current concern at the plant is centered around the safety of employees. Some of the subcontractor suppliers in the area may have been damaged: Contrary to the sturdy buildings of the parent company, these smaller companies are assumed to have less-quake-resistant structures.

Hosiden

There are two opposite rumors about Hosiden's small LCD operations in Osaka: One holds that there was heavy damage, and the other denies any serious impact. The company itself is denying any substantial damage, but as yet we do not have confirmation.

Dataquest Perspective

This tragic event has apparently spared the semiconductor industry to a great extent. No major shortages are expected to emerge, although slight tightness in some silicon wafer areas are probable.

Damage to the Japanese economy with the loss of the Kobe port is hard to speculate, but there should be an impact. The damage to buildings and highways does not match the assumptions for all the regulations and formulas for quake-resistant construction. Architects and city planning people are losing confidence and are afraid that thorough investigation of the damages will result in a complete review of construction standards. This will place an additional burden on the confidence and morale of the Japanese people for a time, but in the end the true Japanese spirit will prevail.

The most notable cost here is the loss of human talent. Inevitably, when the history books are written, this event will be remembered for friends and colleagues that are no longer with us, and for the hearts they touched.

By Clark J. Fuhs, Kunio Achiwa, Yoshihiro Shimada, Naotoshi Yasuhara, Akira Minamikawa, Yoshie Shima, and Junko Matsubara

Dataquest

Perspective

Semiconductor Equipment, Manufacturing, and
Materials Worldwide

Telebriefing Summary

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

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

Introduction

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

What is this telebriefing about?

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

Dataquest

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

DRAM Supply-Side

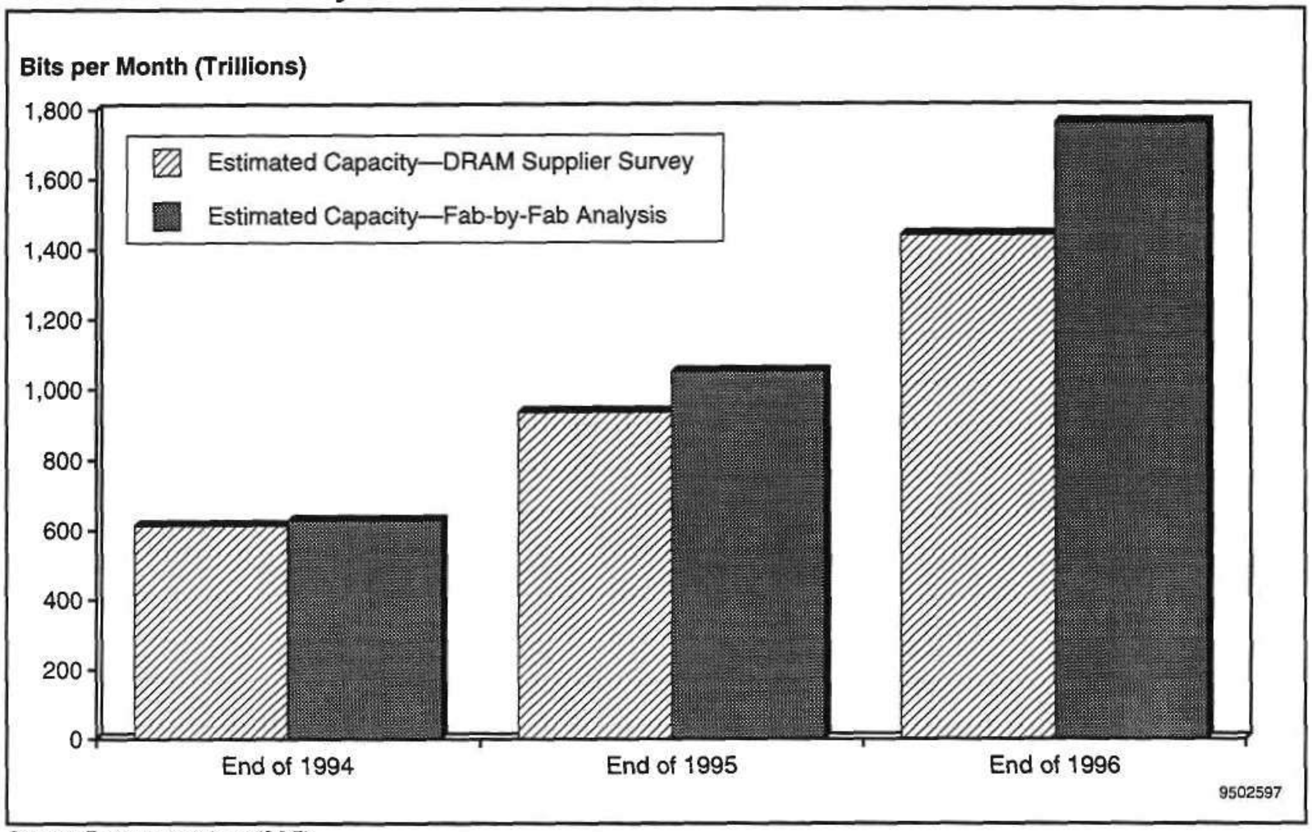
I am Clark Fuhs, a senior analyst from the SEMM group. We track most aspects of the actual manufacturing of semiconductors worldwide. Today we will briefly review the dynamic arena of DRAM capacity and supply.

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

Supply-Side Analytical Methodologies

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

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



Source: Dataquest (June 1995)

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

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

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

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

Three Stages of Capital Spending

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

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

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

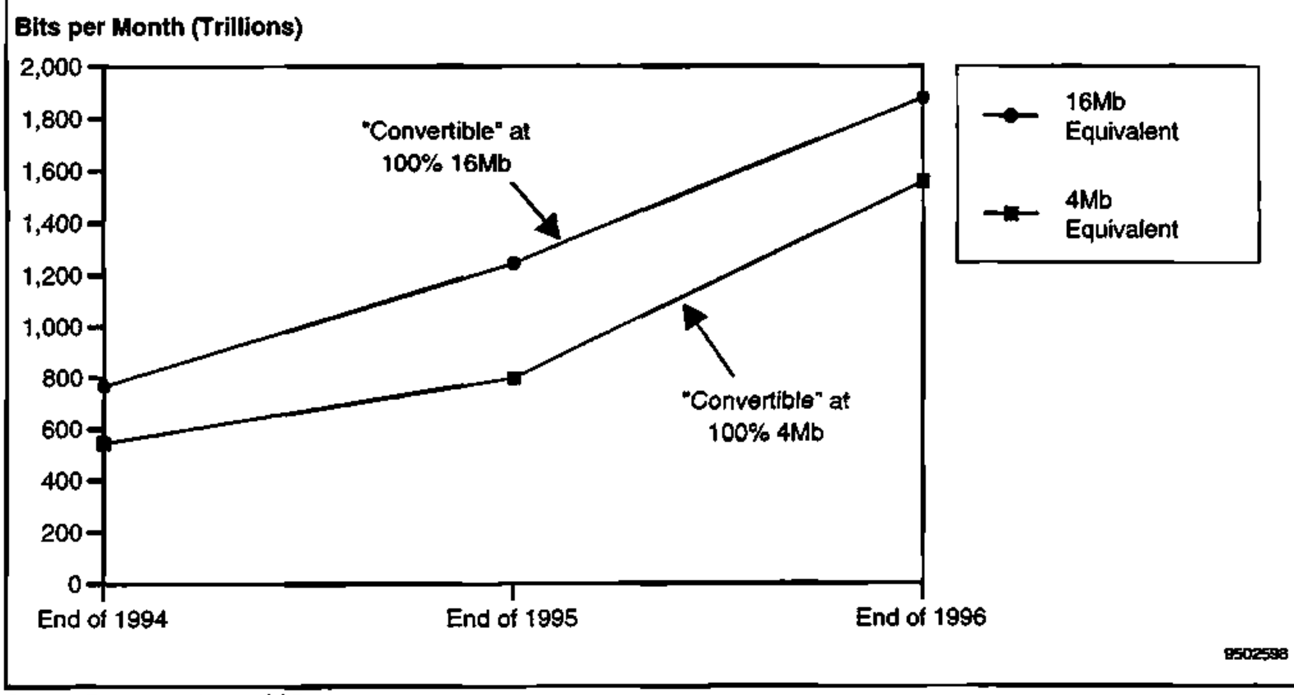
So today there are three types of capacity we must consider—capacity dedicated to 4Mb DRAMs, capacity dedicated to 16Mb DRAMs, and capacity that is "convertible" between the two. Why do suppliers like "convertible" capacity?

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

Industry's DRAM Capacity

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

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



Source: Dataquest (June 1995)

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

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

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

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

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

DRAM Demand-Side

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

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

DRAM Pricing Alert

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

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

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

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

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

PC Forecast Revised Upward

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

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

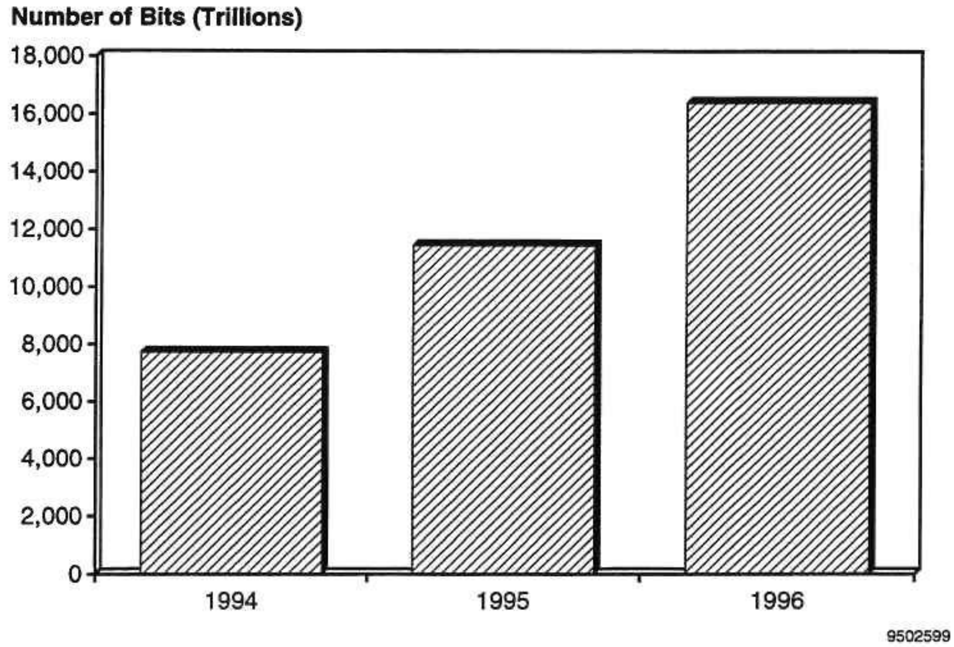
Now let's look at Figures 3 and 4. Figure 3 shows the annual bit demand of the total data processing market and other DRAM markets. We derive this number from our electronic equipment forecast, which includes PC and other data processing forecasts as well as forecasts for other DRAM applications such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

DRAM Shortage Will Continue

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

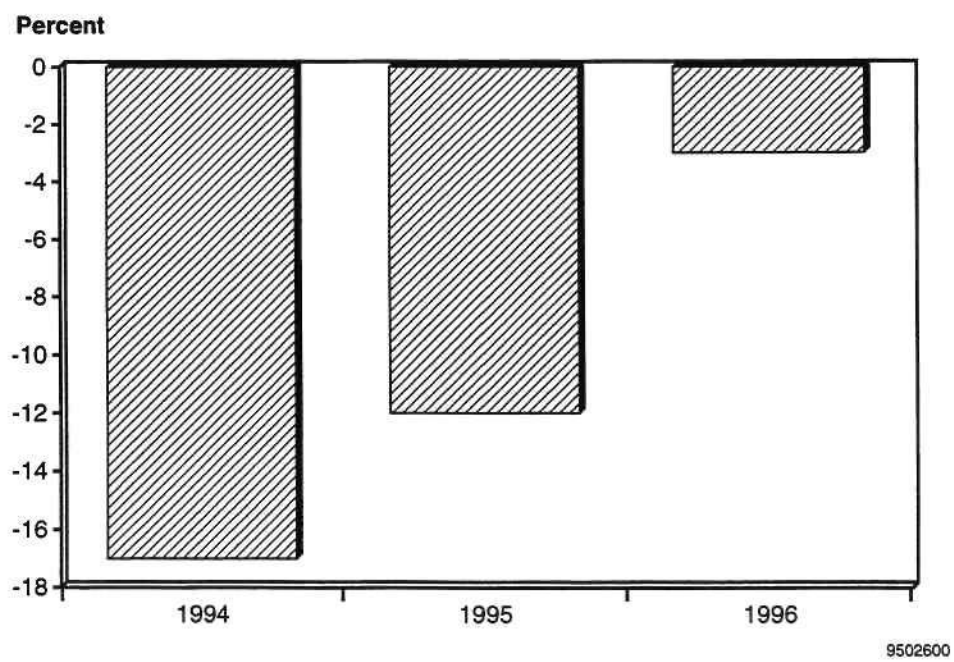
As long as there exists an undersupply, DRAM prices will either hold or go up. Despite a recent increase in our estimates for 4Mb DRAM production in 1995, Dataquest expects the shortage to continue through 1996, mostly

Figure 3
DRAM Demand in Bits



Source: Dataquest (June 1995)

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



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

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

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

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

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

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

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

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

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

Dataquest Perspective

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

Transcript of Telebriefing

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

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

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

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

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

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

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

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

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

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

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

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

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

Q: And how many Pentiums? Twenty-five?

JH: More than 25.

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

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

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

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

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

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

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

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

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

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

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

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

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

As far as selling to the aftermarket, that's more difficult to say because an awful lot of that is the perception of need on the users' behalf. We've heard an argument that the advent of Windows 95 will reduce the main memory size required to support software, and there is technical merit to that argument, because in the virtual memory model that is supported by Windows 95, you do not need as much memory. But we don't buy that. We think that Windows 95 could increase demand simply because there will be a commonly held perception, right or wrong, that you do need more memory for it. Depending on an awful lot of consumer-type things, the market could grow significantly or it could just grow at today's rate.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Q: Where is Korea on the yield curve here?

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

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

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

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

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

Analyst Bios

Ronald A. Bohn, Senior Industry Analyst, Memories Worldwide

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

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

Mr. Fuhs is a Senior Industry Analyst for Dataquest's Semiconductor Equipment, Manufacturing, and Materials service in the Semiconductors group. He is responsible for research and analysis of semiconductor materials and trends in IC manufacturing techniques along with forecasting capital spending and the wafer fab equipment market. Prior to joining Dataquest, Mr. Fuhs was Strategic Marketing Manager for Genus Inc., a manufacturer of advanced chemical vapor deposition (CVD) and high energy ion implantation equipment. During his 10 years at Genus, he held positions of Product Manager, several responsibilities in Product Marketing, and Process Engineer in the metal CVD group. In his most recent position, Mr. Fuhs was responsible for correlating process techniques with demand for equipment and materials. He has been involved with the Modular Equipment Standards Committee of SEMI, a trade organization, as chairman of a task force, authoring a standard. His experience also includes Chevron Oil, where he was a Process Engineer in the Richmond, California, refinery responsible for the hydrogen manufacturing plant. Mr. Fuhs earned a B.S. degree in Chemical Engineering from Purdue University in West Lafayette, Indiana, and received an M.B.A. degree from the University of California at Berkeley.

Mark Giudici, Director and Principal Analyst, Semiconductor Procurement Service

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

Jim Handy, Director and Principal Analyst, Semiconductor Memories Group

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

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Perspective

Semiconductor Equipment, Manufacturing, and Materials Worldwide

Dataquest Predicts

The Cyclicality of the Equipment Market: What Makes It Tick?

Abstract: *We believe that the forces driving the cyclicality of the equipment market have not changed, and that DRAM density crossover and looming price declines mean the equipment market should start a downturn within the next year.*

The wafer fab equipment market has cycled through boom and bust times. With 1994 being an apparent boom year, several questions present themselves: Is there a looming downturn? Why or why not? Are we really changing to a market that is more stable and not subject to the boom-to-bust cycles? In this article, Dataquest describes a new way to view the equipment market—perhaps a way that adds insight to the cyclicality of the business.
By Clark J. Fuhs

Setting the Stage

The year 1994 started great, and it just kept getting better—in somewhat scary proportions. Wafer fab equipment spending in 1994 expanded 50 percent worldwide, driven by an explosive Asia/Pacific region (88 percent growth), a DRAM-sensitive Japan (45 percent growth), and continued heavy expenditure in North America (43 percent growth). This follows a 35 percent growth year worldwide in 1993. Although the outlook for semiconductors in general remains bright, there is cause for concern that the recent buying binge in wafer fab equipment of the last two years, to carry over into at least the first half of 1995, has been too much, and that a normal contraction of the equipment industry is unavoidable, albeit at a historically modest level.

Capital spending in 1994 exploded. The major reason for this is the surprisingly persistent growth in PC unit shipments, and a correction of the underinvestment that had been a part of semiconductor manufacturing since

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1991. Major DRAM expansion accelerated in the second half of 1993 and is expected to continue through the first half of 1995. From what we can see now, there is plenty of equipment that could be brought to bear on 16Mb DRAM capacity by midyear 1995 and online to answer demand through 1996. A marked downturn in the DRAM investment cycle will be triggered by the approach of DRAM price-per-bit crossover of the 16Mb (in the 1Mbx16 configuration), making available some capacity as the 4Mb generation ramps down in the second half of 1995.

Wafer fab equipment spending in 1994 had peak growth of 50 percent worldwide (see Table 1) and is expected to grow 16 percent in 1995 (in a range of 15 to 22 percent worlwide) based on backlog and bookings momentum from the 1994 surge. Segment growth in 1994 into 1995 is being led by DRAM-sensitive equipment, with steppers, high-current and high-voltage implant, wafer inspection, and polysilicon etch exhibiting growth significantly stronger than the market. This mix will change to favor multilevel metal logic capacity as the year progresses. The upper end of the range could easily be reached if DRAM pricing remains firmer than we expect through the first half of 1995.

On a regional basis, North American investment will be driven by stable growth in microcomponents and logic devices, as semiconductors continue to pervade everyday life. Japan has concentrated on ramping memories to preserve its market share against the Koreans and was the second-fastest-growing region in 1994, investing in next-generation memory capacity. Healthy but subdued growth is anticipated in 1995, but a struggling economy and lack of a clear production strategy beyond the DRAM will keep capital investment muted once this DRAM ramp is satisfied. Globalization strategies will benefit both European and Asia/Pacific investment, the latter being the fastest-growing region of the next five years. The emergence of the dedicated foundry will create new opportunities in the Asia/Pacific region over the next several years. Projects being started in 1994 will continue to attract investment, but the last two years saw an investment spike that we believe will be difficult to repeat in growth, but will be sustained as foundry projects are equipped.

Table 1
Worldwide Wafer Fab Equipment Market, Forecast by Region
(Millions of U.S. Dollars, Calendar Year)

	1993	1994	1995	1996	1997	1998	CAGR (%) 1993-1998
Total Wafer Fab Equipment	6,910	10,350	12,031	11,203	11,530	13,731	14.7
Percentage Change	34.9	49.8	16.2	-6.9	2.9	19.1	
North America	2,171	3,105	3,530	3,542	3,752	4,505	15.7
Percentage Change	37.1	43.0	13.7	0.3	5.9	20.1	
Japan	2,424	3,517	3,943	3,541	3,562	3,932	10.2
Percentage Change	14.9	45.1	12.1	-10.2	0.6	10.4	
Europe	967	1,198	1,396	1,352	1,322	1,545	9.8
Percentage Change	53.5	23.9	16.5	-3.2	-2.2	16.9	
Asia/Pacific-ROW	1,348	2,530	3,162	2,768	2,894	3,749	22.7
Percentage Change	68.3	87.7	25.0	-12.5	4.6	29.5	

Source: Dataquest (January 1995)

Wafer Fab Equipment Market Cycles Are Real

The cyclicality of the market will be covered in detail later in this article, but it should be noted here that the wafer fab equipment market has experienced more severe cycles than has the semiconductor industry.

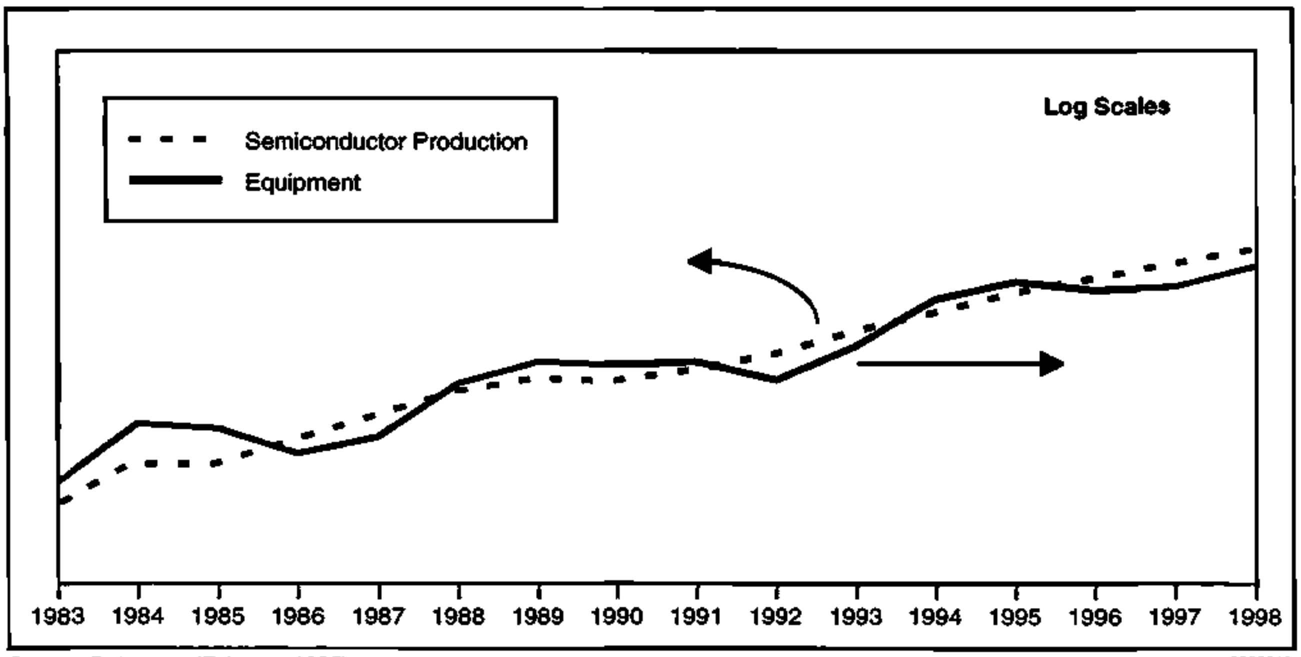
Figure 1 compares the equipment and semiconductor markets. The revenue of both markets are plotted on separate logarithmic scales, and superimposed, in order to directly compare one with the other. As can be seen, the semiconductor chip market has a trend upward—not a straight line, but close to it. However, because the industry cycles through over- and under-capacity situations, capital and equipment spending is more volatile. The wafer fab equipment market can be viewed as "a cyclical market around a trend." As mentioned, the reasons for this will be explored later in this article.

Based on cyclical trends, we would expect 1999 and 2000 to be good years. Our preliminary estimate for the size of the market in the year 2000 is $21 billion to $22 billion.

Forecast Summary

Our forecast for capital spending and wafer fab equipment sales during the next five years assumes the explosive growth in 1994 will carry over into 1995, with a modest decline in equipment spending in 1996 and a relatively flat 1997 before a resumption of double-digit growth in 1998. Although we continue to believe that the cyclical nature of investment in semiconductor capacity will diminish, it will take a couple more boom-and-bust cycles before the underlying semiconductor growth is large enough to dampen the memory component of the cycle. Equipment companies concentrating on or diversified in multilevel metal logic technologies should fare best in the coming slowdown.

Figure 1
Wafer Fab Equipment Market Cyclical around Semiconductor Trend



Source: Dataquest (February 1995) 9500819

Semiconductor manufacturing is a global business. Production of semiconductors is constantly shifting among regions, as new capital money is flowing toward areas of relative lower capital cost and higher growth areas of consumption. Shifts in semiconductor production mean that equipment and material suppliers will absolutely need a global presence in every sense of the word to remain competitive in the market. Product supply and support can no longer concentrate on local trends, as all major semiconductor companies have made it clear they are investing on a worldwide basis.

Dataquest Predicts

We believe that the forces driving the cyclicality of the equipment market have not changed, and that DRAM density crossover and looming price declines mean the equipment market should start a downturn within the next year.

The wafer fab equipment market has cycled through boom and bust times. With the stellar growth of 1994 being within a whisker of the growth experienced in 1988, and 1995 shaping up to be a growth year similar to 1989, questions about the cyclicality of the wafer fab equipment industry have resurfaced. Is this cycle different?

Although the driving forces for the semiconductor industry itself have changed over the last several years, and the long-term growth rates of the IC industry have stabilized at the 15 percent annual range (higher than most people thought a few years ago), we believe that the key driving forces for the *cyclicality* of the equipment market have not changed.

We have been developing and refining various models during the last several months that give us a better picture of the magnitude and timing of these cycles, as well as the triggers and indicators to watch. Our view is that the dynamics of the DRAM market hold the key, and we will explore these dynamics in the remainder of this article.

Trend Modeling Tools and Indicators

We have developed and are refining three models or indicators that will help us understand the magnitude and timing of investment trends in the wafer fab equipment markets. These three models have very different purposes and give an indication of different crosscurrents in the equipment market—although they generally move together within the same cyclical trend. We will detail one of these indicators, but a review of all three is appropriate here.

It should be interesting to note when reviewing these models that none of these models is particularly complex. Each relies on fairly simple input that is well understood. We believe that, if the input is simple, the output can be logically interpreted without much error and without the temptation to read more into it.

Net Cumulative Investment Model

The net cumulative investment (NCI) model tracks the investment of wafer fab equipment relative to semiconductor revenue or production. The model's purpose is to identify the trends and values of the absolute level of business for the wafer fab equipment market (that is, quantitative). It provides an *annual* snapshot of the market, and is more of an indicator of future trends in the aggregate balance of semiconductor capacity. This model is limited in its ability to show any specific timing of an upturn or downturn, but does give a general one- to two-year indication of a turning point.

The basic assumption is that the industry invests a stable percentage of revenue toward wafer fab equipment over the long term. Of course, there are factors that can fundamentally change this level, but these tend to be long-term in nature and do not affect conclusions reached in the near term (two years). If there has been a trend in the last 10 years, it is that the percentage of revenue invested in wafer fab equipment has actually declined slightly.

The model was recently refined to take into account fundamental changes in the long-term demand for semiconductors, which have affected the absolute levels of the equipment market slightly but have not changed the conclusion regarding the cyclicality of the market.

What is this model showing today? The details of the model are described in our most recent forecast report (SEMM-WW-MT-9402, dated December 26, 1994) and will not be shown in detail here. However, the model indicates that the semiconductor industry will be nearly $2.3 billion overinvested in wafer fab equipment (or about 19 percent) by the end of 1995 (assuming a 16 percent growth in wafer fab equipment this year). The last peak in 1989 was at about the 17 percent level, so the current level is within the window for overcapacity to emerge in some areas of the semiconductor market, and is also consistent with the equipment market growing slower than the semiconductor market for 1996 and 1997.

DRAM Quarterly Price Statistic

We have discovered an indicator that appears to have a direct correlation to the cyclicality of the equipment industry. This statistic tracks the relative average DRAM price. This statistic is *not* the price of a particular DRAM, and it is *not* a price-per-bit calculation. It most closely resembles the relative profitability of the DRAM manufacturer and indicates how much the buyers of DRAM are pulling demand for the current mainstream part. If this statistic is rising, demand is accelerating and supply is tight. If this statistic is falling, demand is either falling or making the transition away from the mainstream part. If this statistic is stable, either supply and demand are in balance or the DRAM manufacturer is pricing the parts relatively close to cost.

This statistic and how it relates to the equipment industry is the major focus of this article. This statistic has continued to rise from the third quarter of 1992 through the fourth quarter of 1994—indicating that a significant decline in the equipment market is not expected in the next six to nine months.

Wafer Fab Equipment Leading Indicator

We are refining a monthly leading indicator for wafer fab equipment. The purpose of this indicator is to provide a three- to five-month advance "warning" of major turning points in equipment bookings. We expect to publish this indicator in more detail within the next few months, as refinements are made to the model.

Table 2 summarizes the various models and their characteristics.

Table 2
Summary of Dataquest Indicator Models for Wafer Fab Equipment Market

Dataquest Model	Frequency	Measures	Quantitative?	Indicates Timing?
Net Cumulative Investment	Annual	Equipment spending relative to semiconductor revenue	Yes	1 to 2 years
DRAM Pricing Statistic	Quarterly	DRAM pricing and profitability trends	No	2 to 3 quarters
Wafer Fab Equipment Leading Indicator	Monthly	Acceleration profile of booking trends	Moderately	3 to 5 months

Source: Dataquest (February 1995)

A preliminary curve for this indicator through the end of 1994 does not show any significant downturn in bookings through the first half of 1995, in a broad range of 25 to 40 percent year-over-year growth. We would expect the DRAM price statistic to show weakness before this indicator, however.

Segmenting the Equipment Market: Key to Cyclicality

Historical data (detailed in our forecast report and earlier in this article) clearly shows the equipment market to be cyclical around the trend of semiconductor revenue—but why? Here we will propose a way to view and segment the equipment market that can be used to characterize its cyclicality.

We believe that the market for equipment can be cleanly segmented into two markets—equipment sold for DRAM capacity, and all other capacity (primarily logic and ASIC oriented). This would be a convenient market split for several other reasons. First, the technology road maps for DRAM and logic/ASIC are distinctly for some areas of process equipment, as recently outlined in our Focus Report (SEMM-WW-FR-9401, dated November 28, 1994). Second, semiconductor companies can be segmented both by regional ownership and product strategies along the lines of DRAM, microcomponents, and ASIC/other logic. Last, there is some segmentation along these lines already inherent in how equipment company strategies are developed. For example, most equipment segments that are critical for the DRAM are dominated by Japanese suppliers, and most critical for logic are dominated by U.S. suppliers.

From the perspective of capital spending, this segmentation is also useful. Logic and ASIC device demand (and capital spending for capacity) is driven by the pervasiveness of semiconductors into everyday life, and partially on PC unit demand into the worldwide communications infrastructure. This investment tends to exhibit stable growth and depend more on world economies and global trends in the use of semiconductors, and therefore is event-driven and has only small cyclic fluctuations. Large U.S. companies such as Motorola and Intel, as well as the emerging dedicated foundry companies, are the key drivers of this spending and production.

Investment in DRAM capacity over time does depend on actual demand for bits, with respect to the level of investment, but the timing of that investment has more to do with the pricing of DRAMs and the resulting profitability of DRAM manufacturers. DRAM pricing, large volume demand,

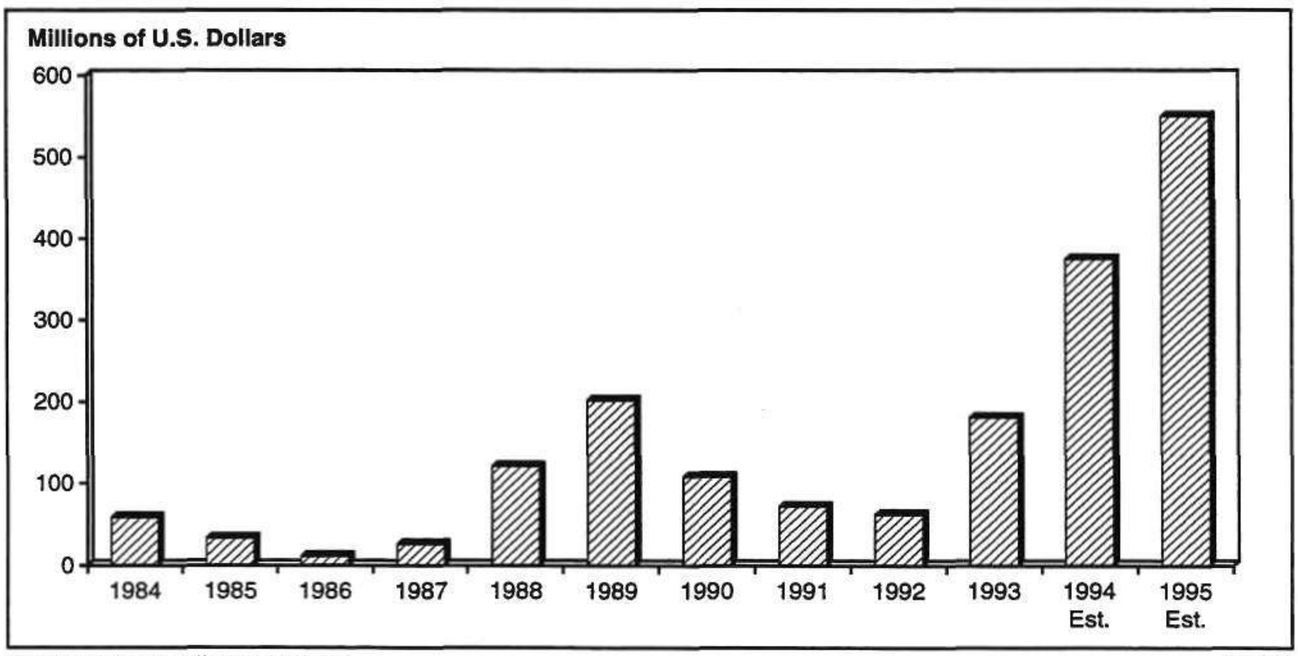
and density crossovers tend to make this investment extremely cyclical and characterized by large equipment orders. Companies such as Micron Technology, Korean companies, most large Japanese companies, and to lesser extent Texas Instruments have a cyclic pattern to capital spending. A case in point is pictured in Figure 2, showing the capital spending trends of Micron Technology—a very well run DRAM company.

Supporting Data for a DRAM-Logic Segmentation

As 1994 unfolded as a classic DRAM investment ramp year, we saw that the best-performing segments either had a direct tie to DRAM technology (such as high-voltage implant) or depended on new DRAM capacity spending to drive large unit consumption (steppers and high-current implant). The latter group also tends to exhibit compound annual growth rates (CAGR) either at or below that for the overall wafer fab equipment market. Further, Dataquest estimates that 40 percent of the wafer fab equipment sold in 1994 went into DRAM capacity. However, DRAMs accounted for only 21 percent of semiconductor revenue in 1994—clearly the amount of investment in capacity in 1994 outstripped what the demand would logically dictate. This is the characteristic of the cyclicality, however, and there are years (both past and in the future) where the investment was/will be below demand.

We have called these segments "DRAM-sensitive" because their market sizes have tended to follow the cyclic nature of DRAM capital spending. One can imagine equipment segments, such as sputtering, that tend to be more closely tied to the logic investment patterns. These "logic-sensitive" segments we believe are less cyclic, when compared to the overall equipment market.

Figure 2
Capital Spending of Micron Technology, 1984-1995



Source: Dataquest (February 1995)

To test our theory, we did an analysis that took four good equipment years (1988-1989, 1993-1994) and compared them with four "bad" equipment years (1986, 1990-1992) to determine any trends.

Table 3 shows a comparison of the overall wafer fab equipment market with the underlying semiconductor market trend (for the year prior). An average "bad" year in semiconductors was 1.5 percent growth, while an average good year saw nearly 26.0 percent growth. The wafer fab equipment market is more volatile/cyclic than its underlying trend market by about 14 to 15 percentage points, both up and down. This top-line analysis determined that the years chosen would characterize the equipment market well.

Table 3
Average "Good" and "Bad" Years for Wafer Fab Equipment and Semiconductors (Percent)

	Weak Periods (1986, 1990-1992)	Strong Periods (1988-1989, 1993-1994)
Wafer Fab Equipment	Down 12.2	Up 41.1
Semiconductor Production (for Year Prior)	Up 1.5	Up 25.7

Source: Dataquest (February 1995)

It is also interesting to note that, for 1995 and 1996, Dataquest is forecasting 14 and 10 percent growth in semiconductors, respectively. The wafer fab equipment forecast is minus 7 percent and plus 3 percent growth for 1996 and 1997, respectively—an average of 14 points lower for the two years combined. This is interesting trivia, and just a reflection of how the forecast model is now tied to the net cumulative investment model.

Table 4 summarizes how major equipment segments have fared in the good years compared to the bad. Although it is not perfect, the general trend holds that the less-cyclic segments tend to be those that are logic-sensitive and the more volatile are those that are DRAM-sensitive.

Tying the Equipment Market Cyclicality to a DRAM Statistic

Earlier in this article we described various models. Now that we have shown that the wafer fab equipment market is cyclic and that cyclicality depends on DRAM investment patterns, we will describe and tie the equipment market to a specific indicator.

To review, a statistic that tracks the relative average DRAM price appears to have a direct correlation to the cyclicality of the equipment industry. This statistic is *not* the price of a particular DRAM, and it is *not* a price-per-bit calculation. It most closely resembles the relative profitability of the DRAM manufacturer and indicates how much the buyers of DRAM are pulling demand for the current mainstream part. The statistic is shown in Figure 3.

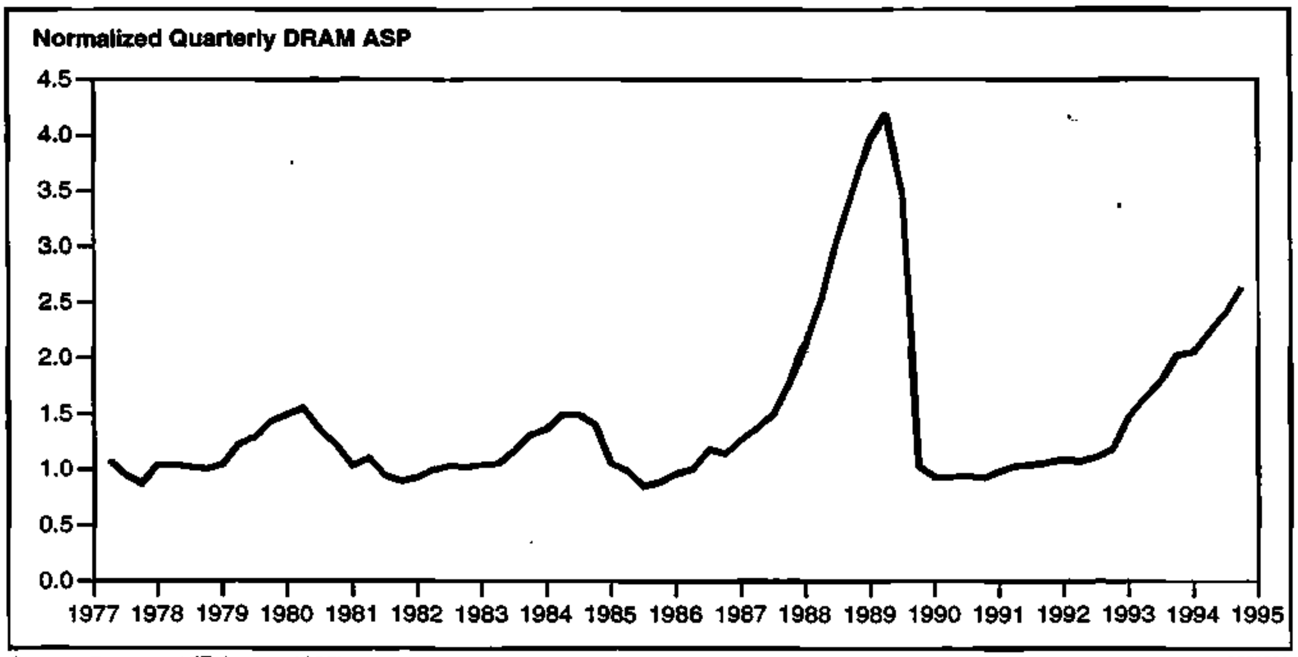
This statistic indicates a very regular pattern, and we have normalized the average selling price (ASP) within each cycle in order to show this regularity. Price peaks have occurred every five years, and are coincidental with a market transfer to the next density level for the DRAM. The 1989 peak

Table 4
Average "Good" and "Bad" Years for Wafer Fab Equipment Segments (Percent)

	Weak Periods (1986, 1990-1992)	Strong Periods (1988-1989, 1993-1994)
High-Current Implant	Down 43.0	Up 69.6
Medium-Current Implant	Down 34.9	Up 51.8
Steppers	Down 16.9	Up 57.6
Diffusion	Down 16.7	Up 50.0
Total Wafer Fab	**Down 12.2**	**Up 41.1**
Dry Etch	Down 10.0	Up 50.5
Critical Dimension	Down 7.0	Up 28.6
CVD	Down 3.9	Up 47.8
Track	Down 2.8	Up 43.3
Sputtering	Down 0.2	Up 34.3
Epitaxial Silicon	Up 3.8	Up 38.4
Auto Wet Stations	Up 5.5	Up 49.4
Wafer Inspection	Up 6.7	Up 70.3
RTP	Up 7.8	Up 21.7
Dry Strip	Up 7.9	Up 38.9

Note: This table represents cyclical trends, therefore segments and periods were excluded when an underlying major trend exists. Example: High-voltage implant is a known DRAM technology but grew more than 300 percent in 1986 because it was an emerging technology. Long-term growth rates for wafer inspection and auto wet stations make these segments perform better than the market historically for all periods analyzed.
Source: Dataquest (February 1995)

Figure 3
Normalized DRAM Price Statistic, 1977-1994



Source: Dataquest (February 1995)
9500821

represents the beginning of the end for the 1Mb DRAM, and the start for the 4Mb DRAM. To better understand the dynamic, let's go through a cycle.

Each cycle consists of about two years of stability, followed by seven to nine quarters of price rise, followed by three to five quarters of price decline. During the price rise, the demand for the mainstream part catches and exceeds supply, which is currently happening at the 4Mb level. Typically, the next-generation DRAM is close to production availability and capacity additions are made in advance of the demand during this time for the next-generation part (this is happening at the 16Mb level). For there to be a price rise, a clear mainstream part has to be in the market, which occurred near the end of 1992 for the 4Mb DRAM.

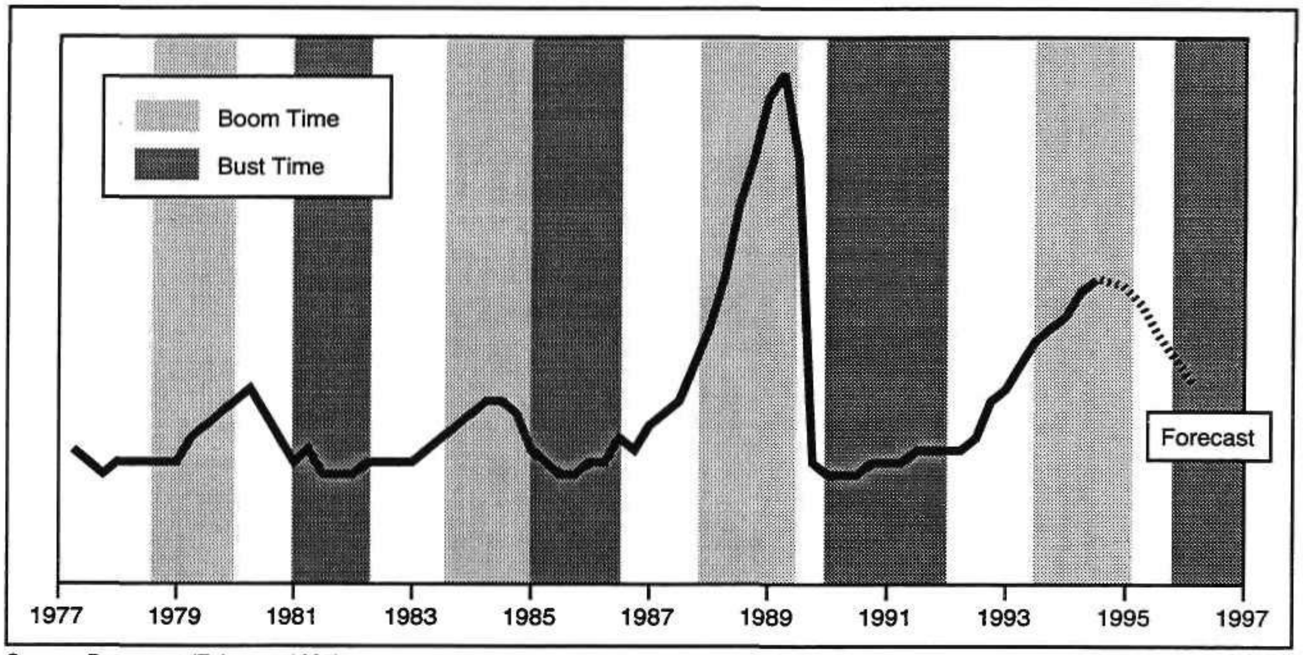
At the price peak, the next generation of DRAM has become popular enough to start to pull demand away from the mainstream generation, thereby applying price pressure to the mainstream product. This does *not* correspond to a price-per-bit crossover, and has preceded the price-per-bit crossover in the past by several quarters. In general, the DRAM buyer has "pulled" the next generation into the market. Once this process starts, several dynamics occur. First, as demand falls off for the mainstream part, companies with a weaker position in the new part tend to lead a price cut to keep the market, putting pressure on profitability and thus available capital for equipment purchases. Second, equipment being used to produce the mainstream part is transferred to the more advanced part to conserve capital and add production capacity for the new part.

With profitability down somewhat, the price stabilizes. As demand ramps further for the new part, shrink designs and yield increases are used to increase capacity instead of capital outlays. This continues until demand outstrips supply by more than about 20 percent, putting upward pressure on prices. Prices and profitability rise, capital is again freed, and the cycle begins again.

In summary, if this statistic is rising, demand is accelerating and supply is tight. If this statistic is falling, demand is either falling or making the transition away from the mainstream part. If this statistic is stable, either supply and demand are in balance or the DRAM manufacturer is pricing the parts relatively close to cost.

How is this tied to the equipment market? As can be seen from Figure 4, where we have overlaid the price statistic with historical boom and bust periods, any time the price statistic rises an equipment boom occurs, and within one to three quarters of the price peak a period of tough times ensues. In effect, this statistic can be viewed as a leading indicator for the equipment industry. This indicator started to rise in the third quarter of 1992. If Dataquest had used this indicator at that time, we would have forecast a start of a boom in 1993. This indicator has continued to rise through the fourth quarter of 1994, indicating that a significant decline in the equipment market is not expected in the next six to nine months.

Figure 4
Wafer Fab Equipment Market Cycles Driven by DRAM Pricing



Source: Dataquest (February 1995)

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Dataquest Perspective

The wafer fab equipment market has cycled through boom and bust times. With the stellar growth of 1994 being within a whisker of the growth experienced in 1988, and 1995 shaping up to be a growth year similar to 1989, we have become concerned about the possibility of tough times ahead. We believe that the key driving forces for the *cyclicality* of the equipment market have not changed.

We have been developing and refining various models over the last several months that give us a better picture of the magnitude and timing of these cycles, as well as the triggers and indicators to watch. Our view is that the dynamics of the DRAM market hold the key, and in particular DRAM price trends and density crossover periods.

All of our analysis indicates that the first half of 1995 will remain strong in the wafer fab equipment market, but the second half may hold some softening. The current DRAM cycle is already into its sixth year, and the price-per-bit crossover of the 16Mb DRAM is imminent (currently about the third quarter of 1995).

Although the severity of this downturn will not be as serious as the past, because the end semiconductor market is strong, the cyclicality of the equipment market still cannot be avoided this time around. Our current forecast is consistent with the DRAM price statistic peaking during the first quarter of 1995, with a price-per-bit crossover for the 4Mb to 16Mb DRAM complete during the third quarter of 1995.

What if the indicators presented here remain positive for the next six months? How would our forecast be modified in July? We would probably nudge up growth in the wafer fab equipment market for 1995 to the low- to midtwenties, place 1996 in slightly positive territory (nearly flat), and bring down 1997 significantly.

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Market Analysis

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Market Analysis

Semiconductor Equipment, Manufacturing, and Materials Worldwide

Market Analysis

1994 Stepper Market: Reflection of the Growing Strength in Semiconductor Production

Abstract: *In this document we will review the 1994 lithography stepper market and its dynamics. We will compare 1994 regional activity and company market share with 1993. The purpose of the document is to set the stage for Dataquest's latest stepper forecast and its underlying assumptions to the end of the century. The stepper forecast and analysis will be published soon in another Market Analysis.*
By Näder Pakdaman

Introduction

The stepper market continues to be a very sensitive indicator of the semiconductor industry's status and its capital spending trends. The evolution and market growth of stepper technologies also serve as a barometer of trends in semiconductor production. Although the semiconductor market grew nearly 30 percent in revenue from 1993 to 1994, the overall front-end equipment market grew by over 56 percent in this time frame. The stepper market accelerated even further with revenue growth of over 80 percent in 1994.

The demand for steppers has gained further momentum in 1995. We recently reported the stepper capacity constraints and backlogs stretching into 1997 (SEMM-WW-MA-9504). The strength of the stepper market was caused not only by increases in unit shipments but also by higher average selling prices (ASPs) of the systems. The production capacity buildup that began in mid-1993 has shown no signs of slowing down, as manufacturers are benefiting from the increased demand in semiconductor applications. This demand is manifest not only in numbers but also for higher-performance ICs. The faster rate of shrinks and emphasis on productivity has driven the higher ASPs of the steppers.

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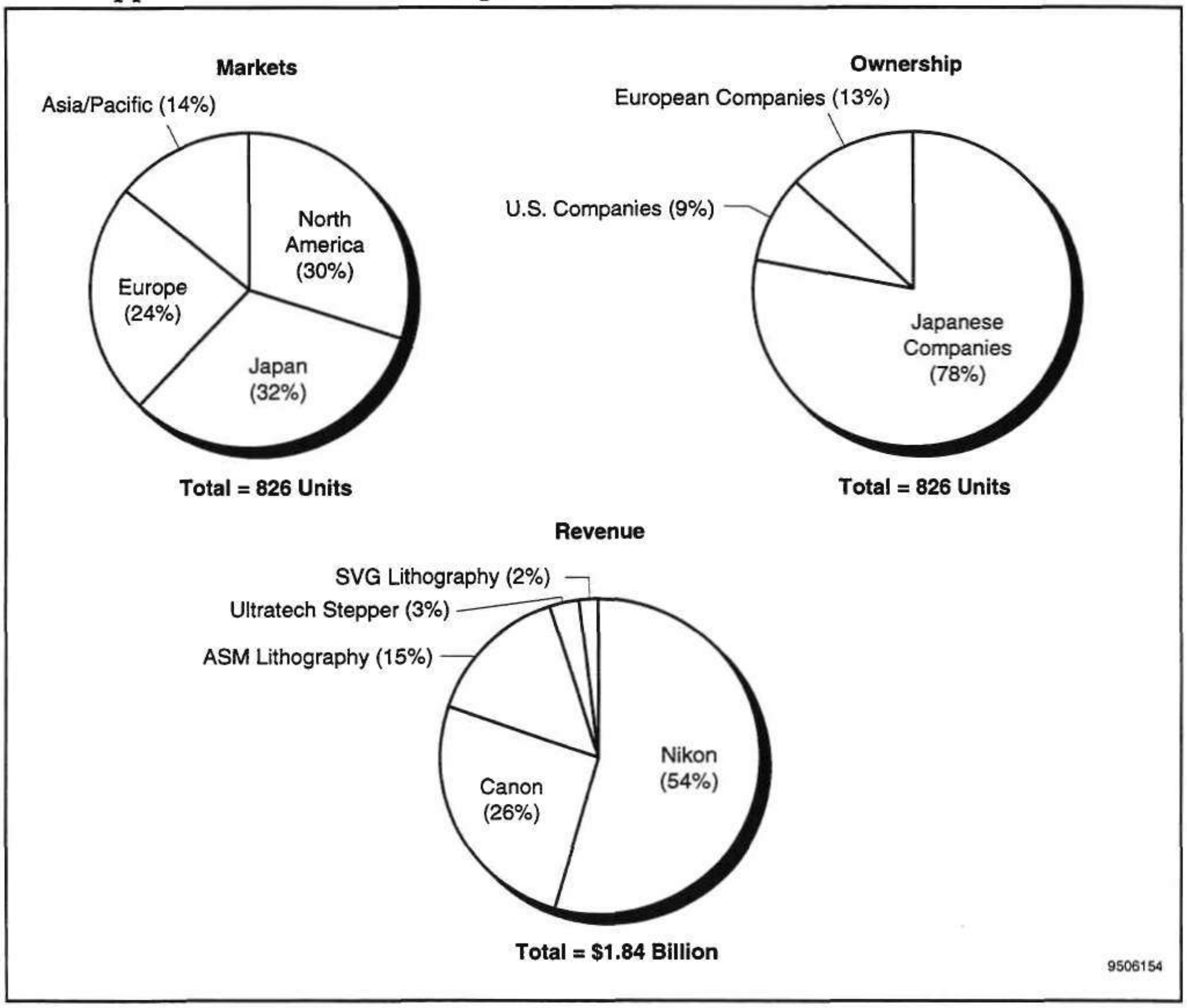
Regional Markets and Analysis

Figure 1 shows the regional market splits, stepper unit shipments from each region, and company market share by revenue. Hitachi's departure from optical lithography changes the 1994 market share of the current five stepper suppliers. In terms of regional unit consumption, we estimated that 251 steppers were shipped into North America. This is 30 percent of the total units, similar to the unit share of this region in 1993. Manufacturers in Japan consumed 264 units, near 30 percent growth over 1993. These units comprised 32 percent of the total worldwide steppers shipped in 1994, below the 36 percent of 532 units we estimated for 1993. The strong growth was primarily a result of the underinvestment in manufacturing capacity by Japanese companies in 1992, for which they have begun to strongly compensate since 1993. But the lower share of the total market exemplifies the strong and undeniable investment trend in the other two markets, Europe and Asia/Pacific. The estimated 6 percent decrease in Japan was compensated equally by these two regions.

Figure 1
1994 Stepper Market and Ownership



Source: Dataquest (November 1995)

Europe and Asia/Pacific are experiencing massive investments by local and foreign capital. The strength of spending in contract manufacturing in Asia/Pacific has been coupled by large investments for DRAM manufacturing, especially in Korea and Taiwan. Along with heavy spending by local manufacturers, large investments of foreign capital and technology have continued to pour into the Asia/Pacific region. We expect local consumption and export markets for semiconductor-related products to continue to attract more capital in both Asia/Pacific and Europe. In Europe, all major local manufacturers have committed to multibillion-dollar manufacturing projects in their local market. The U.S., Japanese, and Korean companies have followed suit with their expansions or new plans and joint ventures in this region.

Table 1 shows Dataquest's estimates of regional revenue and unit growth for each of the stepper suppliers. Europe constituted the largest growth rates over 1993 in both revenue (129 percent) and units (95 percent) than any other region of the world. The growth in revenue for stepper manufacturers in the European market was followed by our estimates of less than 110 percent in Asia/Pacific. North America and Japan followed strongly with 84 and 53.4 percent growths in terms of revenue, respectively.

Company Ranking and Analysis

In terms of units, market share by regional base of company did not change significantly from 1993 in 1994. However, from a revenue perspective, we saw a different picture in 1994, primarily because of Nikon's increased market share. We estimate that Nikon held 49 percent of the total market of $1.02 billion in 1993. Nikon increased its market share to 55 percent of the

Table 1
1994 Regional Unit and Revenue Growth Rates by Company (Percent)

	North America	Japan	Europe	Asia/Pacific	Worldwide
Revenue					
ASM Lithography	42.7	0	167.4	47.4	60.6
Canon	123.4	65.1	81.1	39.6	75.0
Hitachi	-100.0	-100.0	-100.0	-100.0	-100.0
Nikon	122.1	53.8	181.9	203.1	106.1
SVG Lithography	36.0	0	0	10.5	31.7
Ultratech Stepper	25.5	134.9	30.9	309.0	76.3
Total Growth	83.5	53.4	128.7	109.1	82.4
Units					
ASM Lithography	38.5	0	166.7	38.1	55.1
Canon	90.9	45.6	52.6	25.0	52.5
Hitachi	-100.0	-100.0	-100.0	-100.0	-100.0
Nikon	74.1	24.1	127.3	129.2	62.6
SVG Lithography	-16.7	0	0	0	-14.3
Ultratech Stepper	33.3	175.0	71.4	300.0	86.1
Total Growth	57.9	29.4	94.9	78.2	55.3

Source: Dataquest (November 1995)

$1.84 billion in 1994. In spite of strong growth in revenue by every player in the market, except for Ultratech Stepper, every stepper supplier lost market share in 1994 to Nikon.

Table 1 showed that revenue grew faster than units in every region. This difference was the strongest in Europe, followed closely by Asia/Pacific. Therefore it is seen that advanced system installations with higher ASPs in these regions reflect the higher rate of capital spending in the high end of the technology spectrum, compared with previous years. The larger and more mature advanced manufacturing markets in Japan and North America showed a similar trend, although with a smaller difference than the two previous regions.

Table 2 lists the stepper companies by their ranking in unit shipments. The order did not change, except for Hitachi's exit. I-line steppers' share of the technology mix grew over g-line and deep-UV systems, with 68 percent growth from 1993. G-line system shipments grew by 25 percent, and deep-UV shipments fell by 28 percent.

The i-line systems dominated the market with nearly 83 percent of the shipped units. The increase in ASPs was primarily by this technology. Canon begun the large volume shipments of its flagship high-resolution FPA-3000-i4 system in early 1995, therefore its ASPs lagged those of the other two players (Nikon and ASM Lithography, or ASML) in the advanced high-resolution i-line market. A considerable portion of ASML's and Nikon's shipments in 1994 comprised their respective PAS 5500/100 series and the NSR-200511 series steppers. These systems carry a considerably larger price tag than the models they have replaced. Because of more upgrades and newer models capable of higher throughputs in 1995 introduced by all three of these players, we should expect the ASPs of advanced i-line systems to increase even more. We will discuss this important trend further in the forecast document.

As shown in Table 1, Nikon and Canon both had revenue growth in North America of over 120 percent, although Canon's unit growth of over 90 percent was higher than Nikon's 74 percent growth. In Japan, Canon's revenue grew more than Nikon's 54 percent growth. Canon's unit growth rate was

Table 2
1994 Worldwide Stepper Company Ranking (Unit Shipments)

	Units	Share (%)	Change from 1993 (%)	g-Line	i-Line	Deep-UV
Nikon	431	52.2	63	41	384	6
Canon	215	26.0	53	24	191	0
ASM Lithography	107	13.0	55	8	95	4
Ultratech Stepper	67	8.1	86	51	16	0
SVG Lithography	6	0.7	-14	0	0	6
Hitachi	0	0	-100	0	0	0
Worldwide Total Market	826	100.0	55	124	686	16
Percentage Technology Mix				15	83	2

Source: Dataquest (November 1995)

nearly twice that of Nikon's shipments into Japan. We surmise that, although Nikon was shipping relatively higher-priced steppers in 1994 to these two regions, Canon was shipping units at a higher rate. Because the product mixes and technical road map of these two leaders of the stepper market have historically been relatively similar, should we expect their ASPs to converge? In the short term, capacity and backlog will determine the answer. In the long term, however, the ASP-versus-units issue of all the suppliers in the market will be settled more or less in the deep-UV arena, and the dynamics of its adoption in volume manufacturing. Deep-UV lithography will be a major topic in the forecast document.

ASML has had consistent strong growth in the past several years in both revenue and units, without the benefits of sales in the Japanese market. ASML's strong presence in Asia/Pacific (in particular in Taiwan), along with a growing large installed base in North America, has allowed it to better weather the cyclic nature of the stepper market. In 1995, as seen in Table 1, ASML had similar strong growth rates in North America and Asia/Pacific, in both units and revenue. However, its worldwide growth rates were higher than the figures in these two regions, because of its over 165 percent growth in both revenue and units in Europe, ASML's smallest market. Dataquest's recent updated front-end equipment forecast shows over 20 percent average growth in Europe to the end of the century. This is a market that should play a critical role in the worldwide competition for market share.

Ultratech Stepper further grew its leading position in the g-line market in 1994. Ultratech grew its g-line unit shipments by over 50 percent in 1994. This is an arena that Ultratech aptly calls the scanner replacement market. Dataquest estimates that over 55 percent of all square inches of silicon processed in 1994 were for devices that had critical geometries of more than one micron. Although the other players in the market are phasing out their g-line systems (except for special markets or applications) in favor of their high-resolution systems, Ultratech has strengthened its focus on this important market. Many manufacturers, among them producers of microcontrollers, discrete, and analog devices, are well aware of the benefits and advances of steppers over its precedent technology, scanner systems. These benefits include high throughput, larger field sizes, higher resolution along with better overlay, and reliability—in short, higher productivity.

Ultratech's i-line shipments grew from our estimated three units in 1993 to 16 units in 1994. Its 2244i i-line stepper is designed as the high-throughput companion to high-resolution steppers of other stepper suppliers in mix-and-match lithography technology. Ultratech has led the charge in this growing market, and in 1994 introduced a second model of its high-throughput stepper line. The other three players in the i-line market also introduced their respective versions and models of high-throughput systems in 1994. For the 1995 market and future years, Dataquest will begin to estimate the number of steppers used as the high-throughput systems in mix-and-match scenarios.

We estimate that SVG Lithography (SVGL) shipped one fewer Micrascan unit in 1994 than it did in 1993. However the ASPs of the systems shipped grew by over 30 percent, and this resulted in an overall growth in revenue for SVGL. SVGL has built a backlog that signifies the onset of deep-UV lithography's merge with mainstream processing. SVGL has continued to make investments to increase capacity and also develop the Micrascan III, a 0.25-micron version of its step-and-scan steppers. The introduction and capacity availability of the Micrascan III is a significant event for SVGL, because Nikon's recent shipment of its first NSR-201 0.25-micron deep-UV scanning system into IBM's East Fishkill, New York, facility has raised the bar in deep-UV stepper technology.

SVGL should not be solely evaluated on the basis of market share, but should also be viewed from the prism of the deep-UV stepper technology and market dynamics. SVGL had a watershed year in 1994, and the events did not concern the immediate market. The negotiations with Canon over the licensing of SVGL's deep-UV step-and-scan Micrascan technology was finally terminated after more than a year of discussions without an agreement. SVGL in turn found other partners to address its capacity and R&D capital needs. SEMATECH, along with several U.S. semiconductor manufacturers, committed nearly $100 million of capital to further develop the Micrascan technology and build the infrastructure for sales and support of this critical lithography technology. Our forecast document will discuss in detail our assumptions on the evolution of the deep-UV market.

Dataquest Conclusions

The stepper market in 1994 spearheaded the strong growth in the front-end equipment market. The strength was in both units and ASPs. One other very important facet of the 1994 market was the growing difference in the resolution capabilities of the high-resolution steppers and the critical geometries of the advanced ICs in volume manufacturing. Most of the high-resolution steppers shipped in 1994 were geared to process sub-0.5-micron devices. Manufacturers historically have leveraged the added flexibility in manufacturing by processing the critical geometries of the ICs at resolutions lower than the capability of the steppers. This so-called resolution gap increased noticeably in 1994, as critical device geometries processed in advanced manufacturing were more or less in the 0.5-micron regime and the mass of the steppers shipped throughout 1994 increasingly tended toward the 0.35-micron capabilities. We have observed the same trend continuing in 1995 and will further discuss the ramifications of this technology gap in the stepper forecast document.

In summary, we saw the following trends:

- ASPs grew faster than units in every region.
- Europe and Asia/Pacific led the market in growth of revenue and units, which accompanied strong growth in North America and Japan.
- The company rankings did not change, while Nikon and Ultratech increased their market share.
- Mix-and-match continued its ascent from a concept to a practical solution in addressing rising costs and the increasing need for productivity.

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Market Analysis

Semiconductor Equipment, Manufacturing, and Materials Worldwide

Market Analysis

Lithography Stepper Capacity: Bottleneck of Semiconductor Production

Abstract: *Semiconductor manufacturing's unprecedented and sustained growth of the past several years has put a significant strain on the infrastructure of the markets that support it. In manufacturing semiconductors, lithography defines capacity and technical capability. The capacity constraints of the suppliers in this critical lithography stepper market are discussed in this article by looking at each stepper supplier.*
By Nader Pakdaman

Stepper Suppliers Step Up Capacity

Nikon recently announced expansion of its stepper production facility in Kumagaya, Japan. The company will increase output at its main plant to nearly 1,000 steppers per year from a current capacity of about 650 units. The primary emphasis will be on the high-end i-line systems (NSR-2205i11D and beyond) and the newly announced scanning stepper (NSR-S201A deep-UV system). Full capacity will be reached gradually through 1996.

At about the same time, Ultratech Stepper and ASM Lithography (ASML) announced that they are holding preliminary discussions to form a strategic alliance. Ultratech and ASML will offer their clients the option of mixing and matching their respective noncritical and critical resolution steppers. The primary goal of the discussions is to focus on developing faster responses to capacity constraints.

Dataquest Analysis

The news releases on both of these announcements were short but significant. Without steppers, one cannot build a fab and expect to pattern the

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circuits on the silicon. Concerns about infrastructure constraints in the semiconductor industry are mounting. Could the current undercapacity in manufacturing curtail the semiconductor industry's goal of surpassing $300 billion by the end of the century? These concerns are balanced by warnings of historical overinvestment patterns that have taken the industry through some very hard times. There is merit to both of these arguments. As usual, the reality will probably lie somewhere in between and be more complex than either.

In a recent update of the semiconductor revenue forecast, Dataquest increased its forecast of average growth rates for the industry to over 20 percent until the end of the decade. Growth rates had been just over 15 percent for the first half of the decade. We believe this increase is a fundamental indicator of the growing prevalence of semiconductors in our lives. From set-top boxes to PCs and communications applications, semiconductors are changing all facets of our lives at home and work.

The other fundamental aspect of the industry is the cyclical nature of the markets and investment patterns that have produced cycles of relatively stronger and slower years. As the industry migrates to a new device generation, the cycle begins with investment to address undercapacity. Then, as device shrinks take hold and yield increases, demand is met and a period of overcapacity may occur. This cyclical pattern is seen very clearly in the DRAM market.

In short, we are experiencing a fundamentally stronger demand for semiconductors that the industry is addressing by unprecedented increases in capacity. However, the central cyclical drivers still exist in the market. In Dataquest's view, the issue of over- and undercapacity will not prevail uniformly in all markets and for all ICs. The Dataquest forecasts for the semiconductor market and the directly related manufacturing equipment and materials market reflect both the growth in demand and the cyclical nature of the market.

Since 1993, megafab announcements have become daily news. Capital spending figures for fabs ranging from $1 billion to $2 billion are now taken as ordinary events. The technology and capacity of these fabs are defined by the number and capabilities of their lithography steppers.

The lithography tools supply-demand equation has been producing backlogs extending into the first quarter of 1997. This may sound fantastic, but if these backlogs are not addressed in a timely fashion by stepper suppliers, it could spell disaster. As both technology and users' needs evolve, these extended delivery times could translate into changing specifications. Changes in the market over such an extended period could even spur cancellations. A more balanced supply-demand picture with realistic backlogs would make planning and investment for stepper manufacturers and semiconductor manufacturers a more reasonable and less chaotic exercise.

All of the major stepper manufacturers (ASML, Canon, Nikon, SVG Lithography, and Ultratech Stepper) are facing historic capacity demands. Inability to address the problem could spell loss of market share in a segment that accounts for over 15 percent of the total front-end equipment market, on average. Dataquest estimated the stepper market at $1.8 billion in 1994.

Current estimates call for this market to reach $5 billion by the end of the decade.

Nikon has led the stepper market with shares about and above 50 percent in the last several years. Nikon's current capacity is approximately 650 stepper units a year. For 1995, this capacity should preserve the company's position in a market that we estimate will surpass 1,000 steppers for the first time, with over 1,200 steppers shipped to manufacturers. Nikon plans to sustain and even gain market share by quickly increasing capacity in a market that is highly cyclical. The peak and trough years of the stepper market are very steep. But we estimate that the growing demand in production will not be met by capacity until 1997, at least, and that the slowdowns that follow will not be as severe as those of previous cycles. Nikon's lens capacity, or the better availability of glass, is even more critical. It takes over a year to anneal the quartz material used in the optical train of the steppers. We must assume that Nikon has been planning this increase for many months and that its glass capacity will match its 1,000-stepper goal.

Nikon's Japanese counterpart, Canon, has been increasing capacity since early 1994. By our estimate, Canon is now running at a capacity of over 400 steppers per year. We expect Canon to increase its capacity to preserve and perhaps increase its share of about 25 percent of the stepper market. Canon is on a very aggressive product introduction path as it tries to reestablish itself as a leader for 0.25-micron deep-UV lithography scanning tools.

The Ultratech and ASML announcement is also directly related to the capacity issue. ASML has been working hard with its optical shop, the lens supplier Zeiss of Germany, to increase capacity for its systems. Sophisticated tools and major investments are required to process the glass and manufacture and test the optical train for all stepper manufacturers. Based on announcements made by ASML and Zeiss, Dataquest estimates their lens capacity at fewer than 180 units for 1995. This figure could easily grow in the next several years.

ASML's primary strategy is to compete with Canon and Nikon on the high-resolution stepper front as the industry moves to 0.35-micron and smaller geometries. However, resolution is not the only measure of steppers and equipment. Cost-effectiveness and productivity must match technical capabilities. Because of this, stepper manufacturers have introduced mix-and-match lithography as a means of reducing cost and increasing throughput.

Ultratech has led the way in matching its high-throughput systems in a mix with high-resolution steppers on the fab floor. Canon, ASML, and Nikon have all followed suit with their high-throughput systems. By our estimates, Ultratech shipped nearly 70 steppers for semiconductor manufacturing in 1994. The company has been growing strongly in all regions of the world with its i-line steppers for mix and match. Unlike other players in the market, which have product lead times of 18 months or more, Ultratech enjoys turnaround times of six to nine months. This is primarily because of the relatively simple optical design of the Ultratech steppers.

The agreement between Ultratech and ASML translates into a marketing strategy that would allow semiconductor manufacturers to choose between two mix-and-match scenarios. ASML and Ultratech will each propose two mix-and-match packages to the customer. ASML will offer one package pairing its high-resolution stepper with its own high-throughput system and one with the Ultratech companion. Ultratech will offer its system partnered with ASML's equivalent to the high-resolution stepper (which the prospective client may have already chosen) or with the non-ASML stepper.

Discussions between the companies are still in the preliminary stages. Both will benefit from this agreement even if cooperation goes no further than the outlines of their announcement. Most Ultratech high-throughput steppers are matched with Canon and Nikon steppers because of the massive installed base of these two vendors. Ultratech will be well positioned to enjoy the benefits of ASML's client base and to further solidify its position in the critical mix-and-match arena. In turn, ASML will get much-needed capacity relief for its high-resolution steppers.

It will be interesting to see what other synergy may exist between these two players. In 1994, ASML and Ultratech together held over 18 percent of a market that totaled more than $1.8 billion. Each has been growing over 60 to 70 percent per year in the past several years. Ultratech's presence in Japan may compensate for ASML's lack of visibility in this critical market. From a manufacturing point of view, both companies rely heavily on their external suppliers in strategic OEM agreements. Could this similarity and flexibility in manufacturing strategy and this partnership in mix and match lead to cooperation and exchange of technology?

We cannot close this discussion without mentioning the other critical player in the market, SVG Lithography (SVGL). For SVGL, more than any other company in the market, capacity does not merely translate into market share but may determine its future. SVGL's deep-UV Micrascan has led lithography's foray into sub-0.5 micron deep-UV scanning lithography. Dataquest estimates that SVGL holds over 25 percent of the installed base of deep-UV steppers, trailing only Nikon's near-40 percent share of installed deep-UV systems.

Nikon's shipment earlier this year of the first NSR-S201A 0.25-micron deep-UV scanning system to IBM's East Fishkill, New York, plant has the market awaiting SVGL's next stepper—the Micrascan III. However, semiconductor manufacturers are also interested in seeing how SVGL will build the infrastructure needed to support the deep-UV market into the next century. SVGL has benefited from the approval and financial backing of several U.S. semiconductor manufacturers and SEMATECH. Nobody doubts that SVGL's position in technology is formidable, but annual unit shipments now in the low teens would have to increase to levels of deep-UV stepper capacity comparable to SVGL's competitors—ASML, Canon, and Nikon.

Semiconductor revenue and the ensuing growth in capital spending have translated into long backlogs for equipment suppliers, particularly for stepper manufacturers. If stepper undersupply is gating the supply of chips, the market's ability to spur demand by producing in volume and at lower cost will be greatly inhibited. We believe that by mid-1996, even at the current high rate of demand, increases in stepper capacity will relieve the pressure on the market. Through adoption of mix-and-match lithography strategies and/or faster shrinks of IC designs, semiconductor manufacturers will address the growing demand for their products.

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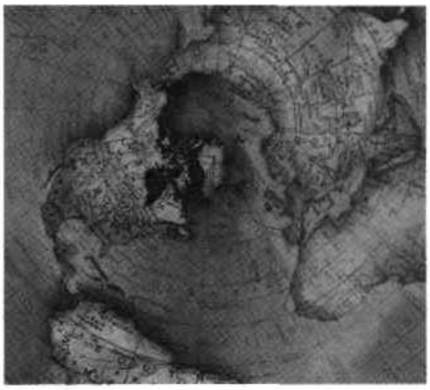

Dataquest

Year-End 1995 Forecast: Capital Spending, Wafer Fab Equipment, and Silicon

Market Trends

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Year-End 1995 Forecast: Capital Spending, Wafer Fab Equipment, and Silicon

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Table of Contents

Table of Contents (Continued)

List of Figures

List of Tables

Chapter 1
Executive Summary

Year-End 1995: Backlog Heaven ... Needed for 1997

The year 1995 was one of those that the industry almost wishes will not be repeated for a while, because the infrastructure of supply is being strained. Backlogs in the equipment industry exploded in 1995, with reports that stepper lead times are over one year. Companies are having trouble filling all their open positions, and silicon supplies are extremely tight. Yet the engines of demand for semiconductors—PCs and communications/networking equipment—continue. A monthly leading indicator we have been developing went crazy in April and has not rested since.

A couple of trends do concern us, however. The number of planned fabs announced in the forecast horizon has increased dramatically from about 85 one year ago (counting 1994 and after) to over 130 (counting 1995 and after). The density of new fabs, about 35 per year, has not changed much, but the announcement horizon has lengthened. A year ago new fabs were announced to come on line in 18 to 21 months. Today, with the huge backlogs in equipment companies, announcements are made for fabs 24 to 30 months ahead. Funding to place an order for a stepper is generally done *before* ground is broken on a new fab, just to get in line. There are already about 25 fabs announced to come on line in 1998—a visibility that is uncharacteristic.

Are these fabs real? We believe so, because in order to achieve a $330 billion semiconductor market by 2000, the industry needs to maintain a run rate of 30 to 35 fabs per year. Our concern is that the 1996 and 1997 run rates are slightly ahead of this figure, and some of the 1997 and 1998 fabs may be delayed by six to 12 months, softening the quality of backlogs for 1997.

Although we think the recent talk on DRAM pricing has been overblown (we see continued shortages through 1996), we do believe we are past the "pinch point" in the supply/demand imbalance, and availability of DRAM is beginning to improve. We are now viewing 1997 as a year for a slight oversupply of DRAM (based on silicon area capacity), so capital investment in 1997 is likely to cool in this area.

Does this spell doom for 1997? No, the foundry industry supply will get tighter in 1996, leading to increased spending for logic-oriented capacity over DRAM starting late in 1996 and continuing into 1997. The foundry market will not see relief in capacity until the middle of 1998, by our silicon area-based capacity analysis.

What Are the Trends?

On the heels of booming growth in 1994, global semiconductor capital spending grew another 72 percent during 1995 to $38 billion. Anticipated continued tight capacity and a strong semiconductor market in 1995 mean continued growth into 1996, now forecast at about 30 percent.

North America is showing consistent strength, with a 69 percent growth in 1995. Worldwide demand for desktop connectivity products and telecommunications equipment continues to fuel the investment strategies in U.S.-manufactured semiconductor products, heavily weighted toward logic and ASIC capacity. North American capital spending is expected to remain strong in 1996 and to moderate in 1997 as these investments are absorbed, but we expect the North American region to grow at faster-than-market rates as foreign multinationals and foundry companies invest in capacity in the United States.

Japanese companies are continuing to invest in semiconductor capacity to preserve their market share position in memories, although the strength of the yen during the middle of the year temporarily put a lid on spending enthusiasm. Japan as a region kept pace with the world in investment in 1994 but lagged the market in 1995 as Japanese companies invested more outside Japan. Healthy, but subdued, growth of 47 percent in spending within Japan occurred during 1995—about 34 percent on a yen basis. Lagging investment patterns in Japan are expected to continue throughout the decade. Japanese companies, however, grew spending during 1995 at about 61 percent worldwide, for a total of $12.2 billion, second only to North American companies' spending of $13.6 billion and well ahead of Asian companies' $9.1 billion.

Dataquest has been bullish on the prospects in Europe, and remained so in 1995, although the region came in slightly under expected spending. European companies are a large part of this expansion, aided by strong domestic economies, and major projects by the multinational manufacturers are also contributing. We still see Europe as a significant growth region for spending through the decade.

Following very strong capital investment growth of 77 percent in 1994, the Asia/Pacific-Rest of World (ROW) region grew an astronomical 104 percent in 1995, as Korean DRAM expansion accelerated (further), foundry expansion in Taiwan, Singapore, and others continued to grow, and new DRAM players entered the scene in Taiwan. These new projects started in 1995 will continue to consume capital funds in 1996. We are expecting about 31 percent growth in 1996. Asia/Pacific-ROW will continue to be one of the fastest-growing regions through this decade.

Dataquest believes that the relatively large capacity expansion of 1993 to 1995 (three-year growth of 265 percent) has now exceeded the three-year growth recorded in the 1987-to-1989 expansion. It should be noted, however, that the two periods are different in two key respects. First, the current period is experiencing accelerated long-term growth for the underlying semiconductor industry, driven by a productivity-related PC boom. The PC boom is expected to continue, so we are not overly alarmed about the magnitude of this cycle. Second, the manufacturing infrastructure is more efficient today, and there is a diminishing return in productivity and yield improvements. This has led to a higher natural capital investment ratio required today than in the 1987-to-1989 period, closer to 22 percent of revenue, on average, being a standard (versus 18 percent in the late 1980s).

However, we also believe that, in 1996, spending will decelerate, starting in the second half of the year, causing a relatively flat spending pattern through 1997 and 1998. Although we continue to believe that the cyclical nature of investment in semiconductor capacity will diminish, the PC boom must continue to drive the underlying semiconductor growth strongly enough to dampen the memory component of the cycle. After a flat two-year period, investments should pick up again in 1999.

Wafer fab equipment spending grew 66 percent in 1995 and is expected to grow 36 percent worldwide in 1996, driven by massive spending in the Asia/Pacific region and strong investments in the United States. DRAM-sensitive Japanese investment and an expanding European production base complete the strong picture for 1996. Segment growth in 1994 and 1995 is being led by DRAM or capital spending-sensitive equipment, with steppers, implant, wafer inspection, and factory automation exhibiting significantly stronger-than-market growth. New technology segments, such as chemical mechanical polishing (CMP), high-voltage implant, and rapid thermal processing (RTP) were the fastest-growing segments. We expect no major segment declines in 1996, as capacity additions are broad-based and worldwide. Record backlog levels going into 1996 will be a buffer against a market decline in 1997, but we do expect softness from the DRAM companies to become evident by the end of 1996.

After strong expansion years from 1993 through 1996, equipment purchases in 1997 should decline markedly, followed by a slight decline in 1998. Investment in DRAM capacity will be curtailed as producers elect to convert their 4Mb DRAM capacity to 16Mb, which adds bit capacity through the instant increase in bits per square inch. Also, many Japanese DRAM facilities now running 150mm wafers will convert to 200mm wafers, further delaying the need for new equipment. DRAM-sensitive equipment technologies or capital-intensive segments such as steppers, implantation, diffusion, and polysilicon etch will be affected more than logic-sensitive technologies such as sputtering, epitaxial reactors, CMP, RTP, nontube chemical vapor deposition (CVD), or metal etch. The next expansion should begin by 1999, driven by 0.35-micron to 0.4-micron capacity expansion.

We have factored in an infrastructure investment in equipment for late 1997 through 1999, which will affect the forecast size of the markets positively. This additional investment will be for initial equipment to fill a couple of 300mm fabs for running silicon by 1999. However, we believe that a significant 300mm equipment market will wait until well after 2000.

Yield enhancement is the trend of the time. Any system technology that can be priced relatively low and that has a direct impact on yield will gain immediate acceptance in volume. Areas emerging today as particularly important are in cleaning technology, photostabilizers, and process control metrology.

The silicon wafer market, driven by a stronger long-term picture for semiconductors in general, will grow faster over the next six years than in the recent past. As the industry moves to a 200mm baseline, the outlook for silicon wafer manufacturers becomes brighter. The current sellers' market in silicon, which we expect to last for several years, will enable the industry to become healthy—a necessity for the semiconductor industry. Silicon manufacturers have answered the call for 200mm capacity, and the semiconductor market has again responded with a cry for more. We believe that the ramp plans of silicon manufacturers in 200mm have been strategically and smartly measured because the memory of the overcapacity of 1985 is still fresh. While there will be activity with 300mm wafers, this is expected to be focused on R&D and of low volume until after the turn of the decade.

Dataquest Perspective

Our forecast for capital spending and wafer fab equipment sales during the next six years assumes that the explosive growth of 1995 will carry over into 1996. These sales are being driven by the PC market, with telecommunications and networking spurring demand for semiconductor chips across a broad spectrum—and with continued tight capacity is convincing companies to expand. Our outlook for the future includes moderated growth in equipment spending in 1997 and a slight decline in 1998 before a resumption of double-digit growth in 1999.

The semiconductor industry is a global manufacturing business. Production of semiconductors is constantly shifting among regions as new capital flows toward areas of relatively lower capital cost and higher consumption growth. Where the PC goes, so go semiconductors. This is true from the perspective of the business forecast as well as the production line. Europe and Asia/Pacific, with very large capital spending upticks over the last several years, will continue to gain share in world production over the next few years.

The shifts and currents in semiconductor production trends mean that equipment and material suppliers will absolutely need a global presence, in every sense of the word, to remain competitive in the market. Product supply and support can no longer concentrate on local trends, because all major semiconductor companies have made it clear that they are investing worldwide. Silicon plants are now being strategically placed, such as Shinetsu Handotai's (SEH's) Malaysia plant and its recently announced joint venture in Taiwan, Komatsu's joint venture with Formosa Plastics in Taiwan, and MEMC Electronic Materials' joint ventures in both Korea (Posco-Hüls) and Taiwan (Taisil).

Taiwan is clearly the new major production growth area. We would expect Malaysia and Thailand to be the next major growth countries in three to five years. Evidence of this includes recent joint-venture fab announcements by Texas Instruments and others.

Further, the concept of contract manufacturing in semiconductors is clearly here to stay. Equipment and material suppliers could find themselves selling their technical products to an international team from several companies, including the manufacturer and the designer.

However, the emergence of the dedicated foundry company, taking ownership of the process and manufacturing flow, will tend to centralize this activity. Dataquest has started a research program in Semiconductor Contract Manufacturing, with a major report expected to be released by the end of January 1996. This report will explore the key trends in contract manufacturing and foundries, including technology trends and supply/demand balance through the decade.

Chapter 2
Semiconductor Capital Spending Forecast

This chapter presents data on worldwide semiconductor capital spending by region. Capital spending in a region includes spending by all semiconductor producers with plants in that region. Components of capital spending are property, plant, and equipment expenditure for front- and back-end semiconductor operations.

Chapter Highlights

This chapter will discuss the following highlights:

- On the heels of booming growth in 1994, global semiconductor capital spending grew another 72 percent during 1995 to $38 billion. Anticipated continued tight capacity and a strong semiconductor market in 1995 mean continued growth into 1996, now forecast at about 30 percent.
- North America is showing consistent strength, with a 69 percent growth in 1995. Worldwide demand for desktop connectivity products and telecommunications equipment continues to fuel the investment strategies in U.S.-manufactured semiconductor products, heavily weighted toward logic and ASIC capacity. North American capital spending is expected to remain strong in 1996 and to moderate in 1997 as these investments are absorbed, but we expect the North American region to grow at faster-than-market rates as foreign multinationals and foundry companies invest in capacity in the United States.
- Japanese companies are continuing to invest in semiconductor capacity to preserve their market share position in memories, although the strength of the yen during the middle of the year temporarily put a lid on spending enthusiasm. Japan as a region kept pace with the world in investment in 1994 but lagged the market in 1995 as Japanese companies invested more outside Japan. Healthy, but subdued, growth of 47 percent in spending within Japan occurred during 1995—about 34 percent on a yen basis. Lagging investment patterns in Japan are expected to continue throughout the decade.
- Japanese companies, however, grew spending during 1995 at about 61 percent worldwide, for a total of $12.2 billion, second only to North American companies' spending of $13.6 billion and well ahead of Asian companies' $9.1 billion.
- Dataquest has been bullish on the prospects in Europe, and remained so in 1995, although the region came in slightly under expected spending. European companies are a large part of this expansion, aided by strong domestic economies, and major projects by the multinational manufacturers are also contributing. We still see Europe as a significant growth region for spending through the decade.
- Following very strong capital investment growth of 77 percent in 1994, the Asia/Pacific-Rest of World (ROW) region grew an astronomical 104 percent in 1995, as Korean DRAM expansion accelerated (further), foundry expansion in Taiwan, Singapore, and others continued to grow, and new DRAM players entered the scene in Taiwan (Powerchip

Semiconductor, Vanguard, and Nan Ya Technology). These new projects started in 1995 will continue to consume capital funds in 1996. We are expecting about 31 percent growth in 1996. Asia/Pacific-ROW will continue to be one of the fastest-growing regions through this decade.

- Earlier this year, we stated that Asia/Pacific would actually exceed North American spending in this decade. During 1995, Asia/Pacific did surpass Japan, becoming the second-largest region for capital investment. However, we believe a renewed interest in setting up capacity in the United States, particularly by Asian companies, coupled with the low cost of capital will keep North American spending slightly ahead of Asia/Pacific spending through this decade. Eventually, as more countries join the semiconductor manufacturing "club" (such as Malaysia and Thailand), Asia/Pacific will become the top region in investment.

Capital Spending Tables

A list of the projected top 20 semiconductor capital spending companies in 1995 is presented in Table 2-1. Capital spending details by region are provided in two tables in this chapter: Table 2-2 shows historical semiconductor capital spending by region for 1987 through 1994, and Table 2-3 shows the capital spending forecast by region for 1994 through 2000. Yearly exchange rate variations can have a significant effect on the interpretation of the 1987-through-1995 data. For more information about the exchange rates used and their effects, see Appendix B.

And the Spending Binge Continues ...

After a three-year rest, the growth cycle began again in a big way in 1993. After a 23 percent growth in semiconductor capital spending in 1993, acceleration growth of 54 percent followed in 1994, and growth now peaks with a 72 percent increase worldwide during 1995, based on our most recent capital spending survey.

The continued growth in PC unit sales, with increased growth in telecommunications and networking products, has created tremendous demand for a variety of semiconductor components. The wafer fab capacity crunch has continued into all regions and most semiconductor products, most notably DRAMs and advanced ASICs. The capacity shortage has given rise to sharp acceleration in capital spending in all areas, with the strongest growth occurring in DRAM expansion in Asia/Pacific and Japan.

The big three Korean companies increased spending an unbelievable 124 percent to a combined total of $5.6 billion in 1995. A mostly new crowd of Taiwanese companies is now entering the DRAM manufacturing business, spending over $1 billion collectively in 1995. Japanese suppliers of memory are increasing investment, as well, for a collective increase of nearly 61 percent, to $12.2 billion, a larger dollar increase than the Korean companies. Intel and Motorola still head the list for 1995 as microprocessor and microcontroller demand continues to be strong. Equipping new and acquired facilities (in the case of Motorola) will continue to drive spending for these companies. The big three Korean companies, with their increase in DRAM capacity spending, now occupy the No. 3, No. 5, and No. 9 spots, and fully 13 companies are now part of the $1 billion spending club, with five near or over $2 billion. NEC, Fujitsu, Hitachi, Toshiba, and IBM

Table 2-1
Semiconductor Capital Spending—Top 20 Spenders, Comparison of 1994 and Projected 1995 Worldwide Capital Spending (Millions of U.S. Dollars)

1995 Rank	1994 Rank	Company	Projected 1995	1994	Change (%)
1	1	Intel	3,538.0	2,419.0	46.3
2	2	Motorola	2,375.0	1,640.0	44.8
3	9	LG Semicon	2,125.0	800.0	165.6
4	3	NEC	2,028.7	1,117.3	81.6
5	5	Samsung	1,975.0	1,000.0	97.5
6	6	Hitachi	1,719.7	969.9	77.3
7	4	Fujitsu	1,606.8	1,072.6	49.8
8	7	Toshiba	1,558.5	933.1	67.0
9	11	Hyundai	1,500.0	700.0	114.3
10	14	IBM Microelectronics	1,200.0	525.0	128.6
11	12	Mitsubishi	1,128.5	675.3	67.1
12	8	Texas Instruments	1,100.0	825.0	33.3
13	16	Siemens AG	1,060.0	410.0	158.5
14	18	Micron Technology	960.0	387.0	148.1
15	15	Matsushita	854.5	513.2	66.5
16	10	SGS-Thomson	850.0	780.0	9.0
17	19	Philips	750.0	385.0	94.8
18	13	Advanced Micro Devices	745.0	625.0	19.2
19	20	Sanyo	672.6	356.1	88.9
20	23	National Semiconductor	597.0	325.0	83.7
		Total Top 20 Companies	28,344.3	16,458.5	72.2
		Total Worldwide Capital Spending	37,993.8	22,036.5	72.4
		Top 20 Companies Percentage of Total	74.6	74.7	

Source: Dataquest (December 1995)

Table 2-2
Worldwide Capital Spending by Region — Historical, Includes Merchant and Captive Semiconductor Companies (Millions of U.S. Dollars)

	1987	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1994
North America	2,622	3,349	3,794	4,217	3,895	4,135	4,943	7,182	13.6
Growth (%)	25.9	27.7	13.3	11.1	-7.6	6.2	19.5	45.3	
Japan	2,458	4,495	5,360	5,596	5,702	3,958	4,413	6,654	4.4
Growth (%)	33.2	82.9	19.2	4.4	1.9	-30.6	11.5	50.8	
Japan (Billions of Yen)	356	584	740	806	768	500	491	677	-1.8
Growth (%)	15.4	64.0	26.7	8.9	-4.7	-34.9	-1.9	38.0	
Europe	885	960	1,186	1,560	1,248	1,188	1,729	2,481	15.9
Growth (%)	15.7	8.5	23.5	31.5	-20.0	-4.8	45.5	43.5	
Asia/Pacific-ROW	540	1,033	1,865	1,542	2,300	2,318	3,238	5,720	25.1
Growth (%)	23.6	91.3	80.5	-17.3	49.2	0.8	39.7	76.7	
Worldwide	6,505	9,837	12,205	12,915	13,145	11,599	14,323	22,037	12.5
Growth (%)	26.8	51.2	24.1	5.8	1.8	-11.8	23.5	53.9	

Source: Dataquest (December 1995)

Table 2-3
Worldwide Capital Spending by Region — Forecast, 1994-2000, Includes Merchant and Captive Semiconductor Companies (Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
North America	7,182	12,169	16,579	18,021	17,954	20,645	25,722	23.7
Growth (%)	45.3	69.4	36.2	8.7	-0.4	15.0	24.6	
Japan	6,654	9,777	12,102	11,766	11,320	12,542	15,986	15.7
Growth (%)	50.8	46.9	23.8	-2.8	-3.8	10.8	27.5	
Japan (Billions of Yen)	677	910	1,192	1,159	1,115	1,236	1,575	15.1
Growth (%)	38.0	34.3	31.1	-2.8	-3.8	10.8	27.5	
Europe	2,481	4,384	5,293	5,521	5,240	5,968	7,402	20.0
Growth (%)	43.5	76.7	20.7	4.3	-5.1	13.9	24.0	
Asia/Pacific-ROW	5,720	11,665	15,308	15,458	14,927	15,623	20,361	23.6
Growth (%)	76.7	103.9	31.2	1.0	-3.4	4.7	30.3	
Worldwide	22,037	37,994	49,281	50,765	49,441	54,778	69,472	21.1
Growth (%)	53.9	72.4	29.7	3.0	-2.6	10.8	26.8	

Source: Dataquest (December 1995)

Microelectronics all make this top 10, as the memory capacity keeps rolling in. In fact, the top spenders from No. 3 through No. 15 are all heavily concentrated in DRAM spending. With the general health of the industry, smaller semiconductor companies in all regions are participating in the capital spending boom in 1995, keeping the concentration of capital spending by the top 20 flat at 75 percent.

Taiwan Semiconductor Manufacturing Co. (TSMC) is on the cusp of debuting on the top 20 list for 1995 with an estimated $585 million spent on capacity. Foundry capacity expansion has now evolved into a major trend. In fact, foundry spending in Asia/Pacific will more than double in 1995 to an estimated $1.8 billion. This industry has been transformed into a dedicated, bona fide business and is no longer a specialized way to use excess capacity.

When Will the Spending Boom End?

Our longer-term forecast projects that significant growth in capital spending will spill into 1996 from sheer momentum, with a moderated growth of 30 percent, concentrated toward filling new fabs with equipment. Thirty new 200mm fabs are planned to come on line in 1996, as well as nine 150mm and smaller fabs, for a total of 39. This compares with a total of 30 for 1995 (18 of which are 200mm). Dataquest believes that, as the end of 1996 approaches, capital spending will begin to decelerate as the capacity additions of 1994 through 1996 are ramped. From what we can see, there is plenty of equipment that could be brought to bear on 16Mb DRAM capacity by the end of 1996 and to be on line to answer demand through 1997.

Overall semiconductor product demand is expected to remain strong through 1996, with long-term sustained growth through 2000 at a compound annual growth rate (CAGR) of 20.1 percent (see Chapter 5). We expect that microcomponent capacity will continue to ramp through 1997 before pausing in 1998, with the next major investment cycle picking up in 1999. Our model does not currently include significantly more 16Mb DRAM capacity expansion (over capacity being put in place in 1995 and 1996) until 1999. In the two "pause" years of 1997 and 1998, we believe DRAM manufacturers will concentrate on converting capacity from 4Mb toward 16Mb, which increases bits per square inch processed, and then concentrate on shrinks to squeeze out value per square inch before a capital cycle starts again. Further, in Japan, we expect that many 4Mb/16Mb fabs now running 150mm wafers will convert to 200mm wafers, further gaining efficiency and productivity from the capital investment made.

Through 2000, we project a five-year worldwide capital spending CAGR of 21.1 percent, slightly ahead of semiconductor consumption growth. We believe that capital spending may be influenced positively in 1997 and 1998 with facility construction and purchase of equipment for the world's first 300mm wafer fab. We have included this infrastructure investment in our model.

Over a year ago, we introduced a model that quantifies the over- and underinvestment picture for wafer fab equipment and semiconductor capacity. Although activity of the last several years has created and sustained a net underinvestment, not fully corrected to overinvestment in 1994, we expect about a 35 percent overinvestment by the end of 1996 (see Chapter 3 and Figures 3-1 and 3-2).

Is There Excessive Spending and Impending Doom?

With capital spending as a percentage of semiconductor revenue likely to exceed 25 percent in 1996, one question is being asked often. Does this spending level point to impending danger for equipment suppliers and a spending crash? We think not.

The industry normally cycles through over- and undercapacity, because there is an inherent lag time between capital investment decisions and productive capacity. This cycle will never disappear. But the levels of spending we are experiencing today have not been seen since 1984, and many people are pointing to the 1985 downturn as an example of what is imminent today.

We think the industry is structured differently today and that there is a valid reason why investment as a percentage of revenue is increasing.

We would split the market into four periods: before 1985, 1985 to 1992, 1993 to 2001(?), and 2002 and after. Let's describe the conditions and trends in the production market and manufacturing infrastructure during these periods.

Before 1985: An Immature Manufacturing Industry

Characteristics of this period are:

- The semiconductor manufacturing infrastructure was fairly immature, characterized by large integrated systems companies, mostly in the United States.
- Manufacturing technology was favored over efficient use of capital, and device performance was favored over yield.
- Capital equipment manufacturers did not assume complete ownership of processes and system performance.
- All of these led to a capital-spending ratio between 26 percent and 30 percent of revenue.

Two things happened that changed the structure. First, the semiconductor downturn in 1985 ended up being extremely bloody. Second, Japanese producers emerged that introduced an element of true manufacturing efficiency into the infrastructure.

1985 Through 1992: Becoming Manufacturing Smart

The Japanese manufacturing ethic and the losses incurred during the 1985 downturn introduced the need for the industry to become more efficient in the manufacturing infrastructure. The following things happened:

- Manufacturing productivity and yield became a focus.
- SEMATECH was formed, in part as a result of the need to coordinate this effort in the United States.
- Equipment companies were expected to take ownership of the process and system performance parameters, and they accepted.
- Equipment performance and productivity increased substantially.

- Fab factory automation migrated from robotics to computer-controlled systems, and statistical process control became commonplace.
- The emergence of Korean companies' manufacturing power provided momentum for this transition.

By 1992, manufacturers had increased yields and fab productivity was up dramatically. During this period, it was natural for the industry to have to spend less on capital equipment, since the return per dollar spent was very high. Capital spending decreased to an artificially low 18 percent of revenue, on average.

Once yields achieved high levels and system productivity approached the point at which it was impractical to continue (to do so would have meant decreased equipment utilization because throughput could exceed practical run rates), the return from these activities diminished. The industry then entered the next period.

1993 through 2001: Growth

Once the industry had built an efficient manufacturing infrastructure, it became ready for the emergence of the semiconductor as the enabling technology in many electronic systems. The industry entered into an era of prosperity. Semiconductors have become the productivity engine for the world's business, implementing communications systems and the power of the PC to improve worker efficiency. We are experiencing the following characteristics:

- Unit growth in semiconductors has required manufacturers to invest in capacity for growth.
- Profitability has attracted new entrants with a focus on manufacturing.
- Dedicated contract manufacturing has emerged as a new manufacturing model for the industry, made possible by equipment efficiencies and the need to separate manufacturing from device innovation.

When the industry reached a point of diminishing returns from yield and equipment productivity, the capital spending ratio could no longer be maintained at artificially low levels. We believe that the current equilibrium level is about 22 percent of semiconductor revenue.

Further, fueled by the growth in the device market, the current boom has been unprecedented in the industry in terms of length and levels of growth in capital spending. This has resulted from the industry's adjustment to a new, higher spending level and the increased unit demand.

Beyond 2001: Maturing Manufacturing Infrastructure

We believe that the emergence of dedicated contract manufacturing means that the industry's manufacturing infrastructure will evolve to a point at which the foundry becomes an integral part of the manufacturing environment, as been the case with electronic equipment in general (Solectron is an example).

The business model of the foundry requires high equipment utilization, and we expect that, in the next five years, this will influence capital efficiency and decrease the capital spending ratio to perhaps 20 percent or

21 percent of revenue. This will not become evident until contract manufacturing increases in scope above the estimated 9 percent of semiconductor production today, to levels that could approach 35 percent to 45 percent by the year 2010.

The North American Market Continues to Exhibit Strategic Strength

Capital spending in North America grew at an accelerated 69 percent in 1995, with most of the investment growth coming from U.S. companies connected with ASIC and logic products. We expect capital spending to decelerate gradually through 1998, with acceleration resuming in 1999, resulting in a CAGR of 23.7 percent for 1994 through 2000. This is among the fastest-growing regions for investment, driven by recent low cost of capital and the need for foreign multinational and foundry manufacturers to be closer to their customers.

This relatively strong growth in capital spending has been driven by growth in PCs, telecommunications, and networking. These products have seen increasing use as tools to increase productivity in the workplace. These electronic products, with their increased semiconductor content, have created enormous demand for microprocessors, microcontrollers, SRAM, programmable logic and memory, standard logic, and peripherals controllers. U.S. companies dominate many of these market segments. These segments combined are expected to maintain fairly stable growth rates over the next few years, with PC growth slowing (but still maintaining a CAGR of 17 percent) and networking and telecommunications expanding. The near-term market for PCs has reaccelerated from Intel's new, aggressive Pentium pricing strategy, which has hastened the conversion to the Pentium.

New products and services such as personal communicators, interactive television, and video-on-demand provide the potential for enormous growth in semiconductor sales, especially for the highly integrated complex logic and signal processing chips that will be the core engines of future systems.

Although the strategic strength of the core logic products makes for a healthy and flourishing semiconductor production environment, it also means less volatility in capital spending. In the boom years of 1994 and 1995, the North American region grew at somewhat lower-than-market rates. This will enable the North American capital spending to grow at faster-than-market rates in slower years like 1997 and 1998. We believe companies will invest strategically in capacity to preserve competitive advantage, and cutbacks are more likely to occur in the smaller companies rather than the first-tier manufacturers.

Capital investments in North America for 1995 came from equipping new fabs by both the majors and smaller companies. The major projects include Intel's Fab 11.2 in New Mexico and expected orders for Fab 12 in Arizona, Advanced Micro Devices' (AMD) Fab 25 in Austin, Texas, Motorola's MOS-13 in Texas and the continued ramp of MOS-12 in Arizona, Cypress' Fab 4 in Minnesota, SGS-Thomson's new Arizona facility, IBM's expansion in Burlington, Vermont (yes, IBM is back), and purchases for Texas Instruments' DMOS-5 fab in Dallas, Texas. Smaller companies are also spurring growth this year, with Integrated Device Technology, VLSI Technology, Zilog, Atmel, International Rectifier, American Microsystems Inc. (AMI), and National Semiconductor all bringing on new capacity. In 1996, equipment installation into these fabs will continue, plus 10 new fabs under construction, such as those of Sony and VLSI Technology in San Antonio, Texas, TwinStar in Texas, and Motorola's MOS-21 in Arizona. Samsung has stated its intention of investing $1 billion to build a fab in the United States. We have factored this and other foreign company fabs, such as TSMC's joint venture foundry and Toshiba's fab with IBM, into our 1997 to 1998 forecast.

Japan: DRAM Capacity Additions Drive Spending, but a Strong Yen Subdues

Japan's 47 percent increase in capital spending in 1995 is only a 34 percent increase on a yen basis, and Japanese companies look to invest outside Japan to optimize buying power. We are forecasting a subdued 24 percent growth in capital spending for 1996, factoring in a slight decline in 1997 as the mission will have been accomplished in DRAMs in the near term.

Some of the Japanese electronics giants are experiencing good profit growth, driven by semiconductor operations. The demand for world memory capacity presented an opportunity to increase profits from semiconductors. Investments by Japanese companies grew by nearly 61 percent in 1995, with an increased amount going overseas. However, as long as the Japanese economy is under pressure, Japanese companies will feel a "patriotic" dedication to invest in Japan, and we see no company spending more than 35 percent of committed investment outside Japan. With the strength of the yen, multinationals are reducing their investment proportion inside Japan as well.

Although new facilities by Japanese companies will come on line outside Japan throughout the rest of this decade, DRAM investments inside Japan are really the only driving force today. Beyond 1995, investment increases in Japan will need to come from growing the domestic economy. Dataquest believes an economic recovery in Japan started in 1994, but with slow acceleration. The degree at which companies will invest will be affected by the strength of this recovery. We are forecasting a below-average CAGR of 15.7 percent in Japan for 1994 through 2000.

One bright spot is that a PC boom could emerge in Japan over the next year or two, spawned by the networking infrastructure that is currently being built. This would breathe new life in the Japanese semiconductor market, and our forecast would brighten a bit. We do not think that even a PC boom, however, would create a forecast better than several percentage points below the world average. The fundamentals of Japanese production capacity are still too heavily concentrated in DRAMs, with no clear future direction emerging yet, which keeps us from being more optimistic about capital activities in Japan.

Europe Sustains Presence as a Growth Market

After a higher-than-expected growth bubble of 46 percent in 1993, European spending "moderated" to a slower-than-market growth in 1994 as multinationals (such as Intel) substantially completed the majority of their expansions in 1993. The growth of 43 percent in 1994 is nonetheless extremely healthy, fueled primarily by European companies themselves—the ever-present SGS-Thomson, Philips expanding in Nijmegen, Netherlands, and Ericsson equipping its expansion.

Europe continues to attract the capital in 1995, growing an impressive 76 percent. Large multinationals are still present, with Motorola upgrading the Scotland fab bought from Digital, the new IBM-Philips venture in Germany, Analog Devices expanding in Ireland, Texas Instruments expanding again in Italy, and the IBM-Siemens fab in France continuing to ramp 16Mb DRAMs. The key expansion is Siemens' new fab in Dresden, Germany, the key driver pulling Siemens into the top 10 in capital spending worldwide. The continued commitment of NEC and other Japanese companies to Europe has been the most recent boost to investment momentum, focused on land and facilities in 1995, bringing the growth in capital spending significantly above the growth in wafer fab equipment. We are looking for continued growth in 1996 of 21 percent as production continues to ramp from these investments and eight new fabs, most notably by GEC-Plessey, NEC, and Temic.

Europe is to be viewed as a strategic location for production to take better advantage of European and 16Mb DRAM growth in the future, driven by the PC production boom (see Chapter 6), while avoiding import tariffs. Samsung has announced a fab to come on line in Europe during 1998, but is still undecided about the exact location.

With a stronger multinational presence starting again in 1995 as economies pick up and with recent trends for PC production and foundry providers (such as Newport WaferFab and Tower Semiconductor), we now expect Europe to be an average investment region in the long term, with a six-year CAGR of 20 percent.

Asia/Pacific Is Madly Investing in Two Distinct Ways

The often-erratic but sustained semiconductor capital spending growth in the Asia/Pacific region continued at the explosive rate of 77 percent in 1994. And those who thought this market could not accelerate from that level should think again—for 1995 is the year in which the Asia/Pacific region became the second-largest expansion region in the world, surpassing Japan in terms of dollars spent (that is, spending within the region, not by companies based in Asia). The region saw 104 percent growth in 1995, and we expect moderated growth of about 31 percent in 1996 as several new fab projects continue to be built and equipped and the number of new projects grows. Longer term, we expect Asia/Pacific's growth in capital spending to be among the most aggressive of any region. Dataquest forecasts a CAGR of 23.6 percent for 1994 through 2000.

Spending in 1995 is focused primarily in two areas: DRAMs and foundry capacity. The Korean conglomerates plan to continue their relentless

DRAM capacity expansion in 1995. Hyundai is installing equipment for its new E-3 project, the third phase of a 200mm wafer, 16Mb DRAM fab started in 1992. LG Semicon (formerly Goldstar) is expanding its equivalent C2 line, in accordance with its agreement with Hitachi for the 16Mb DRAM ramps. LG Semicon is also bringing online the G-FAB for non-DRAM memory products. Samsung is continuing to spend, ramping Line 6, also a 200mm, 16Mb DRAM facility.

The real story in 1995 is the new Taiwan players. Vanguard International will be bringing on its new DRAM fab later this year, and Powerchip and Nan Ya have broken ground on DRAM fabs coming online in 1996. All of these are targeted at 16Mb DRAM running 200mm wafers. Current players such as TI/Acer and MOSel-Vitelic are also increasing their spending with new projects.

Taiwan chip companies TSMC, Macronix, Winbond, and United Microelectronics Corporation (UMC), along with Chartered Semiconductor in Singapore, have undertaken major projects in expanding foundry capacity, and a new foundry player has emerged in Thailand—SubMicron Technology. SubMicron has received funding of $1.6 billion for two separate fab lines, the first to come on line in 1996. Funding has also been allocated to establish a technology park in or near Bangkok, similar to Hsinchu in Taiwan. We have seen the start of this Bangkok park become reality as a new joint venture that includes Texas Instruments has just announced commitments for a new fab there. The combined spending of these companies for foundry (which excludes spending associated with their own products in the case of UMC, Macronix, and Winbond) increased from about $900 million in 1994 to about $1.8 billion in 1995, continuing at significantly higher levels into 1996 and 1997. The driving reason is the changing face of contract manufacturing in semiconductors. Gone are the days where excess fab capacity could support the foundry business of fabless companies (as well as integrated device manufacturers, or IDMs—companies with fabs).

Dataquest estimates that only about 32 percent of the contracted manufacturing of semiconductors originates from fabless companies. The remainder is from IDMs that wish to place lower manufacturing-value-added products away from their own facilities in order to maximize resources and cost, to reduce investment risks using foundries as an extension of their own capacity, or to use the more advanced technology of some foundries as a growth strategy. The last few years have seen the dedicated foundry flourish, mostly in Asia/Pacific. It is still believed that the largest concentration of foundry capacity in the world, however, is in Japan, with companies like Rohm, Seiko-Epson, Sharp, and other large integrated companies.

However, the appetite for leading-edge foundries has caused another transformation to occur. With the cost of capital increasing and investment at a higher level for leading-edge equipment, foundry companies such as Chartered have established longer-term contracts with design companies, often with capital infusions for production equipment. Many joint ventures have been announced in the last several months, and we expect this trend to continue throughout 1996.

The foundry industry is now a strategic industry rather than simply a tactical one. With this transformation nearly complete, we are starting to see dedicated investment to build new foundry capacity.

In addition to the established semiconductor-producing countries, huge long-term opportunities exist in developing countries like China and the Unified States (formerly the Soviet Union). Ultimate demand for semiconductor products in those countries could approach demand in super-consumer countries like the United States and Japan. China, in particular, generates a gross domestic product comparable to that of Japan, if evaluated on the basis of purchasing power parity. U.S., European, and Japanese telecommunications companies are working with the Chinese government to install telephone exchange equipment and digital lines.

Several hurdles must be overcome before either China or Russia becomes a viable market for advanced front-end semiconductor manufacturing. Technology export restrictions must be eased to allow the construction of relatively advanced fabrication facilities. Foreign suppliers must establish local sales and service centers and define their market access. Financing capability must be established by the host countries. Solidification of international trade relationships through participation in the General Agreement on Tariffs and Trade (GATT) must also be established. China's internal political structure poses a potential barrier to maintaining its status as a most favored nation with the United States. It will likely take a few years to sort out these issues. Dataquest assumes that semiconductor investment in China could begin to expand in 1997 (NEC is leading the investment charge today), accelerating into the later half of the decade.

Dataquest believes that the next countries to experience huge front-end semiconductor production growth will be Malaysia and Thailand. The latter's plans for a new science park we have already mentioned, and a new fab has been announced in Malaysia (Sarawak), financed by a group of investors, to start production in 1997.

Who's Investing Where?

Dataquest's recent capital spending survey shows how money is being spent. Table 2-4 summarizes how companies based in different regions are spending their money abroad for 1994, and Table 2-5 summarizes this for 1995. About 78 percent of money spent goes into the domestic economy worldwide, a ratio that held steady for 1994 and 1995.

Asia/Pacific companies have historically invested domestically, but diversification began in 1994 and continued in 1995. About 96 percent of Asia/Pacific companies' spending was domestic in 1994, and this proportion held steady in 1995. We would expect this ratio to decrease significantly over the next two or three years. Europeans have been the most aggressive capital exporters, historically, making only 63 percent of their investments within Europe. This figure has grown slightly to 64 percent in 1995 and should expand in 1996 as the domestic economies have resurged.

Japanese companies are very close to the worldwide average, with about 80 percent domestic investment in 1994, dropping to 75 percent in 1995.

Table 2-4
Regional Investment Patterns of Semiconductor Manufacturers in 1994
(Millions of U.S. Dollars)

	Worldwide	North America	Japan	Europe	Asia/ Pacific-ROW	Percentage of World Spending
North American Companies	8,628.3	6,223.7	566.3	957.4	880.9	39.2
Japanese Companies	7,587.4	545.7	6,087.5	311.5	643.7	34.4
European Companies	1,866.0	277.6	0.4	1,182.7	405.3	8.5
Asia/Pacific-ROW Companies	3,954.7	135.0	0	30.0	3,789.7	17.9
All Companies	22,036.5	7,182.0	6,654.3	2,481.5	5,719.6	100.0
Growth from 1993 (%)	53.8	45.3	50.8	43.5	76.6	

Source: Dataquest (January 1996)

Table 2-5
Regional Investment Patterns of Semiconductor Manufacturers in 1995
(Millions of U.S. Dollars)

	Worldwide	North America	Japan	Europe	Asia/ Pacific-ROW	Percentage of World Spending
North American Companies	13,616.6	9,963.6	588.4	1,525.0	1,539.6	35.8
Japanese Companies	12,194.2	1,390.7	9,187.8	835.3	780.4	32.1
European Companies	3,112.0	466.9	0.6	1,984.1	660.4	8.2
Asia/Pacific-ROW Companies	9,071.0	347.5	0	39.5	8,684.0	23.9
All Companies	37,993.8	12,168.7	9,776.8	4,383.8	11,664.5	100.0
Growth from 1993 (%)	72.4	69.4	46.9	76.7	103.9	

Source: Dataquest (January 1996)

North American companies are also domestic spenders, with about 72 and 73 percent of investment staying at home for 1994 and 1995, respectively.

The North America and Japan regions are net investors, while the Europe and Asia/Pacific regions are net beneficiaries of that investment. This parallels the status of these regions as net exporters and net importers of semiconductors, respectively.

Although all regions are spending in Asia/Pacific and all multinational regions are investing in Europe, only North American companies have the strategic vision to invest in Japan. Japanese companies are also investing on a worldwide basis. We believe this is one of the key elements necessary for a semiconductor company to be competitive on a global basis.

Dataquest Perspective

Capital spending in 1994 exploded and accelerated in 1995. The major reason for this is the surprisingly persistent growth in unit PC shipments, with the aggressiveness of Intel's Pentium pricing strategy. Major DRAM expansion accelerated in the second half of 1993 and will continue throughout 1996. From what we can see now, there is plenty of equipment that could be brought to bear on 16Mb DRAM capacity by the end of 1996 and brought on line to answer demand through 1997. A marked downturn in the DRAM investment cycle will be triggered by the 1Mbx16 configuration of the 16Mb DRAM, achieving yield in the area of 60 percent to 65 percent, which is expected to occur sometime in 1996.

Desktop connectivity products, telecommunications, and the PC market will lead to stable growth in microcomponents and logic devices, giving strategic strength to the North America region. Japanese companies will concentrate on ramping memories in order to hold their market share against Korean and Taiwanese companies. A struggling economy will keep capital investment muted once the DRAM ramp is satisfied. Globalization strategies will benefit both European and Asia/Pacific investment, with Asia/Pacific being the fastest-growing region over the next five years.

Dataquest believes that the relatively strong capacity expansion phase of 1993 to 1995 (with three-year growth of 265 percent) has now exceeded the three-year growth recorded in the 1987 to 1989 expansion. It should be noted, however, that these periods are different in two key respects. The current accelerated long-term growth for the underlying semiconductor industry is driven by a productivity-related PC boom. This PC boom is expected to continue, so we are not overly alarmed about the magnitude of this cycle. The momentum of investments will make 1996 a year of healthy growth in capital spending. Second, the manufacturing infrastructure is more efficient today, and there is a diminishing return in productivity and yield improvements. This has led to a higher natural capital investment ratio being required today than in 1987 to 1989.

However, we also believe that spending will decelerate starting in the second half of 1996, causing a somewhat flat spending pattern through 1997 and 1998. Although we continue to believe that the cyclical nature of investment in semiconductor capacity will diminish, the PC boom must continue to drive the underlying semiconductor growth strongly enough to dampen the memory component of the cycle. After a flat two-year period, investments should pick up again in 1999.

Chapter 3
Wafer Fab Equipment Forecast

This chapter presents data on worldwide spending by region for wafer fabrication equipment. Wafer fab equipment spending in a region includes spending by all semiconductor producers with plants in that region. Included are all classifications of equipment for front-end semiconductor operations.

Chapter Highlights

This chapter will discuss the following highlights:

- Wafer fab equipment spending growth in 1995 exceeded 1994, with over 66 percent growth worldwide, compared to 56 percent growth in 1994.
- The growth was driven across all regions, led by Asia/Pacific (80 percent growth). Continued investment in North America and a DRAM-sensitive Japan (68 and 61 percent growth, respectively) drove the volume for this third year of the boom. Europe, with an emphasis on land and facilities spending in 1995, "lagged" the market in consumption of wafer fab equipment (54 percent growth).
- Momentum and backlogs from 1995 and the 39 new fabs coming on line in 1996 will keep growth intact, and Dataquest is now forecasting a healthy 36 percent growth in wafer fab equipment shipments in 1996.
- Segment growth, beginning in 1994 and continuing in 1995, is being led by DRAM and capital spending-sensitive equipment, with steppers, implant, wafer inspection, and factory automation equipment exhibiting significantly stronger-than-market growth. We expect no major segment declines in 1996, as capacity additions will continue to be broad-based and worldwide.
- New equipment technologies grew exceptionally well in 1995, led by high-voltage implant, CMP, RTP, and nontube reactor CVD. The first three of these segments at least doubled, with the CVD segment growing 89 percent.
- Our model, which measures the net cumulative under- or overinvestment, indicates that, by the end of 1995, the semiconductor manufacturing world will be overinvested in wafer fab equipment by $5.8 billion, or 32.7 percent of the market. This is above the peaks exhibited in 1984 and 1989, so excess capacity should emerge by the end of 1996, probably in the DRAM market, where capacity has been added recently. This is supported by fundamental silicon square-inch area analysis completely recently.
- Capacity constraints remain in the foundry market into 1998, leading to strong logic capacity investment in 1997.
- After strong expansion years in 1993 through 1996, equipment purchases in 1997 should slow markedly, followed by a slight decline in 1998. The next expansion should kick in by 1999, driven by a 0.35-micron to 0.4-micron capacity expansion. The worldwide wafer fab equipment market is forecast to grow at a 21.4 percent CAGR between 1994 and 2000, slightly above the semiconductor market growth.

- We have factored in an infrastructure investment in equipment for 1997 through 1999, which will affect the forecast size of the markets positively. This additional investment will be for initial equipment to fill some 300mm fabs for running silicon by 1999. The bulk of this "300mm equipment bubble" occurs in 1998. However, we believe that a significant 300mm equipment market will not be seen until 2001 or 2002.

This chapter presents historical and forecast data on the worldwide wafer fabrication equipment market, by region and by key equipment segment. In this year-end forecast for wafer fab equipment, we have chosen to focus our forecast of equipment categories on the following specific segments and issues:

- The annual investment theme for 1995 to 2000
- Steppers and automatic photoresist processing equipment (track) in lithography
- Dry etch and CMP in etch and clean
- Silicon epitaxy, CVD, and physical vapor deposition (PVD) in deposition
- Diffusion and RTP
- Ion implantation (medium-current, high-current, and high-voltage)
- Segments of emerging importance

These segments of the equipment market not only represent the majority of all wafer fab equipment expenditure in the world today, but also embody the key technological capability for advanced device production. Highlights of some of the factors affecting individual equipment segment forecasts also are presented.

Equipment spending in a region refers to spending by all companies—both domestic and foreign—within the region. We note also that yearly exchange rate variations can have a significant effect on 1988-through-1995 data appearing in the tables in this chapter. Appendix B details the exchange rates used in this document.

Table 3-1 provides historical market data, by geographic region, for 1988 through 1994. Table 3-2 shows forecast market data, by geographic region, for 1994 through 2000. Table 3-3 presents historical data for key equipment segments for 1988 through 1994. Table 3-4 shows forecast data for key equipment segment for 1994 through 2000.

Table 3-1
Worldwide Wafer Fab Equipment Market, by Region—Historical, 1988-1994
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1988-1994
North America	1,534	1,657	1,589	1,524	1,570	2,129	3,141	12.7
Change (%)	38.9	8.0	-4.1	-4.1	3.0	35.6	47.5	
Japan	2,270	2,813	2,992	3,007	2,096	2,460	3,668	8.3
Change (%)	77.8	23.9	6.4	0.5	-30.3	17.4	49.1	
Europe	662	721	764	641	634	978	1,385	13.1
Change (%)	25.9	8.9	6.0	-16.1	-1.1	54.3	41.6	
Asia/Pacific	519	820	522	843	789	1,309	2,562	30.5
Change (%)	126.6	58.0	-36.3	61.5	-6.4	65.9	95.7	
Total Wafer Fab Equipment	4,984	6,011	5,867	6,014	5,089	6,876	10,755	13.7
Change (%)	58.9	20.6	-2.4	2.5	-15.4	35.1	56.4	

Note: Some columns do not add to totals shown because of rounding.
Source: Dataquest (January 1996)

Table 3-2
Worldwide Wafer Fab Equipment Market, by Region—Forecast, 1994-2000
(Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
North America	3,141	5,262	7,512	7,969	7,855	9,281	11,723	24.5
Change (%)	47.5	67.5	42.8	6.1	-1.4	18.2	26.3	
Japan	3,668	5,901	7,094	6,445	6,082	7,073	9,055	16.3
Change (%)	49.1	60.9	20.2	-9.1	-5.6	16.3	28.0	
Europe	1,385	2,130	2,733	2,590	2,503	2,927	3,655	17.6
Change (%)	41.6	53.8	28.3	-5.3	-3.3	16.9	24.9	
Asia/Pacific	2,562	4,618	6,998	7,705	6,852	7,261	9,931	25.3
Change (%)	95.7	80.2	51.5	10.1	-11.1	6.0	36.8	
Total Wafer Fab Equipment	10,755	17,911	24,338	24,709	23,293	26,542	34,365	21.4
Change (%)	56.4	66.5	35.9	1.5	-5.7	14.0	29.5	

Note: Some columns do not add to totals shown because of rounding.
Source: Dataquest (January 1996)

Table 3-3
Wafer Fab Equipment Revenue by Equipment Segment—Historical, 1988-1994 (Millions of Dollars)

Equipment Segment	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1988-1994
Worldwide Fab Equipment	4,984	6,011	5,867	6,014	5,089	6,876	10,755	13.7
Change (%)	58.9	20.6	-2.4	2.5	-15.4	35.1	56.4	
Steppers	921	1,181	1,052	979	646	1,014	1,838	12.2
Track	253	322	317	364	353	507	711	18.8
Maskmaking Lithography	62	69	47	48	53	52	78	3.8
Other Lithography[1]	245	192	195	158	95	110	112	-12.2
Total Lithography/Track	1,481	1,764	1,612	1,549	1,147	1,683	2,739	10.8
Automated Wet Stations	144	243	268	291	286	285	519	23.8
Other Clean Process	133	134	132	143	103	198	233	9.8
Dry Etch	533	670	690	717	682	1,096	1,555	19.5
Dry Strip	100	121	118	119	123	138	202	12.4
Chemical Mechanical Polishing	NS	NS	NS	11	20	44	65	NA
Total Etch and Clean	911	1,168	1,208	1,281	1,212	1,761	2,573	18.9
Tube CVD	186	220	259	268	213	283	446	15.7
Nontube Reactor CVD	275	388	457	474	437	585	903	21.9
Sputtering	260	320	359	425	446	584	1,025	25.7
Silicon Epitaxy	86	75	68	89	84	83	100	2.7
Other Deposition[2]	165	170	153	147	119	115	101	-7.8
Total Deposition	972	1,173	1,296	1,403	1,300	1,650	2,575	17.6
Diffusion	296	332	325	326	246	342	492	8.9
RTP	22	25	33	46	36	45	80	23.6
Total Diffusion/RTP	318	357	358	372	283	388	572	10.3
Medium-Current Implant	118	131	114	108	83	108	234	12.1
High-Current Implant	241	301	250	228	164	233	391	8.4
High-Voltage Implant	18	25	7	18	16	18	29	8.1
Total Ion Implantation	377	457	370	353	263	359	654	9.6
Total Process Control[3]	608	676	605	643	544	634	1,017	8.9
Factory Automation	130	195	216	227	194	250	412	21.2
Other Equipment	187	222	202	185	146	151	213	2.2
Total FA/Other Equipment	317	417	418	412	340	401	625	12.0
Total Wafer Fab Equipment	4,984	6,011	5,867	6,014	5,089	6,876	10,755	13.7

NS = Not surveyed
NA = Not applicable
[1]Includes contact/proximity, projection aligners, direct-write, and X-ray lithography
[2]Includes evaporation, MOCVD, and MBE
[3]Includes optical CD, CD SEM, wafer inspection, thin film measurement, and other process-control equipment
Note: Some columns do not add to totals shown because of rounding.
Source: Dataquest (January 1996)

Table 3-4
Wafer Fab Equipment Revenue by Equipment Segment—Forecast, 1994-2000 (Millions of Dollars)

Equipment Segment	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
Worldwide Fab Equipment	10,755	17,911	24,337	24,709	23,293	26,542	34,365	21.4
Change (%)	56.4	66.5	35.9	1.5	-5.7	13.9	29.5	
Steppers	1,838	3,274	4,515	3,874	3,337	4,122	5,605	20.4
Track	711	1,214	1,662	1,643	1,468	1,842	2,474	23.1
Maskmaking Lithography	78	104	153	155	161	181	227	19.6
Other Lithography[1]	112	110	124	120	113	122	134	3.0
Total Lithography/Track	2,739	4,701	6,454	5,793	5,079	6,267	8,440	20.6
Automated Wet Stations	519	824	1,144	1,251	1,239	1,340	1,632	21.1
Other Clean Process	233	387	543	580	555	571	691	19.8
Dry Etch	1,555	2,507	3,339	3,527	3,422	3,769	4,811	20.7
Dry Strip	202	336	443	445	432	499	622	20.6
Chemical Mechanical Polishing	65	152	268	338	366	465	684	48.1
Total Etch and Clean	2,573	4,205	5,736	6,140	6,014	6,644	8,440	21.9
Tube CVD	446	623	803	863	814	956	1,220	18.2
Nontube Reactor CVD	903	1,703	2,371	2,584	2,511	2,800	3,653	26.2
Sputtering	1,025	1,562	2,040	2,184	2,131	2,346	2,986	19.5
Silicon Epitaxy	100	157	222	258	271	300	351	23.2
Other Deposition[2]	101	120	146	138	123	122	134	4.9
Total Deposition	2,575	4,164	5,581	6,025	5,851	6,524	8,344	21.6
Diffusion	492	674	893	975	897	1,048	1,323	17.9
RTP	80	168	260	310	364	393	471	34.5
Total Diffusion/RTP	572	842	1,154	1,286	1,260	1,441	1,794	21.0
Medium-Current Implant	234	424	535	485	397	411	543	15.1
High-Current Implant	391	670	961	880	755	823	1,168	20.0
High-Voltage Implant	29	122	178	148	146	186	258	43.7
Total Ion Implantation	654	1,216	1,674	1,513	1,298	1,420	1,969	20.2
Total Process Control[3]	1,017	1,742	2,356	2,464	2,356	2,636	3,330	21.9
Factory Automation	412	740	1,020	1,088	1,022	1,160	1,509	24.1
Other Equipment	213	300	363	400	413	451	540	16.8
Total FA/Other Equipment	625	1,040	1,382	1,488	1,435	1,611	2,048	21.9
Total Wafer Fab Equipment	10,755	17,911	24,337	24,709	23,293	26,542	34,365	21.4

[1]Includes contact/proximity, projection aligners, direct-write, and X-ray lithography
[2]Includes evaporation, MOCVD, and MBE
[3]Includes optical CD, CD SEM, wafer inspection, thin film measurement, and other process-control equipment
Note: Some columns do not add to totals shown because of rounding.
Source: Dataquest (January 1996)

Annual Investment Themes for 1994-2000

Behind our equipment and segment forecasts are assumptions about how semiconductor producers will perform and invest. These are summarized in Table 3-5 for 1995 through 2000. The following areas are considered: the availability of profits for reinvestment, memory versus logic growth, technology shifts, and brick and mortar versus equipment purchases.

Table 3-5
Annual Driving Forces and Investment Themes for Wafer Fab Equipment, 1995-2000

	1995	1996	1997	1998	1999	2000
Logic Semiconductor Unit Growth*	Solid	Solid	Moderate	Moderate	Moderate	Solid
Investment in Logic Capacity*	Solid	Solid	Solid	Moderate	Moderate to Weak	Solid
Memory Semiconductor Unit Growth*	Solid	Moderate	Weak	Moderate	Solid	Strong
Investment in Memory Capacity*	Strong	Moderate	Weak	Weak	Moderate	Strong
Front-End Equipment versus Facilities Loading of Capital	Facilities	Equipment	Balanced	Facilities	Equipment	Equipment
Primary Technologies Invested	0.35-0.6 micron	0.35-0.5 micron	0.35-0.5 micron	0.3-0.5 micron	0.25-0.4 micron	0.25-0.4 micron

*Scale: Strong > Solid > Moderate > Weak > Dead
Source: Dataquest (December 1995)

When Will Capacity Expand to Meet Demand? An Update of the Over- or Underinvestment Model

In our forecasts last year, we introduced a model that provided a measure of the net cumulative over- or underinvestment in wafer fab equipment to support capacity needs. Since equipment purchases precede actual capacity on line by a number of months or quarters, this model could be viewed as a gross "leading indicator" of capacity shortages and excesses. The results of this model are closer to a one-and-one-half-year to three-year indicator of turning points in the equipment industry. The methodology of the net cumulative investment (NCI) model is linked to our longer-range forecast model.

Our methodology starts with the following key assumptions and baselines:

- Long-term growth rates for semiconductors and wafer fab equipment are correlated. In other words, semiconductor revenue and profits are needed before money can be spent on equipment, and vice versa.
- Also, net cumulative investment equals zero over time, which means that in a noncyclical environment where annual growth rates are constant, investment and capacity are at equilibrium at all times. Of course, the semiconductor industry cycles through over- and underinvestment.

- The output is a tangible number, and is in dollars of over- or underinvestment at year-end. However, the more useful output of the model divides this gross dollar number by the wafer fab equipment market size. The result is a figure for percentage of market that is repeatable in level from cycle to cycle.
- To take into consideration the long-term growth of the semiconductor and equipment industries, the model has a factor allowing the fundamentals of the industry to change over time.

A net positive or negative investment is calculated relative to the long-term growth baseline annually and then added to the prior year. The calculation results in a dollar value *net cumulative* over- or underinvestment and has correlated well with historical patterns.

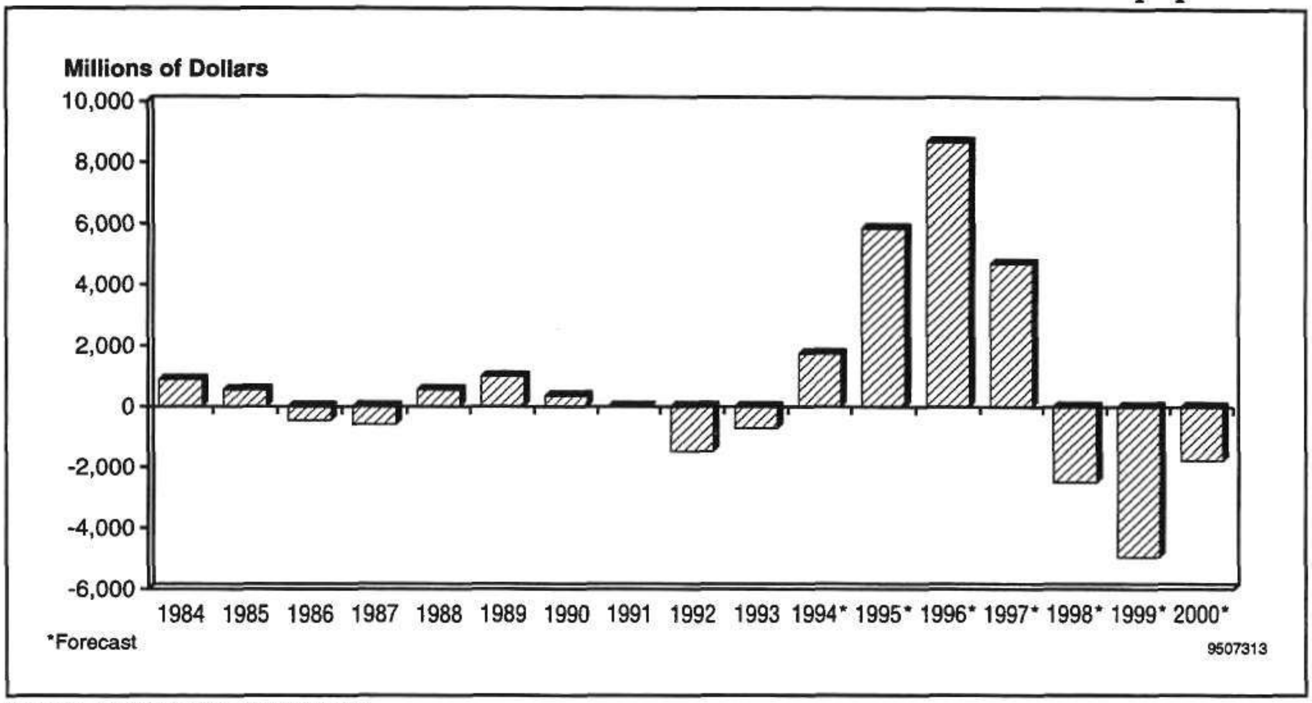
Figures 3-1 and 3-2 show the most recent results of the model, little changed from our midyear forecast update. In absolute dollar terms, by the end of 1995, the industry will be overinvested by $5.8 billion, or 32.7 percent of the wafer fab equipment market, exceeding levels witnessed during the 1984 and 1989 peaks. These levels are being driven by two basic factors. First, PC unit demand is continuing to grow annually in the high teens. About one-third of the semiconductor industry—and over one-half of the capital spending on new capacity—is geared to supporting this demand.

Second, the DRAM market has not yet converted to run the more silicon-efficient 16Mb DRAM, placing this investment cycle about seven years behind the last cycle. DRAM bit demand generally runs at 50 percent annually, and DRAM manufacturing has depended on increasing unit densities (increasing the bits per square inch) to meet this demand. Shrinks of existing generations alone bring only 15 percent to 25 percent annual bits per square inch efficiencies. Converting a fab running 4Mb DRAMs to 16Mb DRAMs would increase bits per square inch by two to three times. Since low yields are holding back the economic conversion of the market, top-line bit demand is translating to square-inch demand (silicon) and the equipment to run it. Since the equipment being installed is fully "convertible" to run 16Mb DRAMs, we can think of these fabs building "pent-up supply" in bits. Once 16Mb DRAM yields (for the 1x16 configuration) exceed 60 percent to 65 percent, it will be more economical to run these lines, and DRAM prices will erode. The current view is that this will not occur until well into 1996.

We have factored into the model an investment in a couple of 300mm fabs starting in 1997 through 1999, with the bulk in 1998. This is considered an equipment "bubble demand" because the equipment will be shipped into a nonproductive fab (so that no semiconductor revenue will be generated initially).

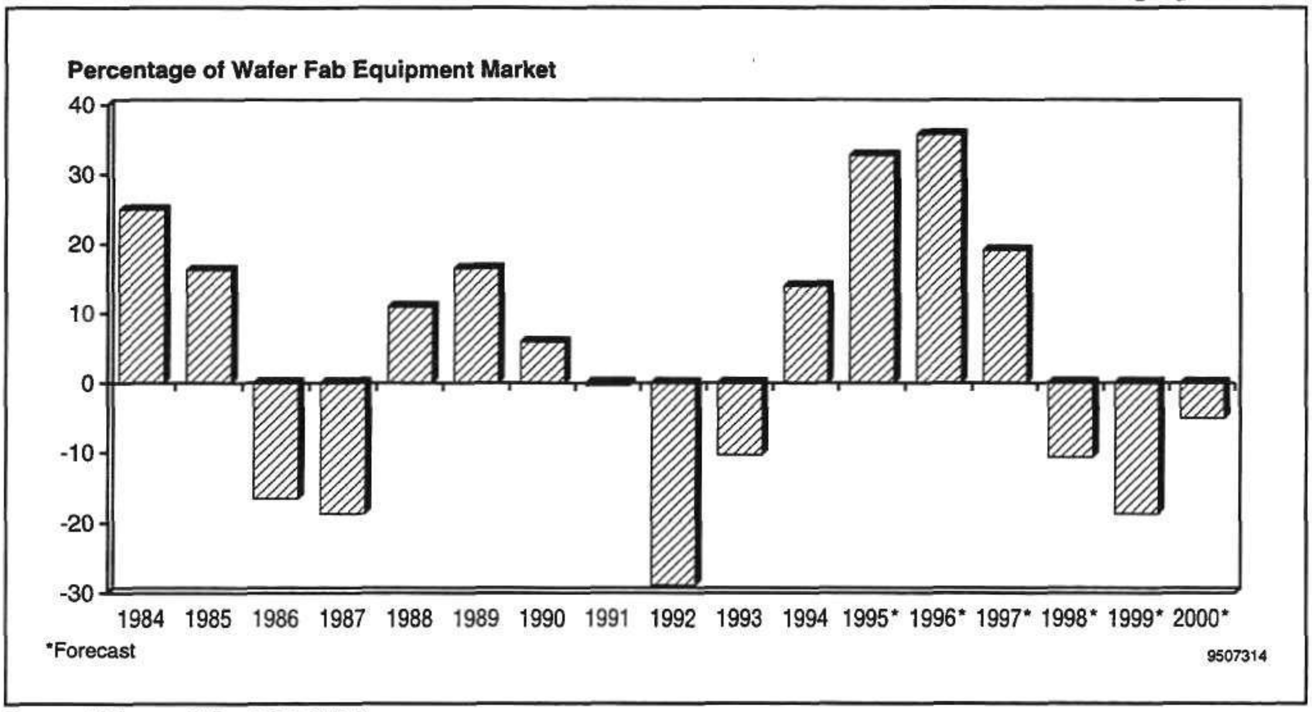
With our forecast for momentum-style growth in 1996 and two pause years in 1997 and 1998, the model indicates a reacceleration of equipment spending starting in 1999.

Figure 3-1
Net Cumulative Over- and Underinvestment of Semiconductor Wafer Fab Equipment



Source: Dataquest (December 1995)

Figure 3-2
Net Cumulative Over- and Underinvestment of Semiconductor Wafer Fab Equipment



Source: Dataquest (December 1995)

When Will Capacity Expand to Meet Demand? A Fundamental Set of Analyses

The NCI model is only a tool to indicate possible future turning points and should not be relied on to forecast capacity supply versus demand absolutely. A more fundamental, basic approach is required for that—looking at square inches of silicon capacity. Calculating how many wafers can be processed and in what type of process is much more enlightening in measuring capacity than focusing on a particular device type. Capacity is very fluid: a stepper does not care whether the picture it takes is for a DRAM, SRAM, or logic device. But there are limits in transferring capacity. For example, logic processes have specialized process techniques that are not found in DRAMs, and vice versa. SRAMs can use a DRAM equipment mix or a logic-oriented process scheme; the latter tends to have faster access times.

There are two major markets that can be isolated in order to understand basic capacity supply and demand: the DRAM market and the foundry market. The latter is particularly interesting for two reasons. First, foundry capacity has tended to be more heavily logic- and ASIC-process oriented, giving us a second perspective on capacity versus supply. Second, the major customer base for foundries is the fabless company, whose products tend to be placed within PC logic and graphics chipsets. Since PCs now account for about one-third of all semiconductor use and around two-thirds of all DRAM consumption and are the main engine driving the current semiconductor boom, looking at PC-related capacity issues is important for understanding potential future equipment market turning points.

The details of these analyses are provided in other Dataquest documents, including Dataquest's Quarterly DRAM Supply/Demand Report and a recent comprehensive study on the foundry market. A summary of the basic results and impacts will be given here.

Supply/demand trends usually show a cycle between oversupply and undersupply. Investment in capacity tends to be in reaction to these situations, and there is inevitably overshoot in both directions. Analysis is based on square inches of silicon, not on revenue, bit demand, or unit demand. If demand for silicon area exceeds supply, the market is technically in undersupply. We will refer to the maximum undersupply point as the market "pinch point."

The following are the basic conclusions and impacts:

- The DRAM market's pinch point occurred in 1995, but DRAM expected to be in undersupply through 1996. The market is expected to reach oversupply by early 1997, and is expected to last 12 to 18 months.
- The foundry market is now in undersupply and is expected to get tighter in 1996. Next year will represent the capacity pinch-point in foundry, and the market is expected to remain in undercapacity through early 1998. The oversupply part of the cycle is expected to be short-lived and to peak in 1999.
- The year 1996 will bring continued tight supply and strong investment in capacity. DRAM prices will edge down early in the year , but only because the upward pressure is no longer present. The market will

begin to transition to the 16Mb density later in the year, and prices will continue to decline gradually into 1997. Foundry prices are expected to edge upward during the year.

- In 1997, there will be crosscurrents: weaker DRAM capacity investment, but continued very strong logic capacity growth. As DRAM goes into oversupply, investment is likely to dry up quickly. But the continued tight supply of foundry and logic capacity is expected to draw continued investment in the United States and Asia in 1997. We expect DRAM investment to decline some 10 percent to 20 percent, while logic investment increases 20 to 30 percent.
- The toughest year will be 1998. Even though DRAM capacity is likely to reach peak oversupply early in the year, reinvestment will not likely occur until 1999. As the foundry market approaches oversupply, logic investment will cool.
- Another crosscurrent year will be 1999. DRAM investment is likely to pick up again, while foundry investment will lag. U.S. logic capacity will likely lead foundry investment out of the "pause." By 2000, the next equipment boom will be under way and is to last through 2001 or 2002.

Highlights of Key Equipment Segment Markets and Forecasts

Steppers and Track

From 1989, the peak year of stepper shipments at more than 950 units, the market tumbled to fewer than 400 tools in 1992 before recovering. In the DRAM-sensitive ramp now occurring, the industry has experienced its first 1,000-stepper year. In fact, we believe that in excess of 1,240 steppers shipped in 1995. Shifts in the product mix toward higher-priced i-line systems and wide field lenses have also driven up average selling prices (ASPs). This, along with the strong yen, has yielded a revenue increase of 78 percent on a dollar basis. This faster-than-market growth is expected to continue into 1996 as semiconductor companies invest in the bottleneck equipment sets and backlogs are at record levels.

Stepper revenue is forecast to grow at a 20.4 percent CAGR, slightly below the market average for 1994 through 2000. Our forecast for stepper unit growth over the five-year forecast horizon remains modest but higher than we have seen in the past, about a 7 percent CAGR between 1994 and 2000.

With the adoption of phase shift mask technology, off-axis illumination techniques as well as conventional i-line tools with variable numerical aperture (NA), i-line is clearly a viable technology down to the 0.30-micron regime and will continue to dominate the overall stepper technology mix through 2000. Excimer/deep-ultraviolet (deep-UV) steppers will begin to represent a more significant portion of the product mix from 1997 onward for use in below-0.30-micron devices and ICs with large chip areas, such as advanced microprocessors, that require large field size capability. Dataquest believes that field size pressures accompanied by shrinking geometries will drive the industry toward step-and-scan (or step-and-stitch) technologies for the majority of excimer/deep-UV shipments, beginning in 1997.

Track equipment is forecast to grow at a 23.1 percent CAGR between 1994 and 2000, slightly ahead of the industry growth of 21.4 percent. Although we believe that the rapid shift in the product mix toward higher-priced systems has been recently completed, we do expect another product shift to occur in the track market and we expect higher ASPs associated with the ramp of deep-UV steppers, which require more sophisticated environmental control systems.

Etch and Clean: Dry Etch and Chemical Mechanical Polishing

Dataquest began covering the chemical mechanical polishing (CMP) market in 1993, a year in which sales increased 121 percent to over $44 million. Dataquest includes the post-CMP clean system, usually sold in conjunction with a CMP tool, as part of the cleaning segment, not in the CMP segment. It was expected that 1994 would be another high growth year, but the market was disappointing, growing at a slower-than-market average to approach $65 million (or 49 percent growth). We believe that this resulted from the time that was required to evaluate the technology and gain production experience with it before widespread adoption occurred.

In 1995, that adoption has started, with CMP systems growing 135 percent to over $152 million. Even though the application appears to be limited to devices with at least three levels of metal, which tends to exclude the DRAM market, acceptance of the technology into the foundry market has been the key. Until recently, most foundries we have talked with had not planned on putting CMP into their standard 0.5-micron process flow. Based on the customer demand, however, and because more robust equipment has been introduced, we now believe that many foundries will offer CMP at 0.5-micron.

These systems are used to remove material from the surface of the wafer, resulting in a flat surface over the entire wafer. This global planarization, primarily of dielectric layers, is required to achieve high yields in devices where three or more levels of metal are used. Today's advanced logic and ASIC devices are fueling this market growth. Dataquest believes that this technology and market will become a major part of semiconductor manufacturing in the long run.

If we were to create a forecast based purely on technology driving the market, we would not slow the CMP market forecast in 1998. However, we believe that in time we will see some holding back of capital investment, and history has shown us that even advanced, emerging technologies are rarely spared in a capital slowdown. Nonetheless, CMP is our fastest-growing segment with a 48.1 percent CAGR for 1994 through 2000.

Dry etch systems continue to exhibit strong revenue growth, with a CAGR of 19.5 percent forecast for 1994 through 2000. Unit shipments are expected to grow as greater multilevel interconnect process capacity is brought online, increasing the need for dielectric and metal capacity. Relatively strong ASP growth will lend additional momentum to dry etch revenue growth as new high-density plasma systems for 0.35-micron applications enter the market and multichamber cluster tools continue to increase their presence. The success of CMP will hold etch below market growth, however, particularly in metal etch as stringer removal becomes a nonissue.

Clean process equipment is forecast to show revenue growth of 20.7 percent annually from 1994 through 2000, basically on par with overall equipment market growth. This market is more heavily dependent on the brick-and-mortar part of the capital investment dollar, as wafer cleaning is a fundamental in all parts of the fab. Automated wet stations dominate this segment, now accounting for nearly 70 percent of the clean process systems. Emerging areas of cleaning tools include (in order of size) spray processors, post-CMP clean, and vapor phase cleaning. As manufacturers look for novel ways to increase yields, we would expect these and other new techniques to evolve and increase in importance.

Deposition: CVD, PVD, and Silicon Epitaxy

CVD equipment sales are predicted to grow at a 23.9 percent annualized rate from 1994 through 2000, above overall equipment growth. The steady growth in multilevel interconnect capacity will continue to generate demand for dielectric and metal CVD systems. ASP growth will also contribute to revenue growth, as more highly integrated systems with improved productivity and particle control appear in the marketplace. Advanced dielectric deposition systems utilizing high-density plasma (HDP) sources will be introduced for intermetal dielectric (IMD) applications for sub-0.5 micron processes. Most systems will be introduced on multichamber cluster platforms. Metal CVD will continue to exhibit strong growth, driven by blanket tungsten for contact and via plugs, CVD barrier metals such as CVD titanium nitride, and dichlorosilane (DCS) tungsten silicide for shrink 16Mb and 64Mb DRAMs. For these reasons, the forecast for nontube CVD systems outperforms tube furnaces.

Sputter deposition systems are forecast to grow at an annualized rate of 19.5 percent for 1994 through 2000. As in the case of dry etch and CVD equipment, continued expansion of multilevel interconnect process capacity is the primary driver behind sputter system growth. Rapid growth in average system ASP has helped to drive total revenue growth in 1994, primarily from the rapid and expanding dominance of Applied Materials in the market. With Applied Materials now accounting for more than 50 percent of the market, the bulk of the ASP increases are behind us. Revolutionary changes in system architecture, pioneered by the Applied Materials Endura system, will continue to yield improvements in film properties, equipment productivity, and defect density. This is a market segment that will be somewhat buffered from a slowdown in DRAM investment as the fundamental growth in the number of metal layers in ASICs and logic devices drives a more stable outlook.

The shift from batch to single-wafer epitaxial systems has been the primary driver of epitaxial deposition systems, as 200mm epitaxial wafer capacity was needed. In 1994 we saw the Applied Materials system become an "Intel-accepted supplier," so silicon companies are investing to add this capacity. However, this capacity is more expensive than wafer suppliers would like, so we expect the concept of "minibatches" to emerge as a viable production strategy, as it has in CVD. Moore Technologies is known to be in the process of releasing such a new product. A strong automotive, power, and discrete device market has increased demand for the specialty batch units. An increased product mix of logic semiconductors, sustained demand for discretes, and 200mm wafer capacity addition will be the primary drivers for epitaxial deposition equipment growth beyond 1995.

Thermal Nondeposition Processes: Diffusion and RTP

Diffusion systems are expected to demonstrate a CAGR of 17.9 percent for 1994 through 2000. The displacement of horizontal tube systems by vertical tube reactors will continue. Newer vertical systems will be configurable as multitube clusters with integrated dry clean capability, to compete with single wafer cluster tools. Tube systems will also incorporate small batch capabilities to offer greater flexibility for custom and semicustom circuit manufacturers.

RTP will grow at an annualized rate of 34.5 percent for 1994 through 2000. This market grew much faster than we anticipated, nearly doubling in 1994 and slightly more than doubling in 1995. The growth in 1994 was primarily fueled by the growing acceptance of self-aligned silicide processes in logic process flows. The growth in 1995 comes from new offerings in the market from Applied Materials, CVC, and Mattson and from the expansion of the application into traditional tube diffusion steps. The real growth for this segment will come from transitioning of the thermal "non-depositing" processes away from diffusion tubes and into single-wafer RTP systems for 300mm wafers. We have factored a large complement of systems into initial 300mm facilities starting in 1997, largely contributing to the higher-than-market growth. RTP systems are primarily used today for silicide anneals and are primarily driven by logic and ASIC capacity.

Dataquest believes that batch tube systems will continue to resist penetration by RTP in areas such as well drive, BPSG reflow, and thermal oxidation because of the demonstrated cost of ownership benefits in these areas, at least through 200mm wafers. For 300mm wafers, there will also be a strong desire on the part of the semiconductor manufacturer to continue to use batch tube systems because these systems offer much better cost efficiencies.

Ion Implantation

Overall ion implantation system revenue is forecast to grow at a CAGR of 20.2 percent for the years 1994 through 2000. This market segment will continue to be one of the most volatile because of the highly device-specific nature of the implant segments and because of the dependence on new fab capacity for unit growth. The fastest-growing segment is expected to be high-energy implantation, which is evoking intense interest because of its potential for process simplification and manufacturing cost reduction. The first year of true production ramp is expected to occur in 1998 as 0.4-micron technologies becomes mainstream, although early adopters such as Samsung have placed high-voltage implant into 16Mb DRAMs.

New implant systems will continue to offer improvement in uniformity, particle control, charging, and wafer throughput. The number of implant steps requiring medium-current ion sources is expected to grow faster than high-dose implant steps, again driven by the higher worldwide semiconductor logic component, with the shallow junctions preferentially driving the trend toward medium-current implants.

However, our forecast does not reflect this trend, with medium-current implant sales lagging the market with only 15.1 percent CAGR. Why?

Recently Eaton, Applied Materials, and Genus introduced expanded capability to existing systems or new systems targeted to compete in more than one segment. For example, Applied Materials' 9500 systems now basically cover both high-current and medium-current capabilities, and Genus' new 1520 model expands the range effectively across high-voltage and medium-current. Traditional batch medium-current systems are effectively being squeezed out of the market. This is occurring because equipment utilization for implanters tends to be among the lowest in the fab. Semiconductor manufacturers, in an effort to increase utilization and reduce cost, are tending to buy equipment with broader ranges.

There are medium-current applications that will still require dedicated medium-current systems, namely high-tilt (>42 degree) implants and V_T adjustment implants. However, these will be executed better using implanters with single-wafer end stations rather than the traditional batch systems.

Dataquest is investigating the "redefinition" of ion implant segments in order to capture this market dynamic better.

Segments and Tools of Emerging Importance

Yield enhancement is the talk of the moment. If a piece of equipment enhances yield directly in any way, particularly if it is an incremental concept and on the lower end of the price scale, it will gain immediate acceptance. Such appears to be the case in three specific areas: photostabilizers, a tool we refer to as a pull dryer, and emerging issues in process control/overlay.

Photostabilizers are relatively small systems, selling for perhaps $200,000, that employ a UV curing technique to treat exposed photoresist on the wafer before placing the wafer into the etcher. Fusion Systems in the United States has been one of the leaders in this area. The system improves the quality of the photoresist in preparation for etch and thus dramatically improves the etch system performance. Samsung is known to have installed many units, and the product segment is starting to attract major interest.

A visit to Steag AG in Germany recently introduced us to the concept of what we currently refer to as a pull dryer. These systems are replacing the spin dryers usually employed within the automated wet stations today. Wafers are placed in the system after a wet cleaning process to dry, but they do not spin. Instead, they are pulled from a bath of isopropyl alcohol (IPA) and water in a controlled fashion into an IPA vapor atmosphere. As the wafer is pulled out, the liquid sheets off the surface in such a way as to leave no water spots, which often hold killer residue defects. Micron Technology is known to have purchased many of these systems, and we expect this technology to be introduced by several companies in the wafer cleaning area.

Process control systems are the core of the yield enhancement movement, and it is estimated that close to 80 percent of the failures in ICs (killer defects) may be attributed to particulate contamination. Therefore, pre- and postprocess particle and defect monitoring and characterization are key to increasing yield. There are several important developments to watch in the equipment segments of process control, which we believe will experience very strong growth in the years ahead. These segments include wafer inspection and review, CD metrology, and thin-film measurement.

Patterned wafer inspection stations have led the way to in-line use in fabs. Demand for unpatterned wafer inspection is also gaining momentum in applications such as post-CMP inspection. Defect review technology has evolved from microscope-based systems to automated stations that characterize defects at the coordinates provided by wafer inspection systems. Laser-based systems, such as Ultrapointe's recently introduced product, address the throughput issue along with increased resolution. With higher throughput and automated capabilities, defect review stations should follow the inspection segment to be used in-line.

The CD-SEM market has grown tremendously in the past several years, with the major thrust being the introduction of high throughput automated SEM systems introduced several years ago. Operator "interpretation" of SEM data and measurement has always been a problem in CD metrology. Today's SEM systems have made qualitative improvement to the electron emission source and are equipped with pattern recognition software and hardware, thus automating the interpretation function. In turn, the ASPs have increased two-fold to about $1.2 million. ASPs will continue to grow along with demand for these automated high-throughput systems.

Thin-film measurement is key to intra- and interlevel metal interconnect and storage capacitance applications. Thin-film measurement systems are used in-line to monitor the in-etch, lithography (photoresist), deposition, and diffusion steps. Although this market has been driven more by logic applications than by memory production, in the past several years, DRAM manufacturers have begun integrating thin-film measurement stations into their process lines.

Dataquest Perspective

Wafer fab equipment spending grew 66 percent in 1995 and is expected to grow 36 percent worldwide in 1996, driven by massive spending in the Asia/Pacific region and a strong investment in the United States. DRAM-sensitive Japan investment and an expanding European production base complete the strong picture for 1996. Segment growth in 1994 and 1995 is being led by DRAM or capital spending-sensitive equipment, with steppers, implant, wafer inspection, and factory automation exhibiting significantly stronger-than-market growth. New technology segments such as CMP, high voltage implant, and RTP were the fastest-growing segments. We expect no major segment declines in 1996, as capacity additions are broad-based and worldwide. Record backlog levels going into 1996 will be a buffer against a market decline in 1997, but we do expect softness from the DRAM companies to become evident by the end of 1996.

After four strong expansion years in 1993 through 1996, equipment purchases in 1997 should decline markedly, followed by a slight decline in 1998. Investment in DRAM capacity will be curtailed as producers elect to convert their 4Mb DRAM capacity to 16Mb, which adds bit capacity through the instant increase in bits per square inch. Also, many Japanese DRAM facilities now running 150mm wafers will convert to 200mm wafers, further delaying the need for new equipment. DRAM-sensitive equipment technologies or capital intensive segments such as steppers, implantation, diffusion, and polysilicon etch will be affected more than logic-sensitive technologies such as sputtering, epitaxial reactors, CMP, RTP, nontube CVD, or metal etch. The next expansion should kick in by 1999, driven by 0.35- to 0.4-micron capacity expansion.

We have factored in an infrastructure investment in equipment for late 1997 through 1999, which will affect the forecast size of the markets positively. This additional investment will be for initial equipment to fill some 300mm fabs to run silicon by 1999. However, we believe that a significant 300mm equipment market will not occur until well after 2000.

Yield enhancement is the trend of the time. Any system technology that can be priced relatively low and that has a direct impact on yield will gain immediate acceptance in volume. Areas emerging as particularly important today are in cleaning technology, photostabilizers, and process control metrology.

Chapter 4
Silicon Wafer Forecast

Dataquest's current forecast and the underlying assumptions behind our expectations for regional silicon wafer demand reflect significant silicon wafer growth in 1995 and 1996, with upward revisions to the 1997 through 2000 forecast, in line with increased semiconductor consumption forecasts worldwide. Our latest forecasts, along with highlights of some of the key factors affecting the regional markets, are presented here.

Silicon Forecast Tables

Tables in this chapter include Dataquest's most recent forecasts of regional unit silicon wafer consumption. Tables 4-1 through 4-5 detail unit consumption by region. Individual forecasts of major product segments such as prime, epitaxial, and test and monitor wafers are included. Tables 4-6 through 4-10 present regional forecasts for wafer size distribution.

Table 4-1
Forecast of Captive and Merchant Silicon* and Merchant Epitaxial Wafers by Region (Millions of Square Inches)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
Worldwide Total Silicon + Epitaxial	2,449.7	2,919.0	3,588.6	4,150.1	4,734.1	5,176.9	5,545.3	6,166.7	13.3
Merchant and Captive Silicon*	2,157.1	2,535.3	3,091.6	3,567.4	4,101.9	4,483.7	4,782.7	5,291.0	13.0
Epitaxial Silicon	292.6	383.7	497.0	582.7	632.2	693.2	762.6	875.7	14.7
North America Total Silicon + Epitaxial	720.0	832.1	1,065.7	1,184.9	1,281.9	1,366.8	1,499.3	1,668.3	12.3
Merchant and Captive Silicon*	565.5	641.9	824.0	900.7	973.1	1,026.6	1,124.6	1,239.7	11.6
Epitaxial Silicon	154.5	190.2	241.7	284.2	308.8	340.2	374.7	428.6	14.5
Japan Total Silicon + Epitaxial	1,127.3	1,279.7	1,505.7	1,726.3	1,917.6	2,052.0	2,145.8	2,333.7	10.5
Merchant and Captive Silicon*	1,038.3	1,160.2	1,349.8	1,547.6	1,725.9	1,843.4	1,917.3	2,073.6	10.2
Epitaxial Silicon	89.0	119.5	155.9	178.7	191.7	208.6	228.5	260.1	13.8
Europe Total Silicon + Epitaxial	291.2	351.2	408.7	474.2	543.2	598.9	650.9	721.0	12.7
Merchant and Captive Silicon*	255.1	296.7	336.4	387.7	448.5	494.9	536.9	590.0	12.1
Epitaxial Silicon	36.1	54.5	72.3	86.5	94.7	104.0	114.0	131.0	15.7
Asia/Pacific-ROW Total Silicon + Epitaxial	311.2	456.0	608.5	764.7	991.4	1,159.2	1,249.3	1,443.7	21.2
Merchant and Captive Silicon*	298.2	436.5	581.4	731.4	954.4	1,118.8	1,203.9	1,387.7	21.3
Epitaxial Silicon	13.0	19.5	27.1	33.3	37.0	40.4	45.4	56.0	19.2

*Includes prime, test, and monitor wafers
Source: Dataquest (January 1996)

Table 4-2
Forecast Growth Rates of Captive and Merchant Silicon* and Merchant Epitaxial Wafers by Region (Percentage of Millions of Square Inches)

	1993	1994	1995	1996	1997	1998	1999	2000
Worldwide Total Silicon + Epitaxial	16.8	19.2	22.9	15.6	14.1	9.4	7.1	11.2
Merchant and Captive Silicon*	16.7	17.5	21.9	15.4	15.0	9.3	6.7	10.6
Epitaxial Silicon	17.7	31.1	29.5	17.2	8.5	9.6	10.0	14.8
North America Total Silicon + Epitaxial	10.6	15.6	28.1	11.2	8.2	6.6	9.7	11.3
Merchant and Captive Silicon*	8.2	13.5	28.4	9.3	8.0	5.5	9.5	10.2
Epitaxial Silicon	20.6	23.1	27.1	17.6	8.7	10.2	10.1	14.4
Japan Total Silicon + Epitaxial	15.9	13.5	17.7	14.7	11.1	7.0	4.6	8.8
Merchant and Captive Silicon*	17.2	11.7	16.3	14.7	11.5	6.8	4.0	8.2
Epitaxial Silicon	2.3	34.3	30.5	14.6	7.3	8.8	9.5	13.8
Europe Total Silicon + Epitaxial	23.9	20.6	16.4	16.0	14.6	10.3	8.7	10.8
Merchant and Captive Silicon*	20.8	16.3	13.4	15.2	15.7	10.3	8.5	9.9
Epitaxial Silicon	51.0	51.0	32.7	19.6	9.5	9.8	9.6	14.9
Asia/Pacific-ROW Total Silicon + Epitaxial	30.8	46.5	33.4	25.7	29.6	16.9	7.8	15.6
Merchant and Captive Silicon*	30.5	46.4	33.2	25.8	30.5	17.2	7.6	15.3
Epitaxial Silicon	36.8	50.0	39.0	22.9	11.1	9.2	12.4	23.3

*Includes prime, test, and monitor wafers
Source: Dataquest (January 1996)

Table 4-3
Forecast of Captive and Merchant Silicon* Wafers by Region (Millions of Square Inches)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
Worldwide Total Silicon*	2,157.1	2,535.3	3,091.6	3,567.4	4,101.9	4,483.7	4,782.7	5,291.0	13.0
Merchant Silicon	2,032.1	2,398.3	3,029.6	3,505.4	4,039.9	4,421.7	4,720.7	5,229.0	13.9
Captive Silicon	125.0	137.0	62.0	62.0	62.0	62.0	62.0	62.0	-12.4
North America Total Silicon*	565.5	641.9	824.0	900.7	973.1	1,026.6	1,124.6	1,239.7	11.6
Merchant Silicon	487.5	551.9	809.0	885.7	958.1	1,011.6	1,109.6	1,224.7	14.2
Captive Silicon	78.0	90.0	15.0	15.0	15.0	15.0	15.0	15.0	-25.8
Japan Total Silicon*	1,038.3	1,160.2	1,349.8	1,547.6	1,725.9	1,843.4	1,917.3	2,073.6	10.2
Merchant Silicon	1,003.3	1,125.2	1,314.8	1,512.6	1,690.9	1,808.4	1,882.3	2,038.6	10.4
Captive Silicon	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	0
Europe Total Silicon*	255.1	296.7	336.4	387.7	448.5	494.9	536.9	590.0	12.1
Merchant Silicon	250.1	291.7	331.4	382.7	443.5	489.9	531.9	585.0	12.3
Captive Silicon	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	0
Asia/Pacific-ROW Total Silicon*	298.2	436.5	581.4	731.4	954.4	1,118.8	1,203.9	1,387.7	21.3
Merchant Silicon	291.2	429.5	574.4	724.4	947.4	1,111.8	1,196.9	1,380.7	21.5
Captive Silicon	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	0

*Includes prime, test, and monitor wafers
Source: Dataquest (January 1996)

Table 4-4
Forecast Growth Rates of Captive and Merchant Silicon* by Region (Percentage of Millions of Square Inches)

	1993	1994	1995	1996	1997	1998	1999	2000
Worldwide Total Silicon*	16.7	17.5	21.9	15.4	15.0	9.3	6.7	10.6
Merchant Silicon	17.6	18.0	26.3	15.7	15.2	9.5	6.8	10.8
Captive Silicon	4.2	9.6	-54.7	0	0	0	0	0
North America Total Silicon*	8.2	13.5	28.4	9.3	8.0	5.5	9.5	10.2
Merchant Silicon	8.1	13.2	46.6	9.5	8.2	5.6	9.7	10.4
Captive Silicon	8.3	15.4	-83.3	0	0	0	0	0
Japan Total Silicon*	17.2	11.7	16.3	14.7	11.5	6.8	4.0	8.2
Merchant Silicon	18.2	12.1	16.9	15.0	11.8	6.9	4.1	8.3
Captive Silicon	-5.4	0	0	0	0	0	0	0
Europe Total Silicon*	20.8	16.3	13.4	15.2	15.7	10.3	8.5	9.9
Merchant Silicon	21.3	16.6	13.6	15.5	15.9	10.5	8.6	10.0
Captive Silicon	0	0	0	0	0	0	0	0
Asia/Pacific-ROW Total Silicon*	30.5	46.4	33.2	25.8	30.5	17.2	7.6	15.3
Merchant Silicon	30.9	47.5	33.7	26.1	30.8	17.4	7.7	15.4
Captive Silicon	16.7	0	0	0	0	0	0	0

*Includes prime, test, and monitor wafers
Source: Dataquest (January 1996)

Table 4-5
Forecast of Merchant Prime and Test/Monitor Wafers by Region
(Millions of Square Inches)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
Worldwide Merchant Silicon	2,032.1	2,398.3	3,029.6	3,505.4	4,039.9	4,421.7	4,720.7	5,229.0	13.9
Growth Rate (%)	17.6	18.0	26.3	15.7	15.2	9.5	6.8	10.8	
Prime	1,616.8	1,892.6	2,280.1	2,568.7	2,943.4	3,293.5	3,589.8	4,033.9	13.4
Test and Monitor	415.3	505.7	749.5	936.7	1,096.5	1,128.2	1,130.9	1,195.1	15.4
North America Merchant Silicon	487.5	551.9	809.0	885.7	958.1	1,011.6	1,109.6	1,224.7	14.2
Growth Rate (%)	8.1	13.2	46.6	9.5	8.2	5.6	9.7	10.4	
Prime	385.1	430.5	594.0	614.7	657.9	709.2	787.7	879.3	12.6
Test and Monitor	102.4	121.4	215.0	271.0	300.2	302.4	321.9	345.4	19.0
Japan Merchant Silicon	1,003.3	1,125.2	1,314.8	1,512.6	1,690.9	1,808.4	1,882.3	2,038.6	10.4
Growth Rate (%)	18.2	12.1	16.9	15.0	11.8	6.9	4.1	8.3	
Prime	800.1	894.5	1,015.8	1,156.2	1,290.4	1,404.4	1,489.4	1,626.8	10.5
Test and Monitor	203.2	230.7	299.0	356.4	400.5	404.0	392.9	411.8	10.1
Europe Merchant Silicon	250.1	291.7	331.4	382.7	443.5	489.9	531.9	585.0	12.3
Growth Rate (%)	21.3	16.6	13.6	15.5	15.9	10.5	8.6	10.0	
Prime	200.1	230.4	242.5	266.5	300.0	344.5	386.2	435.9	11.2
Test and Monitor	50.0	61.3	88.9	116.2	143.5	145.4	145.7	149.1	16.0
Asia/Pacific-ROW Merchant Silicon	291.2	429.5	574.4	724.4	947.4	1,111.8	1,196.9	1,380.7	21.5
Growth Rate (%)	30.9	47.5	33.7	26.1	30.8	17.4	7.7	15.4	
Prime	231.5	337.2	427.8	531.3	695.1	835.4	926.5	1,091.9	21.6
Test and Monitor	59.7	92.3	146.6	193.1	252.3	276.4	270.4	288.8	20.9

Source: Dataquest (January 1996)

Table 4-6
Worldwide Wafer Size Distribution Forecast, 1993-2000

Diameter	Area (Sq. In.)	1993	1994	1995	1996	1997	1998	1999	2000
Percentage Square Inches by Diameter									
2 Inches	3.14	0.1	0.1	0.1	0.1	0	0	0	0
3 Inches	7.07	1.6	1.4	1.1	0.9	0.8	0.6	0.5	0.4
100mm	12.17	16.1	14.8	12.6	10.3	8.6	7.5	6.8	6.0
125mm	19.02	28.8	24.7	21.1	17.9	15.1	13.3	11.9	10.4
150mm	27.38	49.6	48.0	44.9	43.4	43.4	42.1	41.5	40.7
200mm	48.67	3.6	11.0	20.2	27.4	32.1	36.4	39.2	42.4
300mm	109.56	0	0	0	0	0	0	0.1	0.1
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total (MSI)		2,450	2,919	3,589	4,150	4,734	5,177	5,545	6,167
Growth (%)		16.8	19.2	22.9	15.6	14.1	9.4	7.1	11.2
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 Inches	3.14	1.0	1.1	1.2	0.7	0.6	0.7	0.4	0
3 Inches	7.07	5.6	5.7	5.6	5.5	5.1	4.6	4.0	3.5
100mm	12.17	32.5	35.5	37.0	35.2	33.4	31.9	30.9	30.4
125mm	19.02	37.1	37.9	39.9	39.0	37.6	36.2	34.7	33.6
150mm	27.38	44.4	51.2	58.9	65.8	75.1	79.5	84.0	91.6
200mm	48.67	1.8	6.6	14.9	23.4	31.2	38.8	44.7	53.7
300mm	109.56	0	0	0	0	0	0.01	0.06	0.08
Total Wafers (Millions)		122.5	138.0	157.5	169.6	183.1	191.7	198.7	213.0
Average Wafer Diameter (Inches)		5.05	5.19	5.39	5.58	5.74	5.86	5.96	6.07

Source: Dataquest (January 1996)

Table 4-7
North American Wafer Size Distribution Forecast, 1993-2000

Diameter	Area (Sq. In.)	1993	1994	1995	1996	1997	1998	1999	2000
Percentage Square Inches by Diameter									
2 inches	3.14	0.1	0.1	0.1	0	0	0	0	0
3 inches	7.07	1.2	1.1	1.0	0.9	0.7	0.6	0.5	0.3
100mm	12.17	22.4	20.1	17.1	14.4	12.7	11.4	10.4	9.2
125mm	19.02	26.5	21.7	19.0	16.3	14.6	13.0	11.3	9.6
150mm	27.38	44.0	42.2	39.6	36.9	37.0	36.7	35.4	35.0
200mm	48.67	5.8	14.8	23.2	31.5	35.0	38.2	42.2	45.7
300mm	109.56	0	0	0	0	0	0.1	0.2	0.2
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total (MSI)		720	832	1,066	1,185	1,282	1,367	1,499	1,668
Growth (%)		10.6	15.6	28.1	11.2	8.2	6.6	9.7	11.3
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 inches	3.14	0.2	0.3	0.3	0	0	0	0	0
3 inches	7.07	1.2	1.3	1.5	1.5	1.3	1.2	1.1	0.7
100mm	12.17	13.3	13.7	15.0	14.0	13.4	12.8	12.8	12.6
125mm	19.02	10.0	9.5	10.6	10.2	9.8	9.3	8.9	8.4
150mm	27.38	11.6	12.8	15.4	16.0	17.3	18.3	19.4	21.3
200mm	48.67	0.9	2.5	5.1	7.7	9.2	10.7	13.0	15.7
300mm	109.56	0	0	0	0	0	0.01	0.03	0.03
Total Wafers (Millions)		37.2	40.2	48.0	49.3	51.0	52.4	55.2	58.8
Average Wafer Diameter (Inches)		4.97	5.14	5.32	5.53	5.66	5.76	5.88	6.01

Source: Dataquest (January 1996)

Table 4-8
Japan Wafer Size Distribution Forecast, 1993-2000

Diameter	Area (Sq. In.)	1993	1994	1995	1996	1997	1998	1999	2000
Percentage Square Inches by Diameter									
2 inches	3.14	0	0	0	0	0	0	0	0
3 inches	7.07	1.5	1.4	1.1	0.9	0.8	0.7	0.6	0.5
100mm	12.17	11.5	10.8	9.3	7.9	6.9	6.2	5.6	5.0
125mm	19.02	32.2	29.9	26.2	22.9	20.0	18.3	16.9	15.2
150mm	27.38	53.3	51.6	50.9	51.3	52.3	52.3	52.9	52.5
200mm	48.67	1.5	6.3	12.5	17.0	20.0	22.5	23.9	26.7
300mm	109.56	0	0	0	0	0	0	0.1	0.1
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total (MSI)		1,127	1,280	1,506	1,726	1,918	2,052	2,146	2,334
Growth (%)		15.9	13.5	17.7	14.7	11.1	7.0	4.6	8.8
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 inches	3.14	0	0	0	0	0	0	0	0
3 inches	7.07	2.4	2.5	2.3	2.2	2.2	2.0	1.8	1.7
100mm	12.17	10.7	11.4	11.5	11.2	10.9	10.5	9.9	9.6
125mm	19.02	19.1	20.1	20.7	20.8	20.2	19.7	19.1	18.6
150mm	27.38	21.9	24.1	28.0	32.3	36.6	39.2	41.5	44.7
200mm	48.67	0.3	1.7	3.9	6.0	7.9	9.5	10.5	12.8
300mm	109.56	0	0	0	0	0	0	0.02	0.02
Total Wafers (Millions)		54.4	59.8	66.4	72.6	77.7	80.9	82.8	87.5
Average Wafer Diameter (Inches)		5.14	5.22	5.37	5.50	5.60	5.68	5.74	5.83

Source: Dataquest (January 1996)

Table 4-9
European Wafer Size Distribution Forecast, 1993-2000

Diameter	Area (Sq. In.)	1993	1994	1995	1996	1997	1998	1999	2000
Percentage Square Inches by Diameter									
2 inches	3.14	0.2	0.1	0.1	0	0	0	0	0
3 inches	7.07	1.7	0.7	0.5	0.4	0.2	0.1	0.1	0.1
100mm	12.17	22.0	20.5	18.0	14.2	11.0	9.2	7.9	7.1
125mm	19.02	30.1	21.7	19.3	14.6	11.5	9.8	8.3	7.3
150mm	27.38	42.3	43.0	39.1	37.8	35.3	35.2	35.1	35.0
200mm	48.67	3.7	14.0	23.0	33.0	42.0	45.7	48.6	50.5
300mm	109.56	0	0	0	0	0	0	0	0
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total (MSI)		291	351	409	474	543	599	651	721
Growth (%)		23.9	20.6	16.4	16.0	14.6	10.3	8.7	10.8
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 inches	3.14	0.2	0.1	0.1	0	0	0	0	0
3 inches	7.07	0.7	0.3	0.3	0.3	0.2	0.1	0.1	0.1
100mm	12.17	5.3	5.9	6.0	5.5	4.9	4.5	4.2	4.2
125mm	19.02	4.6	4.0	4.1	3.6	3.3	3.1	2.8	2.8
150mm	27.38	4.5	5.5	5.8	6.5	7.0	7.7	8.3	9.2
200mm	48.67	0.2	1.0	1.9	3.2	4.7	5.6	6.5	7.5
300mm	109.56	0	0	0	0	0	0	0	0
Total Wafers (Millions)		15.5	16.9	18.4	19.2	20.0	21.0	22.0	23.8
Average Wafer Diameter (Inches)		4.89	5.14	5.32	5.61	5.87	6.02	6.14	6.21

Source: Dataquest (January 1996)

Table 4-10
Asia/Pacific-ROW Wafer Size Distribution Forecast, 1993-2000

Diameter	Area (Sq. In.)	1993	1994	1995	1996	1997	1998	1999	2000
Percentage Square Inches by Diameter									
2 inches	3.14	0.6	0.5	0.4	0.3	0.2	0.2	0.1	0.0
3 inches	7.07	2.9	2.4	1.7	1.4	1.1	0.8	0.6	0.5
100mm	12.17	13.0	12.0	9.0	7.1	5.2	4.3	3.9	3.4
125mm	19.02	20.8	17.8	13.5	11.0	8.3	6.6	5.9	5.0
150mm	27.38	56.3	52.3	43.4	39.2	39.1	33.8	32.4	31.0
200mm	48.67	6.4	15.0	32.0	41.0	46.1	54.3	57.0	59.9
300mm	109.56	0	0	0	0	0	0	0.1	0.2
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total (MSI)		311	456	609	765	991	1,159	1,249	1,444
Growth (%)		30.8	46.5	33.4	25.7	29.6	16.9	7.8	15.6
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 inches	3.14	0.6	0.7	0.8	0.7	0.6	0.7	0.4	0
3 inches	7.07	1.3	1.5	1.5	1.5	1.5	1.3	1.1	1.0
100mm	12.17	3.3	4.5	4.5	4.5	4.2	4.1	4.0	4.0
125mm	19.02	3.4	4.3	4.3	4.4	4.3	4.0	3.9	3.8
150mm	27.38	6.4	8.7	9.6	10.9	14.2	14.3	14.8	16.3
200mm	48.67	0.4	1.4	4.0	6.4	9.4	12.9	14.6	17.8
300mm	109.56	0	0	0	0	0	0	0.01	0.03
Total Wafers (Millions)		15.4	21.2	24.7	28.5	34.3	37.4	38.8	43.0
Average Wafer Diameter (Inches)		5.07	5.24	5.60	5.84	6.07	6.28	6.41	6.54

Source: Dataquest (January 1996)

The 200mm Wafer Ramps Up

Dataquest has been studying the subject of 200mm wafers and their ramp rate closely over the last year, particularly in light of the announcements of massive fab capacity planned over the next few years. There are 76 new 200mm fabs expected to come on line from 1995 through 1997, and there are probably several more announcements to come. The largest proportion comes on line in 1996 alone. Wafer suppliers have answered the need with several new wafer plants and billions in committed investment. We continue to believe that the ramp of 200mm wafers will be supply-constrained through the decade—that is to say, the industry cannot convert from 150mm at will. The biggest factor, however, is the consumption of test wafers—now over the ratio of one test wafer for every product wafer. This compares with the industry average of about one test wafer per seven product wafers for sizes below 200mm.

In this forecast update, we have revised the forecast—again upward—to reflect the expected fab activity in each region and the supply increases in place. Our current forecast for the year 2000 represents a level about 15 percent above what the wafer manufacturing industry has committed to supply to date. We stop short of forecasting a shortage of 200mm wafers to the point of restricting ramp-up plans, but buyers of wafers will experience firm-to-rising prices and will be placed on allocation from time to time over the next several years. One issue that semiconductor manufacturers will face is that they may be forced to reduce their test wafer consumption. According to straight demand requirements, the industry will come down only to the level of one test wafer for every 1.5 product wafers, but our forecast assumes that this demand for test wafers will be smaller, more on the order of one test wafer for every 3.5 product wafers. In a recent Focus Report (*Is There a Silicon Shortage Looming?* November 13, 1995, SEMM-WW-FR-9502) we have analyzed demand and supply of 200mm wafers in detail. The 200mm wafer may be in the best supply situation of all areas.

What about 300mm Wafers?

Once the wafer size had been settled and the time horizon for the first 300m plant(s) had been proposed, we initiated a forecast for consumption of 300mm wafers. The level is still commercially zero before the year 2000; however, the recent goal of bringing a fab on line by 1998 or 1999 means that 300mm wafers will be made and significant activity will be occurring in R&D. Although no company has as yet made a firm commitment, we would expect something to be announced soon. This has been quite a story to watch this year. At the beginning of the year, there was great enthusiasm, particularly among Samsung, Motorola, Intel, and a Japanese company. As the year went on, Intel dropped off and both Samsung and Motorola became more cautious. At this point, it is unclear who will step up to the bar, but we would also not be surprised if this were given a one- or two-year rest. SEMATECH is trying to be the champion, but as we have always said: Without funding, it will not happen.

We are assuming that at least two pilot fabs will seek to come on line by 1999.

Further details and issues regarding the move toward 300mm wafers are included in a recent Market Analysis document ("The Move toward 300mm Wafers," May 22, 1995, SEMM-WW-MA-9503). Please refer to that document for a more detailed discussion.

We believe the first commercially productive plant will be started in the 2001-to-2003 period (after the feasibility noted above), with serious volume ramp-up in the 2003-to-2005 period, which would be consistent with shrink 0.25-micron technology being produced primarily on 300mm wafers. This means that 200mm wafers represent at least a two-technology-generation wafer size, and fabs being built today may have longer lives than history would indicate.

Highlights of the North American Silicon Wafer Market and Forecast

Silicon consumption in North America is forecast to grow 28 percent in 1995 to 1,066 million square inches (MSI), followed by mild, 11 percent growth in 1996 to 1,185 MSI. Microprocessor and other logic chip demand has been and will continue to be the key driver behind increased silicon demand in North America, and epitaxial wafer demand is expected to grow faster than the overall market throughout this decade.

Merchant epitaxial wafer consumption will increase 27 percent to 242 MSI, driven in large part by microprocessor manufacturers such as Intel and AMD, which build their microprocessors on epitaxial wafers. The automotive and discrete segments of the chip market have also been much stronger than expected. By 1998, epitaxial silicon will account for 25 percent of the square inches consumed in North America—the highest concentration in any region.

Dataquest's longer-term forecast for North American silicon consumption has increased, in part because of the increase in the overall semiconductor market revision since the last update, but also because we believe that the United States will attract a larger share of foreign multinational fabs, such as those recently announced by Hyundai, TSMC, Toshiba (joint venture fab), and Samsung. We are projecting that total silicon MSI will grow at a 12.3 percent CAGR for 1994 through 2000.

Highlights of the Japanese Silicon Wafer Market and Forecast

Our Japanese silicon consumption forecast has slightly increased from our last update, with the silicon market expected to have grown 18 percent to 1,506 MSI in 1995, with continued strong growth in 1996 and with softening in 1997 through 1999. The persistent high price of 4Mb DRAMs through 1995, with low yields restricting economical production of the more silicon-efficient 16Mb density, is the reason for the continued near-term optimism. As conversion to the 16Mb density occurs, silicon square-inch demand will ease.

Unlike North America, with its sizable CMOS epitaxial wafer market, Japan's merchant epitaxial wafer market is more focused on discrete and bipolar applications. Therefore, a recovery in the economy will have more of an effect on the growth of Japan's epitaxial wafer market, and early indications are that it has kicked into gear. Epitaxial demand is expected to have grown 30 percent in 1995 after a 34 percent increase in 1994. Another good growth year is expected in 1996.

Dataquest's longer-term growth scenario for silicon wafer demand in Japan remains moderately conservative as the country continues to work through difficulties with the economy and semiconductor production infrastructure (too heavily dependent on DRAM). Recent investment patterns, however, indicate that Japanese semiconductor manufacturers are willing to come to the table and invest, preserving their stake in the memory business against Korean companies. The desired shift of the Japanese product mix to higher value-added semiconductors is apparently on the back burner until the current memory cycle subsides, but will come to the forefront soon. We are estimating that silicon demand will grow at a

10.5 percent CAGR for the years 1994 through 2000, the slowest growth of all regions.

Highlights of the European Silicon Wafer Market and Forecast

Demand for silicon wafers in Europe, as well as wafer fabrication equipment, remains heavily dependent on the fab activities of foreign semiconductor firms. With increased presence from European companies, the outlook for silicon consumption has brightened.

European silicon demand has basically remained unchanged from our previous forecast at a level of 409 MSI in 1995, up just over 16 percent from 1994 levels. Siemens Dresden and other DRAM production and U.S. multinationals Intel, Motorola, and Texas Instruments will continue to ramp to answer the PC production boom in Europe, helping silicon consumption grow another 16 percent in 1996. These driving forces have caused us to call Europe the second-fastest-growing region for silicon consumption, growing at a rate of 12.7 percent CAGR through the year 2000.

Epitaxial wafer demand in the region will increase from 36 MSI in 1993 to 72 MSI in 1995, nearly double consumption, a direct result of Intel in Ireland. Beyond 1995, epitaxial wafer demand will come from European producers, primarily from the power/discrete market, leading to a CAGR more than three percentage points above polished bare wafer consumption through the decade.

Highlights of the Asia/Pacific-ROW Silicon Wafer Market and Forecast

Silicon consumption is growing at a 33 percent pace in 1995, the largest growth rate of any region in the world. Production is expanding at a fierce pace and not expected to ease through 1997, as many large 200mm fab projects are in various stages of construction and start-up. Because the Asia/Pacific region collects nearly the largest proportion of 1995 capital, the trend for high silicon consumption growth will continue unabated. The phenomenal growth in Asia/Pacific silicon consumption in 1995 is tied directly to the manufacturing activities of Korean DRAM producers. Growth will be seen here, but increased production in Taiwan, Singapore, and the most recently announced Thailand foundries will also contribute. Foundry-related capital spending in these Asia/Pacific countries has exploded, increasing from about $900 million in 1994 to over $1.8 billion in 1995. As these fabs come on line in 1995 and beyond, they will provide some regional consumption stability as memory-related silicon consumption cools in 1997 and 1998. Taiwan, with its many new DRAM producers coming on line in 1996, will cause silicon consumption to grow by nearly 26 percent again in 1996. Asia/Pacific-ROW remains the fastest-growing silicon consumer, with a forecast five-year CAGR of 21.2 percent.

Silicon Wafer Revenue Forecast

Dataquest has been tracking silicon wafer revenue and market share since 1985, but has always provided forecast information in terms of square inches of area and unit wafer size distributions. With the announcement of the initial public offering of MEMC Electronic Materials in July 1995, we believe it is now important to consider the revenue-generating capability of the industry.

We believe a revenue forecast will benefit our clients, gaining increased visibility for the capital markets. Table 4-11 contains the revenue forecast for silicon wafers worldwide. Our analysis concludes that the revenue forecast would resemble the semiconductor industry more closely than the capital spending markets. The concept of semiconductor revenue per square inch is more closely tied to silicon consumption than raw wafer capacity of the industry. The six-year CAGR of 18.9 percent is about one percentage point below the semiconductor forecast of 20.1 percent, consistent with the model that semiconductor manufacturers will attempt to control the costs associated with manufacturing, which includes using silicon more efficiently in the future. Yet, based on the fact that silicon manufacturers are attaining price increases in a sellers' market, this forecast may prove conservative in the near term.

Table 4-11
Worldwide Merchant Silicon Wafer Revenue Forecast, 1992-2000 (Includes Polished, Virgin Test, and Epitaxial Silicon; Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
Worldwide	2,991	3,554	4,592	6,012	7,470	8,995	10,199	11,256	12,951	18.9
Growth (%)	2.7	18.8	29.2	30.9	24.3	20.4	13.4	10.4	15.1	

Source: Dataquest (January 1996)

Dataquest Perspective

The silicon market, driven by a stronger long-term picture for semiconductors in general, will grow faster over the next six years than it has in the recent past. As the industry moves to a 200mm baseline, the outlook for silicon wafer manufacturers becomes brighter. Silicon manufacturers have answered the call for 200mm capacity, and the semiconductor market has again responded with a cry for more. We believe silicon manufacturers' ramp plans in 200mm have been strategically and smartly measured and that the overcapacity situations of 1985 are being remembered, and we are not expecting that scenario to be repeated.

Although there will be activity with 300mm wafers, this is expected to be focused on R&D and confined to low volumes until after the turn of the decade.

Chapter 5
Semiconductor Consumption Forecast

This chapter presents data on the worldwide semiconductor market by region. The regional semiconductor market, or regional semiconductor consumption, deals with where chips are consumed; this contrasts with regional semiconductor production, which deals with where chips are manufactured. The data presented here is for the merchant market and does not include the value of chips made by captive semiconductor manufacturers for internal use.

This is an excerpt from the Semiconductor Five-Year Forecast, published by Dataquest in October 1995 (SCND-WW-MT-9502). Further details about this forecast can be found in that publication.

Yearly exchange rate variations can have a significant effect on the 1988-through-1995 data in the following tables. For more information about the exchange rates used and their effects, see Appendix B.

Semiconductor Consumption

Table 5-1 shows revenue and growth from semiconductor shipments for 1988 through 1994, by region. Table 5-2 shows revenue and growth from semiconductor shipments for 1994 through 2000, by region.

Table 5-1
Worldwide Semiconductor Consumption by Region—Historical (Includes Merchant Semiconductor Companies Only; Millions of U.S. Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1994
North America	15,844	17,070	16,540	16,990	20,430	27,926	35,939	16.1
Growth (%)	23.2	7.7	-3.1	2.7	20.2	36.7	28.7	
Japan	20,772	21,491	20,257	22,496	20,579	24,645	31,010	7.6
Growth (%)	39.2	3.5	-5.7	11.1	-8.5	19.8	25.8	
Europe	8,491	9,498	10,415	11,014	12,218	15,461	20,819	17.0
Growth (%)	30.7	11.9	9.7	5.8	10.9	26.5	34.7	
Asia/Pacific-ROW	5,752	6,280	7,333	9,194	12,034	17,486	22,812	29.4
Growth (%)	45.0	9.2	16.8	25.4	30.9	45.3	30.5	
Worldwide	50,859	54,339	54,545	59,694	65,261	85,518	110,580	15.3
Growth (%)	33.0	6.8	0.4	9.4	9.3	31.0	29.3	

Source: Dataquest (January 1996)

Table 5-2
Worldwide Semiconductor Consumption by Region—Forecast (Includes Merchant Semiconductor Companies Only; Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
North America	35,939	47,805	60,307	71,508	80,947	92,908	112,325	20.9
Growth (%)	28.7	33.0	26.2	18.6	13.2	14.8	20.9	
Japan	31,010	41,843	47,638	52,760	58,446	65,241	75,680	16.0
Growth (%)	25.8	34.9	13.8	10.8	10.8	11.6	16.0	
Europe	20,819	28,995	35,517	39,674	44,895	51,859	62,231	20.0
Growth (%)	34.7	39.3	22.5	11.7	13.2	15.5	20.0	
Asia/Pacific-ROW	22,812	31,145	39,446	46,419	54,311	65,736	81,250	23.6
Growth (%)	30.5	36.5	26.7	17.7	17.0	21.0	23.6	
Worldwide	110,580	149,788	182,908	210,361	238,599	275,744	331,486	20.1
Growth (%)	29.3	35.5	22.1	15.0	13.4	15.6	20.2	

Source: Dataquest (January 1996)

Chapter 6
Semiconductor Production Forecast

This chapter presents data on worldwide semiconductor production by region. Semiconductor production is defined by the place where the wafers are fabricated, and regional semiconductor production includes all production in the region, including merchant and captive producers and all foreign producers. For instance, North American semiconductor production includes Digital Equipment Corporation and Delco fabs, as well as the North American fabs of Japanese and European companies.

Yearly exchange rate variations can have a significant effect on the 1988-through-1995 data in the following tables. For more information about the exchange rates used and their effects, see Appendix B.

The semiconductor industry has a global manufacturing business. Production of semiconductors is constantly shifting among regions as new capital flows to areas of relatively lower capital cost and areas of higher growth in consumption. Dataquest reviews some of the trends and potential impacts for the future.

Historical Semiconductor Production

Table 6-1 shows historical semiconductor production for 1988 through 1994, by region. Dataquest follows a methodology that uses our fab database, estimating the memory, microcomponent, and logic production components separately and estimating net production among regions for foundry activity. This approach provides insight in observing and forecasting production trends.

Because of the reclassification as merchant of the MOS portion of IBM Microelectronics' business, the captive production figures changed dramatically in 1993. However IBM's bipolar production, which is consumed internally, is still classified as captive by Dataquest.

Captive Semiconductor Production

Semiconductor production from captive manufacturers is estimated to be $1.98 billion in 1994, down from just over $2 billion in 1993. IBM has restructured and entered the merchant semiconductor market as of 1993. Dataquest has reclassified IBM's MOS semiconductor production to merchant, but the bipolar products (exclusively used internally) are still reported as captive. This part of IBM's business will be converted to MOS over the next four to five years and had resulted in a lower production figure for captive production in 1994 and the future.

Captive producers may consider moving to merchant to take better advantage of the worldwide growth of semiconductors, leveraging their investments in plant and equipment for higher return in a larger end-user base. Others may elect to take advantage of the evolving and maturing foundry business, electing to contract out their manufacturing rather than investing in expensive new facilities for their relatively small production base. We have not, however, included any such movement to merchant or fabless status in our captive production forecast.

Table 6-1
Worldwide Semiconductor Production by Region—Historical (Merchant and Captive Semiconductor Company Sales; Millions of U.S. Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1988-1994
Total North America	20,533	22,232	24,202	26,039	29,457	33,446	40,268	11.9
Growth (%)	20.8	8.3	8.9	7.6	13.1	13.5	20.4	
Percentage of Worldwide	37.3	37.6	40.8	40.4	41.8	38.2	35.8	
Merchant	17,326	18,464	20,453	22,275	25,248	31,745	38,508	14.2
Captive	3,207	3,768	3,749	3,764	4,209	1,701	1,760	-9.5
Total Japan	26,732	28,527	26,384	28,338	28,023	34,744	44,670	8.9
Growth (%)	40.5	6.7	-7.5	7.4	-1.1	24.0	28.6	
Percentage of Worldwide	48.6	48.2	44.5	44.0	39.8	39.7	39.7	
Merchant	26,388	28,119	25,977	27,925	27,664	34,744	44,670	9.2
Captive	344	408	407	413	359	0	0	-100.0
Total Europe	5,854	6,451	6,350	6,979	8,589	11,772	15,780	18.0
Growth (%)	23.9	10.2	-1.6	9.9	23.1	37.1	34.0	
Percentage of Worldwide	10.6	10.9	10.7	10.8	12.2	13.4	14.0	
Merchant	5,277	5,782	5,723	6,396	7,957	11,452	15,560	19.7
Captive	577	669	627	583	632	320	220	-14.8
Total Asia/Pacific-ROW	1,868	1,974	2,392	3,097	4,391	7,577	11,842	36.0
Growth (%)	71.8	5.7	21.2	29.5	41.8	72.6	56.3	
Percentage of Worldwide	3.4	3.3	4.0	4.8	6.2	8.7	10.5	
Merchant	1,868	1,974	2,392	3,097	4,391	7,577	11,842	36.0
Captive	NA	NA	NA	NA	NA	NA	NA	
Worldwide	54,987	59,184	59,328	64,453	70,460	87,539	112,560	12.7
Growth (%)	31.4	7.6	0.2	8.6	9.3	24.2	28.6	
Merchant	50,859	54,339	54,545	59,693	65,260	85,518	110,580	13.8
Growth (%)	33.0	6.8	0.4	9.4	9.3	31.0	29.3	
Captive	4,128	4,845	4,783	4,760	5,200	2,021	1,980	-11.5
Growth (%)	15.2	17.4	-1.3	-0.5	9.2	-61.1	-2.0	

NA = Not applicable
Source: Dataquest (January 1996)

The Move toward Asia Continues, Europe Growth Rests Temporarily

The production trends of the last three years may contain two or three surprises. Of no surprise is the strong growth in Asia/Pacific production, over 10 percent of worldwide production in 1994. The strength of Asian DRAM producers and the emergence of the foundry market have been and will continue to be the key drivers in that growth. Increased, and somewhat uninhibited, capital spending recently will certainly continue this trend.

What may be the first surprise is the strength in European production, expanding from just under 11 percent of the semiconductors produced in 1991 to 14 percent in 1994. This is also remarkable in that the last three years have been good overall growth years, resulting in the region's production more than doubling in three years. Why the move to Europe? With the region's economies recovering and the PC boom continuing, Europe has attracted PC production, particularly in the United Kingdom. Semiconductor production has moved along with the PC, with Intel and DRAM producers worldwide taking part. Also, the acceleration of telecommunications-related semiconductor production benefits European companies. Dataquest believes that, although multinationals will continue to invest heavily in Europe, the trend is in a holding pattern in part because of the concentration of spending growth in Asia.

The second surprise may be the relative decline in the percentage of the world's production being done in the United States. Over the last two years, North American production decreased from about 42 to 36 percent of the world's production overall. Several factors are at work here. First, North American multinational companies have been investing heavily overseas. North America has been a net exporter of capital for several years now, as foreign companies have yet to balance the scales with investments inside the United States. This trend should stabilize over the next several years because Japanese and Korean companies have started to accelerate their investment in the United States.

Second, although U.S. companies are recognized as technology leaders, they have recently begun calling on foreign producers to manufacture their products in the foundry market. Fabless companies have been the key drivers of the market to this point, but starting in 1994 we saw a major shift in increasing use of foundries by IDMs. In 1995 we expect U.S. IDMs to increase their foundry purchases by 100 percent, with most of this production overseas. The imbalance in the concentration of foundry capacity is starting to make U.S. semiconductor companies a little nervous and they have actually impressed upon key foundry suppliers the need to begin building production in the United States. In fact, TSMC recently announced plans to build a major fab in the United States, and we believe that other foundry companies are likely to follow. Clearly, users of foundry have stated a preference for close access to the fab. Foundry providers with capacity in the United States are likely to have a more stable customer base.

And third, although Japanese and European companies have invested somewhat outside their own countries, these companies have remained "patriots of the domestic economy" and have kept the vast majority of their investment within their region. This, along with the strong DRAM market over the last two years, has stabilized the Japanese production proportion over the last two years, keeping the share of the production market at about 40 percent (this could be surprise No. 3). However the DRAM market is cyclical, and Japanese foundries will feel pressure from Asian producers, so we expect a resumption of the gradual decay in the base of production in Japan through the rest of the decade.

Semiconductor Production Trends: Accelerating Shift to Asia/Pacific

Table 6-2 shows forecast semiconductor production by region for the period from 1994 through 2000. The major trend is the growth of the Asia/Pacific region, mostly at the expense of Japan. Companies such as TSMC and UMC in Taiwan, Chartered Semiconductor in Singapore, and SubMicron Technology in Thailand will accelerate capacity rapidly beginning in 1996. New DRAM companies (Vanguard, Powerchip Semiconductor, and Nan Ya Technology) have sprung up in Taiwan and likely to further erode Japanese DRAM share. By 2000, Dataquest believes that Asia/Pacific-ROW will expand to over 14 percent on a revenue basis.

North America will remain steady on a percentage basis as the lower cost of capital and clear leadership in technology and design motivate companies to invest in the United States. Europe production share is expected to expand slightly, with a product mix shifting toward a higher memory component, driven by the need for proximity to PC production as more DRAM capacity is added by large international companies over the next several years. Japan's share of production is likely to continue to erode as the cost of capital remains high and as Japanese companies increasingly invest in capacity overseas.

Table 6-2
Worldwide Semiconductor Production by Region—Forecast (Merchant and Captive Semiconductor Company Sales; Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
Total North America	40,268	55,181	66,049	75,487	85,641	99,595	119,715	19.9
Growth (%)	20.4	37.0	19.7	14.3	13.5	16.3	20.2	
Percentage of Worldwide	35.8	36.4	35.8	35.6	35.6	35.9	35.9	
Merchant	38,508	53,474	64,384	73,837	83,987	97,889	118,009	20.5
Captive	1,760	1,707	1,665	1,650	1,654	1,706	1,706	-0.5
Total Japan	44,670	58,867	70,968	78,885	87,089	99,268	117,678	17.5
Growth (%)	28.6	31.8	20.6	11.2	10.4	14.0	18.5	
Percentage of Worldwide	39.7	38.8	38.4	37.2	36.2	35.8	35.3	
Merchant	44,670	58,867	70,968	78,885	87,089	99,268	117,678	17.5
Captive	NA	NA	NA	NA	NA	NA	NA	
Total Europe	15,780	20,381	25,353	29,951	34,406	40,013	48,095	20.4
Growth (%)	34.0	29.2	24.4	18.1	14.9	16.3	20.2	
Percentage of Worldwide	14.0	13.4	13.7	14.1	14.3	14.4	14.4	
Merchant	15,560	20,221	25,241	29,871	34,358	39,983	48,065	20.7
Captive	220	160	112	80	48	30	30	-28.3
Total Asia/ Pacific-ROW	11,842	17,226	22,315	27,768	33,165	38,604	47,734	26.2
Growth (%)	56.3	45.5	29.5	24.4	19.4	16.4	23.6	
Percentage of Worldwide	10.5	11.4	12.1	13.1	13.8	13.9	14.3	
Merchant	11,842	17,226	22,315	27,768	33,165	38,604	47,734	26.2
Captive	NA	NA	NA	NA	NA	NA	NA	NA
Worldwide	112,560	151,655	184,685	212,091	240,301	277,480	333,222	19.8
Growth (%)	28.6	34.7	21.8	14.8	13.3	15.5	20.1	
Merchant	110,580	149,788	182,908	210,361	238,599	275,744	331,486	20.1
Growth (%)	29.3	35.5	22.1	15.0	13.4	15.6	20.2	
Captive	1,980	1,867	1,777	1,730	1,702	1,736	1,736	-2.2
Growth (%)	-2.0	-5.7	-4.8	-2.6	-1.6	2.0	0.0	

NA = Not applicable
Source: Dataquest (January 1996)

Dataquest Perspective

Where the PC goes, so go semiconductors. This is true from the perspective of the business forecast as well as the production line. Europe and Asia/Pacific, with very large capital spending upticks over the last several years (continuing in 1995 in Asia) will gain share in world production over the next several years.

The shifts and currents in semiconductor production trends mean that equipment and material suppliers will absolutely need a global presence in every sense of the word to remain competitive in the market. Product supply and support can no longer concentrate on local trends, because all major semiconductor companies have made it clear they are investing on a worldwide basis.

Taiwan is clearly the new major production growth area. We would expect Malaysia and Thailand to become the next major growth countries in three to five years. Evidence of this includes recent joint-venture fab announcements by Texas Instruments and others. Silicon plants are now being strategically placed, such as SEH's Malaysian plant and its recently announced joint venture in Taiwan, Komatsu's joint venture with Formosa Plastics in Taiwan, and MEMC's joint ventures in both Korea (Posco-Hüls) and Taiwan (Taisil).

Further, the concept of contract manufacturing in semiconductors is clearly here to stay. Equipment and material suppliers could find themselves selling their technical products to an international team from several companies, including the manufacturer and the designer. However, the emergence of the dedicated foundry company, taking ownership of the process and manufacturing flow, will tend to centralize this activity. Dataquest has started a research service in Semiconductor Contract Manufacturing, with a major report planned for the end of January 1996. This report will explore the key trends in contract manufacturing and foundries, including technology trends and supply/demand balance through the decade.

Appendix A

Economic Assumptions, Fourth Quarter 1995

Optimism of International Business Executives Continues to Decline

Dun & Bradstreet's most recent quarterly survey of international business executives revealed slipping optimism about the near-term growth of net sales and net profits worldwide. Survey respondents also disclosed reduced optimism about near-term growth of selling prices, employment, and inventories worldwide. The continued decline in expectations furthered the trend toward reduced optimism that emerged at the beginning of 1995. Global business executives now anticipate more moderate expansion than they did a year ago when optimism was at its peak for the current business cycle.

Despite Slipping Expectations, the Near-Term Outlook for the World Economy Remains Strong

Although the number of bears grew among international executives, the results of the Dun & Bradstreet survey continued to indicate that executives, on balance, are bullish about the world economy. Solid growth in sales and profits is expected in nearly every region of the world, and most regions anticipate some increase in selling prices accompanied by steady employment and inventories. Only Japanese, Mexican, and Brazilian executives expressed contrarian pessimistic near-term views. In these countries, the outlook continues downcast, especially for selling prices, employment, and inventories.

The Long-Term Outlook for the World Economy Likewise Remains Strong

The latest long-term forecasts from Dun & Bradstreet subsidiary A.C. Nielsen also indicate that the world economy will prosper through 2000. These forecasts indicate that the world's developed economies will continue to experience moderate but healthy economic growth through 2000. Growth among developed economies is forecast to average 2.5 percent in 1995, following 2.9 percent growth in 1994. Growth is anticipated to increase gradually to the end of the decade, reaching 3.1 percent by 2000. Growth among the world's emerging economies will continue to vary by region. Emerging Asia/Pacific economies should continue to post impressive rates of growth. Growth among these economies is forecast to average 7.9 percent in 1995, following 8.2 percent growth in 1994. Growth is anticipated to slow somewhat by 2000 but even then will still be an enviable 6.7 percent annually. Emerging Latin American and Eastern European economies will continue to lag behind their Asia/Pacific counterparts. Growth among emerging Latin American economies (Argentina, Brazil, Chile, Mexico, and Venezuela) is forecast to be 0.5 percent in 1995, largely because of anticipated contractions in Mexico and Argentina. Growth is anticipated to accelerate through the end of the decade, rising to 5.5 percent by 2000. Emerging Eastern European economies are forecast to experience 3.7 percent growth in 1995, up from 0.4 percent in 1994. Growth among these economies is expected to accelerate, reaching 4.4 percent by 2000.

A summary of gross domestic product (GDP) and consumer price index (CPI) forecasts for the G7 nations is shown in Tables A-1 and A-2, respectively.

Table A-1
Gross Domestic Product/Gross National Product Growth Rates: Outlook as of December 15, 1995—Constant Prices and Exchange Rates, Local Currencies (Percent)

Year	United States	Canada	Japan	France	Germany	Italy	United Kingdom
1990	1.2	-0.2	4.8	2.5	NA	2.1	0.6
1991	-0.6	-1.8	4.3	0.8	NA	1.3	-2.3
1992	2.6	0.6	1.1	1.3	1.8	0.7	-0.5
1993	3.1	2.2	-0.2	-1.5	-1.2	-1.2	2.1
1994	4.1	4.6	0.5	2.9	3.0	2.2	3.9
1995	3.3	2.2	0.5	2.7	2.3	3.0	2.8
1996	3.1	2.5	2.0	2.3	2.5	2.7	2.8
1997	3.7	3.0	2.6	2.9	2.8	2.6	2.8
1998	3.2	2.9	3.2	3.2	3.1	2.5	2.7
1999	3.1	2.8	3.5	3.1	2.8	2.5	2.7
2000	3.0	2.8	3.2	3.0	2.7	2.5	2.7

Source: A.C. Nielsen

Table A-2
Consumer Price Index Growth Rates: Outlook as of December 15, 1995 (Percentage Change)

Year	United States	Canada	Japan	France	Germany	Italy	United Kingdom
1990	5.4	4.8	3.1	3.4	NA	6.1	9.5
1991	4.2	5.6	3.3	3.1	NA	6.4	5.9
1992	3.0	1.5	1.6	2.4	4.0	5.4	3.7
1993	2.9	1.8	1.3	2.1	4.1	4.2	1.6
1994	2.6	0.2	0.7	1.7	1.8	3.9	2.4
1995	2.9	2.2	0.0	1.9	2.0	5.3	3.5
1996	2.8	2.5	0.2	2.5	2.3	4.5	3.0
1997	2.8	2.4	0.5	2.4	2.4	3.9	2.8
1998	2.6	2.2	0.7	2.3	2.2	3.5	2.6
1999	2.5	2.1	0.9	2.2	2.0	3.2	2.5
2000	2.4	2.0	1.0	2.1	2.0	2.9	2.4

NA = Not available
Source: A.C. Nielsen

Americas: Continued Stability for the United States and Canada; Increased Uncertainty for Mexico and Brazil

Dun & Bradstreet survey results continue to indicate high optimism in both the United States and Canada. Executives in both countries anticipate stable conditions over the near term with only moderately slower economic expansion and sustained high levels of employment. In contrast, conditions in Mexico and Brazil appear increasingly uncertain. Once again, continuing economic and political instability in Mexico made it impossible to gather any meaningful survey results for the country. In Brazil, all survey indexes registered sharp declines for the second survey in a row. Brazilian expectations for the near-term have now turned deeply pessimistic for net profits and employment. Longer-term growth forecasts for the Americas are as follows:

- The United States' GDP is now forecast to grow 3.3 percent in 1995, down from 4.1 percent growth in 1994. Growth is anticipated to decelerate to 3.1 percent in 1996. Growth is then expected to quicken slightly, averaging 3.2 percent annually through 2000.
- Canada's GDP is now forecast to grow 2.2 percent in 1995, down from 4.6 percent growth in 1994. Growth is anticipated to increase to 2.5 percent in 1996. Growth is then expected to further accelerate through 2000, averaging 2.9 percent annually.
- Mexico's GDP is now forecast to contract 5.5 percent in 1995, a sharp reversal from the 3.7 percent growth experienced in 1994. Growth of 2.0 percent is anticipated in 1996. Growth is then expected to accelerate, averaging nearly 5.0 percent annually through 2000.
- Brazil's GDP is now forecast to grow 5.0 percent in 1995, down from 5.7 percent growth in 1994. Growth is anticipated to slow further to 4.0 percent in 1996. Growth is then expected to accelerate through 2000, averaging just over 5.5 percent annually.

Europe: Optimism Remains Buoyant

Dun & Bradstreet survey results reveal buoyant near-term optimism among European executives. All survey indexes remained positive, with some indexes inching up slightly over the values observed in the last survey. Expectations of significantly faster near-term growth in Germany and Italy offset lower levels of near-term optimism in the United Kingdom and Belgium. Longer-term growth forecasts for Europe are as follows:

- France's GDP is now forecast to grow 2.7 percent in 1995, down from 2.9 percent growth in 1994. Growth is anticipated to slow further to 2.3 percent in 1996. Growth is then expected to increase, averaging slightly over 3.0 percent annually through 2000.
- Germany's GDP is now forecast to grow 2.3 percent in 1995, down from 3.0 percent in 1994. Growth is anticipated to increase to 2.5 percent in 1996. Growth is then expected to further accelerate through 2000, averaging nearly 2.9 percent annually.

- Italy's GDP is now forecast to grow 3.0 percent in 1995, up from 2.2 percent growth in 1994. Growth is anticipated to slow somewhat to 2.7 percent in 1996. Growth is then expected to level off and average slightly over 2.6 percent annually through 2000.
- The United Kingdom's GDP is now forecast to grow 2.8 percent in 1995, down from 3.9 percent growth in 1994. Growth is anticipated to remain the same in 1996 at 2.8 percent. Growth is then expected to remain steady through 2000, averaging just over 2.7 percent annually.

Japan and Asia/Pacific: Outlook in Japan Remains Glum

Dun & Bradstreet survey results indicate that pessimism continues to darken Japanese expectations. The survey indexes for selling prices and inventories remain negative. The positive indexes for net sales and employment recorded in the last survey registered marked declines, with the latter actually turning negative. Although the yen has weakened somewhat since summer, the relative strength of the yen against the U.S. dollar and other currencies continues to impact both Japan and the rest of Asia. Imports from the United States and elsewhere induced by the strong yen continue to depress Japanese prices and profit margins. Added to this, the strong yen continues to depress exports and encourage the migration of Japanese manufacturing to other parts of Asia. Longer-term forecasts for Japan and Asia/Pacific are as follows:

- Japan's GDP is now forecast to grow 0.5 percent in 1995, unchanged from 1994. Growth is anticipated to accelerate to 2.0 percent in 1996. Growth is then expected to further accelerate through 2000, averaging 3.1 percent annually.
- China's GDP is now forecast to grow 9.5 percent in 1995, down from 11.8 percent in 1994. Growth is expected to slow in 1996 to 9.0 percent. Further deceleration of growth is expected through 2000 as the Chinese economy matures.
- Taiwan's GDP is now forecast to grow 6.9 percent in 1995, down from 6.5 percent growth in 1994. Growth is anticipated to slow back to 6.5 percent in 1996. Growth is then anticipated to remain at or near this level through 2000.
- South Korea's GDP is now forecast to grow 9.0 percent in 1995, up from 8.4 percent in 1994. Growth is anticipated to decelerate to 7.5 percent in 1996. Growth is then expected to settle down to 7.0 percent annually through 2000.

Dun & Bradstreet's quarterly International Survey of Business Expectations is modeled on its quarterly Survey of U.S. Business Expectations, which has been conducted in the United States since 1947. Survey participants are asked if they expect increases, decreases, or no change in their sales, profits, prices, inventories, and employment levels in the upcoming quarter, compared with the same quarter a year ago. Results of the U.S. survey have proven highly accurate, with quarterly forecasts closely paralleling actual performance.

The current international survey, completed in September 1995, uses similar sampling and interviewing procedures in all countries. Hence, the results provide unique "apples-to-apples" comparisons of trends in business expectations worldwide. The Dun & Bradstreet index figures discussed here represent the net percentage of survey respondents expecting higher sales, profits, and so on. The indexes are calculated by subtracting the percentage of respondents expecting decreases from those expecting increases. GDP and CPI growth rates quoted here are A.C. Nielsen's most current forecasts from December 1995.

Appendix B

Exchange Rates

Dataquest does not forecast exchange rates per se; however, we do forecast semiconductor-related markets in several regions of the world, and we use the U.S. dollar as a common currency for intermarket comparisons and aggregation. In general, in the forecast period Dataquest assumes that the actual exchange rate of the full month before the month in which the forecast-input assumptions are set will apply throughout all future months of the forecast interval. For the forecasts presented here:

- Actual monthly exchange rates were used for all months in the historical interval up to September 1995.
- The September 1995 exchange rate was then assumed to hold for October through December 1995 and throughout 1996 to 2000.

Dataquest uses an average annual exchange rate to convert annual revenue from local currency values to U.S. dollar values. Table B-1 outlines the rates used in the forecasts presented here.

Table B-1
Exchange Rates per U.S. Dollar

Country	1994	1995*	U.S. $ Appreciation 1994-1995 (%)*	1996-2000*
Argentina (Peso)	NA	1.00	NM	1.00
Australia (Dollar)	NA	1.35	NM	1.33
Austria (Schilling)	11.40	10.09	-11.49	10.18
Bangladesh (Taka)	NA	NA	NM	40.36
Belgium (Franc)	33.36	29.52	-11.53	29.76
Brazil (Cruzeiro)	NA	0.91	NM	0.95
Bulgaria (Lev)	NA	NA	NM	68.05
Canada (Dollar)	NA	NA	NM	1.34
Chile (Peso)	NA	394.27	NM	397.49
China (Yuan)	8.54	8.35	-2.16	8.32
Colombia (Peso)	NA	903.68	NM	957.86
Cyprus (Pound)	NA	NA	NM	0.45
Czech Republic (Koruny)	NA	NA	NM	26.65
Denmark (Krone)	6.35	5.61	-11.62	5.62
Dominican Republic (Peso)	NA	NA	NM	13.81
Ecuador (Sucre)	NA	NA	NM	2,637.58
ECU	0.84	0.77	-8.28	0.78
Finland (Markka)	5.21	4.38	-15.94	4.33
France (Franc)	5.54	4.99	-9.92	4.98
Germany (Mark)	1.62	1.44	-11.43	1.45
Greece (Drachma)	242.06	231.10	-4.53	234.43
Guatemala (Quetzal)	NA	NA	NM	5.84
Hong Kong (Dollar)	7.73	7.74	0.11	7.74
Hungary (Forint)	NA	NA	NM	132.63

(Continued)

Table B-1 (Continued)
Exchange Rates per U.S. Dollar

Country	1994	1995*	U.S. $ Appreciation 1994-1995 (%)*	1996-2000*
India (Rupee)	31.15	31.91	2.44	32.86
Indonesia (Rupiah)	NA	2,240.77	NM	2,266.01
Ireland (Punt)	0.67	0.62	-6.70	0.62
Israel (New Sheqalim)	NA	NA	NM	3.03
Italy (Lira)	1,609.34	1,634.59	1.57	1,620.50
Japan (Yen)	101.81	93.04	-8.61	98.52
Malaysia (Ringgit)	2.62	2.50	-4.64	2.50
Mexico (Peso)	NA	6.17	NM	6.32
Morocco (Dirham)	NA	NA	NM	8.52
Netherlands (Guilder)	1.82	1.61	-11.54	1.62
New Zealand (Dollar)	NA	1.52	NM	1.53
Norway (Krone)	7.04	6.34	-10.06	6.33
Pakistan (Rupee)	NA	NA	NM	31.40
Paraguay (Guarani)	NA	NA	NM	1,965.99
Peru (New Sol)	NA	2.24	NM	2.25
Philippines (Peso)	NA	25.69	NM	25.99
Poland (Zloty)	NA	NA	NM	2.38
Portugal (Escudo)	165.63	150.08	-9.39	151.17
Romania (Lei)	NA	NA	NM	2,090.10
Russia (Ruble)	NA	NA	NM	4,450.87
Singapore (Dollar)	1.53	1.43	-6.46	1.42
Slovakia (New Koruna)	NA	NA	NM	30.37
South Africa (Rand)	NA	NA	NM	3.65
South Korea (Won)	802.84	770.75	-4.00	770.69
Spain (Peseta)	133.48	124.91	-6.41	124.41
Sweden (Krona)	7.70	7.25	-5.80	7.12
Switzerland (Franc)	1.37	1.19	-13.20	1.18
Taiwan (Dollar)	26.45	26.49	0.15	27.28
Thailand (Baht)	25.36	24.89	-1.85	25.07
Tunisia (Dinar)	NA	NA	NM	0.94
Turkey (Lira)	NA	44,573.38	NM	48,473.10
United Kingdom (Pound)	0.65	0.63	-3.33	0.64
Uruguay (Peso)	NA	NA	NM	6.63
Venezuela (Bolivar)	NA	NA	NM	169.79
Vietnam (Dong)	NA	NA	NM	11,027.79
Zimbabwe (Dollar)	NA	NA	NM	8.69

*Estimated
NA = Not available; not tracked until 1995
NM = Not meaningful
Source: Dataquest (December 1995)

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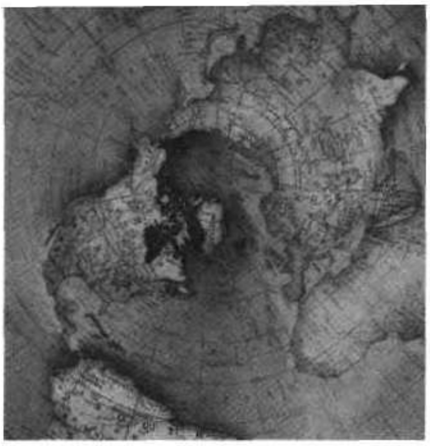

Dataquest

Asia/Pacific Fab Database

Market Statistics

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
Product Code: SEMM-WW-MS-9506
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Filing: Market Analysis

Asia/Pacific Fab Database

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Table of Contents

List of Tables

Note: All tables show estimated data.

Asia/Pacific Fab Database

Background

This document contains the Asia/Pacific portion of Dataquest's wafer fab database. The Semiconductor Equipment, Materials, and Manufacturing Worldwide (SEMM) program uses both primary and secondary research to update this data. The tables in this report cover both merchant and captive production and pilot-line facilities, although our surveys and database also include R&D fabs.

Research Methodology

Dataquest conducts extensive annual surveys, complemented with quarterly secondary research. This data is then supplemented and cross-checked with various other information sources.

General Definitions

Fab line: A fab line is a semiconductor processing facility equipped for all front-end wafer manufacturing. Occasionally, there are two or more separate product-specific fab lines or wafer sizes in a single cleanroom. In this situation, Dataquest documents the cleanroom as separate fab lines if the company dedicates equipment to each wafer size or product line. Therefore, a company may operate many fab lines at one location.

Front-end wafer processing: Dataquest defines front-end wafer processing as all steps involved in semiconductor processing, beginning with initial oxide and ending at wafer probe.

Production fab: A wafer fab capable of front-end processing more than 1,250 wafers per week is a production fab (type = F).

Pilot fab: A wafer fab capable of front-end processing 1,250 or fewer wafers per week is a pilot fab (type = P).

Worldwide Geographic Region Definitions and Regional Roll-Ups

Americas

Includes Central America (all nations), Canada, Mexico, United States and Puerto Rico, and South America (all nations).

Japan

Japan is the only single-country region.

Europe, Africa, and Middle East

Includes Africa (all nations), Albania, Andorra, Armenia, Azerbaijan, Belarus, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Gibraltar, Hungary, Iceland, Israel, Italy, Kazakhstan, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Middle East (all nations), Moldova, Monaco,

Netherlands, Norway, Poland, Romania, Russia, San Marino, Scandinavia, Slovakia, Spain, Sweden, Sweden, Switzerland, Tajikistan, Turkey, Turkmenistan, Ukraine, United Kingdom, Uzbekistan, Vatican City, and Yugoslavia (all nations within the former Yugoslavia).

Asia/Pacific

Includes Australia, Bangladesh, Cambodia, China, Hong Kong, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, and Vietnam.

Definition of Table Columns

Products Produced contains details for seven product categories. The nomenclature used within the seven product groups of the fab database is as follows, with definitions where warranted:

- Analog
  - A/D D/A: Analog-to-digital, digital-to-analog converter
  - AUTOMOTIVE: Dedicated to automobile applications
  - CODEC: Coder/decoder
  - INTERFACE: Interface IC
  - LIN: Linear/analog device
  - MDIODE: Microwave diode
  - MESFET: Metal semiconductor field-effect transistor
  - MFET: Microwave field-effect transistor
  - MIXSIG ASIC: Mixed-signal/linear ASIC
  - MODEM: Modulator/demodulator
  - MMIC: Monolithic microwave IC
  - OP AMP: Operational amplifier
  - PWR IC: Power IC
  - REG: Voltage regulator
  - SMART PWR: Smart power
  - SWITCHES: Switching device
  - TELECOM: Telecommunications chip
- Memory
  - DRAM: Dynamic RAM
  - EEPROM or E2: Electrically erasable PROM
  - EPROM: Ultraviolet erasable PROM

- FERRAM: Ferroelectric RAM
- FIFO: First-in/first-out memory
- FLASH: Flash memory
- MEM: Memory
- NVMEM: Nonvolatile memory (ROM, PROM, EPROM, EEPROM, FERRAM)
- PROM: Programmable ROM
- RAM: Random-access memory
- ROM: Read-only memory
- SPMEM: Other specialty memory (such as dual-port, shift-register, color lookup)
- SRAM: Static RAM
- VRAM: Video RAM

- Micrologic
  - ASSP: Application-specific standard product
  - BIT: Bit slice (subset of MPU functions)
  - DSP: Digital signal processor
  - LISP: 32-bit list instruction set processor for AI
  - MCU: Microcontroller unit
  - MPR: Microperipheral
  - MPRCOM: MPR digital communication (ISDN, LAN, UART, modem)
  - MPU: Microprocessor unit
  - RISC: Reduced-instruction-set computation 32-bit MPU
- Standard logic
  - LOG or LOGIC: Standard logic
- ASIC logic
  - ARRAYS: Gate array
  - ASIC: Application-specific IC
  - CBIC: Cell-based IC
  - CUSTOM: Full-custom IC (single user)
  - FPGA: Field-programmable gate array
  - PLD: Programmable logic device

- Discrete
  - DIODE
  - DIS or DISCRETE: Discrete
  - FET: Field-effect transistor
  - GTO: Gate turn-off thyristor
  - HEMT: High-electron-mobility transistor
  - IGBT: Insulated gate bipolar transistor
  - MOSFET: MOS-based field-effect transistor
  - PWR TRAN: Power transistor
  - RECTIFIER
  - RF: Radio frequency
  - SCR: Schottky rectifier
  - SENSOR
  - SST: Small-signal transistor
  - THYRISTOR
  - TRAN: Transistor
  - ZENER DIODE
- Optoelectronic
  - CCD: Charge-coupled device (imaging)
  - COUPLER: Photocoupler
  - IED: Infrared-emitting diode
  - IMAGE SENSOR
  - LASER: Semiconductor laser or laser IC
  - LED: Light-emitting diode
  - OPTO: Optoelectronic
  - PDIODE: Photo diode
  - PTRAN: Photo transistor
  - SAW: Surface acoustic wave device
  - SIT IMAGE SENSOR: Static induction transistor image sensor

Process Technology column lists four major types of technologies. This column also lists uncommon technologies with information on well types, logic structure, and number of metal levels. Definitions used in the "Process Technology" column are as follows:

- MOS (silicon-based)
  - CMOS: Complementary metal-oxide semiconductor

- MOS: N-channel metal-oxide semiconductor (NMOS) and p-channel metal-oxide semiconductor (PMOS).
- M1: Single-level metal
- M2: Double-level metal
- M3: Triple-level metal
- N-WELL
- P-WELL
- POLY1: Single-level polysilicon
- POLY2: Double-level polysilicon
- POLY3: Triple-level polysilicon

■ BiCMOS (silicon-based)

- BiCMOS: Bipolar and CMOS combined on a chip
- BiMOS: Bipolar and MOS combined on a chip
- ECL I/O: ECL input/output
- TTL I/O: TTL input/output

■ Bipolar (silicon-based)

- BIP or BIPOLAR: Bipolar
- ECL: Emitter-coupled logic
- TTL: Transistor-transistor logic
- STTL: Schottky TTL

■ Gallium arsenide and other compound semiconductor materials

- GaAs: Gallium arsenide
- AlGaAs: Gallium aluminum arsenide
- GaAs on Si: Gallium arsenide on silicon
- GaP: Gallium phosphide
- HgCdTe: Mercuric cadmium telluride
- InAs: Indium arsenide
- InGaAs: Indium gallium arsenide
- InP: Indium phosphide
- InSb: Indium antimony
- LiNbO3: Lithium niobate
- SOS: Silicon on sapphire

Minimum Geometry is the smallest feature attainable in production volumes, measured in microns, at the critical mask layers.

Wafer Diameter represents the wafer diameter usually expressed colloquially in inches. However, for wafers greater than 3 inches in diameter, the colloquial expression becomes grossly inaccurate. When calculating square inches, Dataquest uses the following approximations:

- Stated diameter 4 inches (100mm) = Approximate diameter 3.938 inches
- Stated diameter 5 inches (125mm) = Approximate diameter 4.922 inches
- Stated diameter 6 inches (150mm) = Approximate diameter 5.906 inches
- Stated diameter 8 inches (200mm) = Approximate diameter 7.87 inches

Estimated Maximum Wafer Starts per Month is the equipment-limited wafer start capacity per four-week period. Start capacity is limited only by the installed equipment in the fab and the complexity of the process it runs, not by current staffing or the number of shifts operating.

Table 1
Asia/Pacific Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
ADVANCED MICROELECTRONICS PRODUCTS	SCIENCE PARK	TAIWAN	FAB 1	NA	CMOS	2	4	1988		10,000	F
ADVANCED S/C MANUF OF SHANGHAI (ASMC)	SHANGHAI	CHINA	FAB 1	LIN DIGITAL IC FOR T.V. EPROM	CMOS	0.8	6	1992		10,000	F
AMALGAMATED WIRELESS	SYDNEY	AUSTRALIA	NA	ASIC	CMOS	1.5	6	1989		7,000	F
ASMC (Formerly Shanghai Radio No. 7)	SHANGHAI	CHINA	FAB 1	LIN DIGITAL IC for TV EPROM	CMOS	0.8	6	1995		10,000	F
BEIJING NO.3 SEMICONDUCTOR APPLIANCE	BEIJING	CHINA	NA	REGULATORS, TELECOM	CMOS MOS	5	3	1988		10,000	F
CHARTERED SEMICONDUCTOR	SINGAPORE	SINGAPORE	FAB I	MPU MCU MPR ASIC ANALOG SRAM EEPROM OTHER MEM	CMOS	0.5	6	1989	23,000	24,000	NFAT
CHARTERED SEMICONDUCTOR	SINGAPORE	SINGAPORE	FAB II	LOGIC SRAM	CMOS	0.5	8	1995	3,000	30,000	NFAT
DAEWOO	GURO-DONG, SEOUL	KOREA	BIPOLAR	ANALOG	BIPOLAR	2	4	1986		10,000	FAT
DAEWOO	GURO-DONG, SEOUL	KOREA	MOS	CUSTOM ASIC	CMOS NMOS	1	4	1988		10,000	F
DONGSUNG	ICHUN, KYUNGKI-DO	KOREA	BIPOLAR	DIODE, RECTIFIER	BIPOLAR	5	4	1983		30,000	FAT
EPISIL TECHNOLOGIES, INC.	SCIENCE PARK	TAIWAN	FAB 1	EPI WAFER FOR MODE TRAN & ICs	EPI	5	4	1986		7,200	FN
EPISIL TECHNOLOGIES, INC.	SCIENCE PARK	TAIWAN	FAB 2	BIPOLAR IC, POWER TRAN	BIPOLAR	5	5	1991		6,000	FN
ERSO	HSINCHU	TAIWAN	FAB 1	4Mb 16Mb DRAM	CMOS	0.5	6	1991		4,000	PR
FINE MICROELECT.	SCIENCE PARK	TAIWAN	NA	OPTO TRAN	NA		3	1970		10,000	FAT
GENERAL INSTRUMENT	HSI TIEN CITY	TAIWAN	NA	PWR DIS	BIP		3	1985		12,000	F
HOLTEK	SCIENCE PARK	TAIWAN	FAB 1	MPR, MCU, TELECOM	CMOS	1.2	5	1991		30,000	F
HUA KO ELECTRONICS	TAI PO	HONG KONG	NA	MPU LIN ASIC LOG SRAM ROM	CMOS MOS	2.5	4	1982		8,000	PAT
HUA YUE MICROELECTRONICS CO. LTD.	SHAOXING	CHINA	FAB 1	CONSUMER ICs ASIC	CMOS	3	4	1993		20,000	F
HUA YUE MICROELECTRONICS CO. LTD.	SHAOXING	CHINA	FAB 2	CONSUMER ICs ASIC	CMOS	3	5	1994		7,000	F
HUAJING ELECTRONICS GROUP	WUXI	CHINA	FAB 1	CONSUMER ICs, AUDIO VISUAL	NA	1.5	4	1994		25,000	F

(Continued)

Table 1 (Continued)
Asia/Pacific Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
HUALON MICROELECTRONICS	SCIENCE PARK	TAIWAN	FAB 1	CONSUMER, TELECOM ICs	CMOS	0.8	5	1988		26,000	F
HUALON MICROELECTRONICS	SCIENCE PARK	TAIWAN	FAB 1B	ROM SRAM	CMOS	0.6	5	1994		12,000	F
HYUNDAI	ICHIN, KYUNGKI-DO	KOREA	FAB 4	4Mb 16Mb DRAM	CMOS	0.5	8	1993		10,000	F
HYUNDAI	ICHIN, KYUNGKI-DO	KOREA	FAB 5	16Mb 64Mb DRAM	CMOS	0.35	8	1994		25,000	F
HYUNDAI	ICHUN, KYUNGKI-DO	KOREA	MOS FAB 1-A	256K DRAM SRAM	CMOS	1	5	1985		15,000	F
HYUNDAI	ICHUN, KYUNGKI-DO	KOREA	MOS FAB 1-B	64K 256K 1Mb SRAM	CMOS	0.8	5	1985		8,000	F
HYUNDAI	ICHUN, KYUNGKI-DO	KOREA	MOS FAB 2-A	1Mb 4Mb DRAM	CMOS	0.7	6	1986		15,000	F
HYUNDAI	ICHUN, KYUNGKI-DO	KOREA	MOS FAB 2-B	4Mb DRAM	CMOS	0.6	6	1992		10,000	F
HYUNDAI	ICHUN, KYUNGKI-DO	KOREA	MOS FAB 3	4Mb DRAM	CMOS	0.5	6	1989		20,000	F
HYUNDAI	ICHUN, KYUNGKI-DO	KOREA	MOS R&D	DRAM	CMOS	0.25	6	1989		3,000	PR
JINAN NO.1	JINAN	CHINA	NA	LOG OP AMP	NA	5	3	1985		10,000	P
JINAN NO.2	JINAN	CHINA	NA	1K SRAM 4K DRAM	MOS	5	3	1989		8,000	P
KODENSHI	IRI	KOREA	NA	OPTO BIP	COMPOUND BIP			1995	25,000	25,000	NF
KOREAN ELECTRONIC CO.	GUMI-CITY, KYUNGBUK	KOREA	BIP LINE 1	ANALOG TRANS	BIPOLAR	1.5	4	1975		20,000	FAT
KOREAN ELECTRONIC CO.	GUMI-CITY, KYUNGBUK	KOREA	BIP LINE 2	ANALOG ICs ASIC	BIPOLAR	1.2	5	1985		15,000	F
KUKJE	SHIHUNG KYUNGKI-DO	KOREA	NA	OPTOELECTRONICS	GaAs	5	3	1992		4,000	FAT
LG SEMICON	CHONGJU-CITY, CHOONGBUK	KOREA	C2, PHASE 2	16Mb DRAM	CMOS	0.5	8	1995		20,000	F
LG SEMICON	CHONGJU-CITY, CHOONGBUK	KOREA	C1, PHASE 1	1Mb 4Mb DRAM	CMOS	0.8	6	1989		30,000	F
LG SEMICON	CHONGJU-CITY, CHOONGBUK	KOREA	C1, PHASE 2	4Mb DRAM	CMOS	0.7	6	1991		30,000	F
LG SEMICON	CHONGJU-CITY, CHOONGBUK	KOREA	C2, PHASE 1	16Mb DRAM	CMOS	0.5	8	1993		15,000	F
LG SEMICON	GUMI-CITY, KYUNGBUK	KOREA	G-FAB	SRAM ROM MEMORY	CMOS	0.5	8	1995		15,000	F
LG SEMICON	GUMI-CITY, KYUNGBUK	KOREA	GUMI BIPOLAR	ANALOG LOGIC	BIPOLAR	3	4	1980		25,000	FAT
LG SEMICON	GUMI-CITY, KYUNGBUK	KOREA	GUMI MOS	SRAM ROM LOGIC	CMOS NMOS	1.5	5	1984		15,000	F
MACRONIX, INC	SCIENCE PARK	TAIWAN	FAB 1-A	FOUNDRY	CMOS	0.45	6	1994		25,000	FN

(Continued)

Table 1 (Continued)
Asia/Pacific Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
MACRONIX, INC.	SCIENCE PARK	TAIWAN	FAB 1	ROM EPROM 1Mb 4Mb FLASH DRAM	CMOS	0.8	6	1992		16,000	FNDT
MOSEL-VITELIC CORPORATION	SCIENCE PARK	TAIWAN	FAB 1-A	DRAM VRAM	CMOS MOS	0.5	6	1995	1,000	30,000	F
MOTOROLA	TIANJIN	CHINA	MOS-17	TELECOM ASIC RF	CMOS	0.5	8				F
MOTOROLA ELECTRONICS	SEREMBAN	MALAYSIA	ISMF	PWR TRAN DIS SST SMALL SIGNAL	BIPOLAR	3	4	1988	300	4,000	FRAT
PHOTRONICS	NA	TAIWAN	NA	OPTO	NA		3			10,000	FAT
RAMAX	MELBOURNE	AUSTRALIA	NA	FERRAM	CMOS GaAs			1990			F
RCL SEMICONDUCTORS	TAI PO	HONG KONG	NA	MEM MPU LOG LIN TRAN	CMOS	2.5	4	1982		4,000	PAT
RCL SEMICONDUCTORS	TAI PO	HONG KONG	NA	NA	CMOS	2.5	5	1993		6,000	F
RECTRON LTD.	TAIPEI	TAIWAN	NO. 1	DIS	NA		2	1983		90,000	FAT
SAMMI	YONGIN KYUNGKI-DO	KOREA	III-V	LED LD HEMT	GaAs	5	3	1992		4,000	FAT
SAMSUNG	BUCHON-CITY, KYUNGKI-DO	KOREA	BIPOLAR LINE	ANALOG	BIPOLAR	3	4	1978		40,000	F
SAMSUNG	BUCHON-CITY, KYUNGKI-DO	KOREA	MOS LINE	MPU MCU MPR LOGIC	CMOS NMOS	2	5	1974		30,000	F
SAMSUNG	KIHEUNG-UP, KYUNGKI-DO	KOREA	FAB 1	MOS IC	CMOS	1.5	4	1984		35,000	F
SAMSUNG	KIHEUNG-UP, KYUNGKI-DO	KOREA	FAB 2	SRAM MASK ROM	CMOS	1.2	6	1985		35,000	F
SAMSUNG	KIHEUNG-UP, KYUNGKI-DO	KOREA	FAB 3	1Mb DRAM VRAM SRAM	CMOS	0.8	6	1988		35,000	F
SAMSUNG	KIHEUNG-UP, KYUNGKI-DO	KOREA	FAB 4	4Mb DRAM SRAM	CMOS	0.6	6	1990		35,000	F
SAMSUNG	KIHEUNG-UP, KYUNGKI-DO	KOREA	FAB 5	4Mb 16Mb DRAM	CMOS	0.5	8	1992		25,000	F
SAMSUNG	KIHEUNG-UP, KYUNGKI-DO	KOREA	FAB 6	16Mb 64Mb DRAM	CMOS	0.35	8	1994		30,000	F
SAMSUNG	KIHEUNG-UP, KYUNGKI-DO	KOREA	R&D	R&D	CMOS	0.3	6	1989		3,000	PR
SGNEC SHOUGANG	BEIJING	CHINA	NA	MCU LOGIC	CMOS	1.2	6	1994	5,000	5,000	FAT
SGS-THOMSON	ANG MO KIO	SINGAPORE	BIPOLAR COMPLEX	CONSUMER ICs, PWR AMPS ANALOG	BIPOLAR	3	5	1984		37,000	FR
SGS-THOMSON	ANG MO KIO	SINGAPORE	BIPOLAR STANDARD	ANALOG OPTO DISCRETE	BIPOLAR	8	5	1984		40,000	PR
SGS-THOMSON	ANG MO KIO	SINGAPORE	MOS	MPR ASIC ANALOG	CMOS MOS	2	5	1988		28,000	F

(Continued)

Table 1 (Continued)
Asia/Pacific Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
SHANGHAI BELLING MICROELECTRONICS	SHANGHAI	CHINA	NA	TELECOM CONSUMER ICs DIS	CMOS	1.2	4	1989		11,000	F
SHANGHAI RADIO NO.7	SHANGHAI	CHINA	FAB 1	NA	BIPOLAR CMOS	3	5	1991		10,000	F
SUZHOU PLANT	SUZHOU	CHINA	NA	LOG OPTO CONSUMER	BIP TTL MOS		3	1990			FAT
TECH SEMICONDUCTOR	SINGAPORE	SINGAPORE	PHASE 1	4Mb 16Mb 64Mb DRAM	CMOS	0.5	8	1993	4,000	12,000	F
TEMIC	SHANGHAI	CHINA	NA	HYBRID	NA						F
TI/ACER	SCIENCE PARK	TAIWAN	FAB 1	4Mb DRAM	CMOS MOS	0.6	6	1991		20,000	FAT
TI/ACER	SCIENCE PARK	TAIWAN	FAB 1-B	4Mb/16Mb DRAM	CMOS	0.5	8	1995		15,000	F
TSMC	SCIENCE PARK	TAIWAN	FAB 1	MEMORY MICRO LOGIC ANALOG	CMOS BiCMOS	0.8	6	1988	19,000	19,000	FN
TSMC	SCIENCE PARK	TAIWAN	FAB 2-A	LOGIC	CMOS	0.6	6	1990	34,000	37,500	FN
TSMC	SCIENCE PARK	TAIWAN	FAB 2-B	SRAM	CMOS	0.5	6	1992	29,000	37,500	FN
TSMC	SCIENCE PARK	TAIWAN	FAB 2-C	FOUNDRY	NA	0.6	6	1994	7,000	7,000	F
TSMC	SCIENCE PARK	TAIWAN	FAB 3	DRAM SRAM ROM LOG CUSTOM	CMOS BiCMOS	0.35	8	1995	4,000	30,000	FN
UMC	SCIENCE PARK	TAIWAN	FAB 1	CONSUMER IC LOGIC TFT-LCDs	CMOS NMOS	0.8	4	1982		50,000	NFAT
UMC	SCIENCE PARK	TAIWAN	FAB 2	MPR MPU SRAM ROM I/O	CMOS	0.5	6	1989		45,000	FN
UMC	SCIENCE PARK	TAIWAN	FAB 3-A	SRAM ROM LOGIC MPU MPR	CMOS	0.5	8	1995	1,000	25,000	FN
VANGUARD INTERNATIONAL	SCIENCE PARK	TAIWAN	FAB 1A	4Mb 16Mb DRAM	CMOS	0.4	8	1995		14,000	F
WINBOND	SCIENCE PARK	TAIWAN	FAB 1	TELECOM ICs, DIALERS	CMOS	0.8	5	1988		22,000	F
WINBOND	SCIENCE PARK	TAIWAN	FAB 2	SRAM RISC LAN	CMOS BiCMOS	0.6	6	1992		35,000	F

NA = Not applicable
Fab Types:
F = Production-Based Fab
R = Semiconductor R&D and/or Trial Production Facility
P = Pilot Line (Initial Production or Intended Low Volume)
T = Test and Assembly (Formerly A)
Q = Quick-Turn Fab
N = Nondedicated Foundry Service Available
D = Design Center
Source: Dataquest (December 1995)

Table 2
Asia/Pacific Future Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
ASMC (Formerly Shanghai Radio No.7)	SHANGHAI	CHINA	FAB 1	LIN DIGITAL IC for TV EPROM	CMOS	0.8	6	1995		10,000	F
BENTLEY HALL & CO. (Financiers)	SARAWAK	MALAYSIA	NA	NA	NA	0.35	8	1997		25,000	F
CHARTERED SEMICONDUCTOR	SINGAPORE	SINGAPORE	FAB II	LOGIC SRAM	CMOS	0.5	8	1995	3,000	30,000	NFAT
DONGSUNG	ICHUN, KYUNGKI-DO	KOREA	BIPOLAR	DIODE, RECTIFIER	BIPOLAR	5	4	1996		30,000	FAT
HOLTEK	SCIENCE PARK	TAIWAN	FAB 2	MPR MCU	CMOS	0.45	6	1997		16,000	F
HUAJING ELECTRONICS GROUP	WUXI	CHINA	FAB 2	TELECOM CONSUMER AUTO ICs ASIC DIS	CMOS	0.8	6	1997		10,000	F
HUALON MICROELECTRONICS	SCIENCE PARK	TAIWAN	FAB 2	SRAM	CMOS BICMOS	0.5	8	1996	5,000	10,000	F
HYUNDAI	ICHIN, KYUNGKI-DO	KOREA	FAB 6	64Mb DRAM	CMOS	0.35	8	1996		30,000	F
KODENSHI	IRI	KOREA	NA	OPTO BIP	COMPOUND BIP			1995	25,000	25,000	NF
LG SEMICON	CHONGJU-CITY, CHOONGBUK	KOREA	C2, PHASE 2	16Mb DRAM	CMOS	0.5	8	1995		20,000	F
LG SEMICON	CHONGJU-CITY, CHOONGBUK	KOREA	C1, PHASE 3	16Mb 64Mb DRAM	CMOS	0.35	8	1997		30,000	F
LG SEMICON	GUMI-CITY, KYUNGBUK	KOREA	G-FAB	SRAM ROM MEMORY	CMOS	0.5	8	1995		15,000	F
MACRONIX, INC.	SCIENCE PARK	TAIWAN	FAB 2	ROM EPROM LOGIC	CMOS	0.35	8	1997		20,000	F
MOSEL-VITELIC CORPORATION	SCIENCE PARK	TAIWAN	FAB 1-A	DRAM VRAM	CMOS MOS	0.5	6	1995	1,000	30,000	F
MOSEL-VITELIC CORPORATION	SCIENCE PARK	TAIWAN	FAB 1-B	4Mb 16Mb 64Mb DRAM, SRAM	CMOS	0.35	6	1996		15,000	F
MOSEL-VITELIC CORPORATION	SCIENCE PARK	TAIWAN	FAB 2	16Mb DRAM SRAM	CMOS	0.35	8	1998	15,000	25,000	F
NAN YA TECHNOLOGY	TAO YUAN	TAIWAN	FAB 1	16Mb 64Mb DRAM	CMOS	0.45	8	1996		20,000	F
POWERCHIP SEMICONDUCTOR (ELITE GROUP)	SCIENCE PARK	TAIWAN	NA	16M DRAM	CMOS	0.4	8	1996	15,000	15,000	F
SAMSUNG	KIHEUNG-UP, KYUNGKI-DO	KOREA	FAB 8	64Mb DRAM	CMOS	0.3	8	1997		25,000	F
SAMSUNG	KIHEUNG-UP, KYUNGKI-DO	KOREA	FAB 7	16Mb 64Mb DRAM	CMOS	0.35	8	1996		20,000	F
SUBMICRON TECHNOLOGY	BANGKOK	THAILAND	FAB 1	FOUNDRY	CMOS	0.5	8	1996	2,000	20,000	FN
TECH SEMICONDUCTOR	SINGAPORE	SINGAPORE	PHASE 2	64Mb 256Mb DRAM	CMOS	0.35	8	1997	4,000	20,000	F

(Continued)

Table 2 (Continued)
Asia/Pacific Future Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
TI/ACER	SCIENCE PARK	TAIWAN	FAB 1-B	4Mb/16Mb DRAM	CMOS	0.5	8	1995		15,000	F
TSMC	SCIENCE PARK	TAIWAN	FAB 3	DRAM SRAM ROM LOG CUSTOM	CMOS BiCMOS	0.35	8	1995	4,000	30,000	FN
TSMC	SCIENCE PARK	TAIWAN	FAB 4	LOG CUSTOM MPU MEM	CMOS BiCMOS	0.35	8	1996	2,000	25,000	FN
UMC	SCIENCE PARK	TAIWAN	FAB 3-A	SRAM ROM LOGIC MPU MPR	CMOS	0.5	8	1995	1,000	25,000	FN
UMC	SCIENCE PARK	TAIWAN	FAB 3-B	SRAM ROM LOGIC MPU MPR	CMOS	0.35	8	1996	1,000	15,000	FN
UMC-JV1	SCIENCE PARK	TAIWAN	FAB IIIB	SRAM MPR GRAPHIC CHIPS FOUNDRY	CMOS	0.35	8	1997		20,000	F
UMC-JV2	SCIENCE PARK	TAIWAN	NA	FOUNDRY	CMOS	0.35	8	1997		20,000	F
UMC-JV3	SCIENCE PARK	TAIWAN	NA	FOUNDRY	CMOS	0.35	8	1997		20,000	F
VANGUARD INTERNATIONAL	SCIENCE PARK	TAIWAN	FAB 1A	4Mb 16Mb DRAM	CMOS	0.4	8	1995		14,000	F
VANGUARD INTERNATIONAL	SCIENCE PARK	TAIWAN	FAB 1B	16Mb DRAM	CMOS	0.35	8	1997		15,000	F
WINBOND	SCIENCE PARK	TAIWAN	FAB 3	LOGIC SRAM NON VOLATILE MEMORY	CMOS	0.35	8	1997		40,000	F

NA = Not applicable
Fab Types:
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Source: Dataquest (December 1995)

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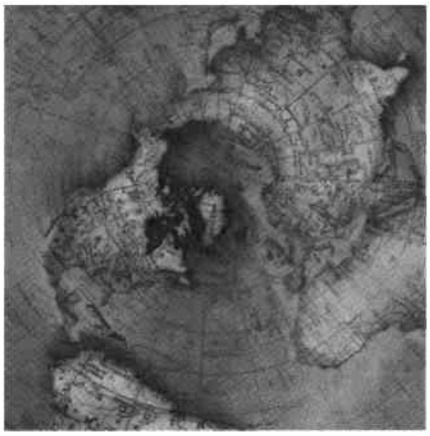

Dataquest

Europe, Africa, and the Middle East Fab Database

Market Statistics

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
Product Code: SEMM-WW-MS-9505
Publication Date: December 25, 1995
Filing: Market Analysis

Europe, Africa, and the Middle East Fab Database

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Table of Contents

List of Tables

Note: All tables show estimated data.

Europe, Africa, and the Middle East Fab Database

Background

This document contains the Europe, Africa, and Middle East portion of Dataquest's wafer fab database. The Semiconductor Equipment, Materials, and Manufacturing Worldwide (SEMM) program uses both primary and secondary research to update this data. The tables in this report cover both merchant and captive production and pilot-line facilities, although our surveys and database also include R&D fabs.

Research Methodology

Dataquest conducts extensive annual surveys, complemented with quarterly secondary research. This data is then supplemented and cross-checked with various other information sources.

General Definitions

Fab line: A fab line is a semiconductor processing facility equipped for all front-end wafer manufacturing. Occasionally, there are two or more separate product-specific fab lines or wafer sizes in a single cleanroom. In this situation, Dataquest documents the cleanroom as separate fab lines if the company dedicates equipment to each wafer size or product line. Therefore, a company may operate many fab lines at one location.

Front-end wafer processing: Dataquest defines front-end wafer processing as all steps involved in semiconductor processing, beginning with initial oxide and ending at wafer probe.

Production fab: A wafer fab capable of front-end processing more than 1,250 wafers per week is a production fab (type = F).

Pilot fab: A wafer fab capable of front-end processing 1,250 or fewer wafers per week is a pilot fab (type = P).

Worldwide Geographic Region Definitions and Regional Roll-Ups

Americas

Includes Central America (all nations), Canada, Mexico, United States and Puerto Rico, and South America (all nations).

Japan

Japan is the only single-country region.

Europe, Africa, and Middle East

Includes Africa (all nations), Albania, Andorra, Armenia, Azerbaijan, Belarus, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Gibraltar, Hungary, Iceland, Israel, Italy, Kazakhstan, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Middle East (all nations), Moldova, Monaco,

Netherlands, Norway, Poland, Romania, Russia, San Marino, Scandinavia, Slovakia, Spain, Sweden, Sweden, Switzerland, Tajikistan, Turkey, Turkmenistan, Ukraine, United Kingdom, Uzbekistan, Vatican City, and Yugoslavia (all nations within the former Yugoslavia).

Asia/Pacific

Includes Australia, Bangladesh, Cambodia, China, Hong Kong, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, and Vietnam.

Definition of Table Columns

Products Produced contains details for seven product categories. The nomenclature used within the seven product groups of the fab database is as follows, with definitions where warranted:

- Analog
  - A/D D/A: Analog-to-digital, digital-to-analog converter
  - AUTOMOTIVE: Dedicated to automobile applications
  - CODEC: Coder/decoder
  - INTERFACE: Interface IC
  - LIN: Linear/analog device
  - MDIODE: Microwave diode
  - MESFET: Metal semiconductor field-effect transistor
  - MFET: Microwave field-effect transistor
  - MIXSIG ASIC: Mixed-signal/linear ASIC
  - MODEM: Modulator/demodulator
  - MMIC: Monolithic microwave IC
  - OP AMP: Operational amplifier
  - PWR IC: Power IC
  - REG: Voltage regulator
  - SMART PWR: Smart power
  - SWITCHES: Switching device
  - TELECOM: Telecommunications chip
- Memory
  - DRAM: Dynamic RAM
  - EEPROM or E2: Electrically erasable PROM
  - EPROM: Ultraviolet erasable PROM

- FERRAM: Ferroelectric RAM
- FIFO: First-in/first-out memory
- FLASH: Flash memory
- MEM: Memory
- NVMEM: Nonvolatile memory (ROM, PROM, EPROM, EEPROM, FERRAM)
- PROM: Programmable ROM
- RAM: Random-access memory
- ROM: Read-only memory
- SPMEM: Other specialty memory (such as dual-port, shift-register, color lookup)
- SRAM: Static RAM
- VRAM: Video RAM

- Micrologic
  - ASSP: Application-specific standard product
  - BIT: Bit slice (subset of MPU functions)
  - DSP: Digital signal processor
  - LISP: 32-bit list instruction set processor for AI
  - MCU: Microcontroller unit
  - MPR: Microperipheral
  - MPRCOM: MPR digital communication (ISDN, LAN, UART, modem)
  - MPU: Microprocessor unit
  - RISC: Reduced-instruction-set computation 32-bit MPU
- Standard logic
  - LOG or LOGIC: Standard logic
- ASIC logic
  - ARRAYS: Gate array
  - ASIC: Application-specific IC
  - CBIC: Cell-based IC
  - CUSTOM: Full-custom IC (single user)
  - FPGA: Field-programmable gate array
  - PLD: Programmable logic device

- Discrete
  - DIODE
  - DIS or DISCRETE: Discrete
  - FET: Field-effect transistor
  - GTO: Gate turn-off thyristor
  - HEMT: High-electron-mobility transistor
  - IGBT: Insulated gate bipolar transistor
  - MOSFET: MOS-based field-effect transistor
  - PWR TRAN: Power transistor
  - RECTIFIER
  - RF: Radio frequency
  - SCR: Schottky rectifier
  - SENSOR
  - SST: Small-signal transistor
  - THYRISTOR
  - TRAN: Transistor
  - ZENER DIODE
- Optoelectronic
  - CCD: Charge-coupled device (imaging)
  - COUPLER: Photocoupler
  - IED: Infrared-emitting diode
  - IMAGE SENSOR
  - LASER: Semiconductor laser or laser IC
  - LED: Light-emitting diode
  - OPTO: Optoelectronic
  - PDIODE: Photo diode
  - PTRAN: Photo transistor
  - SAW: Surface acoustic wave device
  - SIT IMAGE SENSOR: Static induction transistor image sensor

Process Technology column lists four major types of technologies. This column also lists uncommon technologies with information on well types, logic structure, and number of metal levels. Definitions used in the "Process Technology" column are as follows:

- MOS (silicon-based)
  - CMOS: Complementary metal-oxide semiconductor

- MOS: N-channel metal-oxide semiconductor (NMOS) and p-channel metal-oxide semiconductor (PMOS).
- M1: Single-level metal
- M2: Double-level metal
- M3: Triple-level metal
- N-WELL
- P-WELL
- POLY1: Single-level polysilicon
- POLY2: Double-level polysilicon
- POLY3: Triple-level polysilicon

■ BiCMOS (silicon-based)

- BiCMOS: Bipolar and CMOS combined on a chip
- BiMOS: Bipolar and MOS combined on a chip
- ECL I/O: ECL input/output
- TTL I/O: TTL input/output

■ Bipolar (silicon-based)

- BIP or BIPOLAR: Bipolar
- ECL: Emitter-coupled logic
- TTL: Transistor-transistor logic
- STTL: Schottky TTL

■ Gallium arsenide and other compound semiconductor materials

- GaAs: Gallium arsenide
- AlGaAs: Gallium aluminum arsenide
- GaAs on Si: Gallium arsenide on silicon
- GaP: Gallium phosphide
- HgCdTe: Mercuric cadmium telluride
- InAs: Indium arsenide
- InGaAs: Indium gallium arsenide
- InP: Indium phosphide
- InSb: Indium antimony
- LiNbO3: Lithium niobate
- SOS: Silicon on sapphire

Minimum Geometry is the smallest feature attainable in production volumes, measured in microns, at the critical mask layers.

Wafer Diameter represents the wafer diameter usually expressed colloquially in inches. However, for wafers greater than 3 inches in diameter, the colloquial expression becomes grossly inaccurate. When calculating square inches, Dataquest uses the following approximations:

- Stated diameter 4 inches (100mm) = Approximate diameter 3.938 inches
- Stated diameter 5 inches (125mm) = Approximate diameter 4.922 inches
- Stated diameter 6 inches (150mm) = Approximate diameter 5.906 inches
- Stated diameter 8 inches (200mm) = Approximate diameter 7.87 inches

Estimated Maximum Wafer Starts per Month is the equipment-limited wafer start capacity per four-week period. Start capacity is limited only by the installed equipment in the fab and the complexity of the process it runs, not by current staffing or the number of shifts operating.

Table 1
Europe, Africa, and Middle East Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
ABB SEMICONDUCTOR	LENSBURG	SWITZERLAND	NA	DIS	BIPOLAR		4				F
ABB-HAFO AB	JARFALLA	SWEDEN	NA	ASIC MIXED SIGNAL CUSTOM	CMOS	1.25	4	1991	2,000	3,500	PRNTD
AEG AG (DAIMLER BENZ)	ULM	GERMANY	ULM RSCH	3D ICs mm-WAVE OPTO	GaAs MOS			1991			FNRD
AMS AUSTRIA MIKRO SYSTEME INTERNATIONAL	UNTERPREMSTATTEN	AUSTRIA	NA	ASIC ANALOG	CMOS BiCMOS NMOS PMOS	0.8	4	1983	1,000	16,000	FRQTD
ANALOG DEVICES	LIMERICK	IRELAND	NA	ANALOG LIN AD/DA TELECOM	BiCMOS	2	4	1986		20,000	FR
ANALOG DEVICES	LIMERICK	IRELAND	NA	DSPs ANALOG	CMOS BiCMOS	0.6	6	1995		4,400	PR
ANSALDO TRASPORTI	GENOA	ITALY	LINITA	PWR DIS	BIP 1M	2	4	1970		6,000	FAT
AT&T MICROELECTRONICS	MADRID	SPAIN	NA	CBIC CUSTOM DSP	CMOS	0.6	6	1988		16,000	FATND
ATMELCORPORATION (ES2)	ROUSSET CEDEX	FRANCE	ES2	CBIC ARRAYS CUSTOM MIXSIGASIC	CMOS M2 POLY1	0.6	6	1987		1,500	PQRNA-DT
ATMOS/ELPOL	WARSAW	POLAND	NA	ASIC	NA	2	4				P
BANEASA S.A. (IPRS)	BUCHAREST	ROMANIA	NA	THYRISTOR DIODE LIN	BIP						F
BT&D TECHNOLOGIES	IPSWICH	ENGLAND	NA	OPTO LASER LED	NA	1	2	1987		320	FPRADT
ELMOS GMBH	DORTMUND	GERMANY	NA	ASIC HV MIXED SIGNAL	CMOS	1	4	1985	10,000	60,000	F
EM MICROELECTRONICS-MARIN S.A.	MARIN	SWITZERLAND	Fab 3	ASIC ANALOG	CMOS BiCMOS	1	6	1991	40,000	80,000	FQRNTD
ERICSSON	KALMAR	SWEDEN	NA	PWR DISCRETE	BIP		4	1972		25,000	DFAT
ERICSSON	KISTA	SWEDEN	NA	ASICS(TELECOM CHIPS)	CMOS BICMOS	0.5	6	1994		1,000	P
FUJITSU	NEWTON AYCLIFFE	ENGLAND	PHASE 1	4Mb/16Mb DRAM ASIC	CMOS	0.8	6	1991		5,600	FAT
FUJITSU	NEWTON AYCLIFFE	ENGLAND	PHASE 2	16Mb DRAM	CMOS	0.5	6	1994		14,000	F
GEC PLESSEY	LINCOLN	ENGLAND	NA	SRAM MPU ASIC DISCRETE	CMOS	1	4	1981	1,000	2,300	PR
GEC PLESSEY	OLDHAM	ENGLAND	NA	MPR ASIC DISCRETE	BIPOLAR	1	4	1984	2,000	12,000	FQRTD

(Continued)

Table 1 (Continued)
Europe, Africa, and Middle East Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
GEC PLESSEY	PLYMOUTH	ENGLAND	NA	MPU DSPs ASIC ANALOG	CMOS	0.7	6	1987	330	3,000	FQRD
GEC PLESSEY	ROBOROUGH	ENGLAND	NA	ASIC DSP TELECOM	CMOS NMOS M3	0.7	6	1987		6,000	FDT
GEC PLESSEY	SWINDON	ENGLAND	NA	ANALOG	BIPOLAR	0.5	4	1961		8,000	FRTD
GEC PLESSEY	WEMBLEY	ENGLAND	NA	NA	GaAs		3				PR
GENERAL INSTRUMENTS	CRICKLADE	ENGLAND	NA	DIS	BIP		4			10,000	DFAT
HITACHI	LANDSHUT	GERMANY	E2	16Mb DRAM MCU	CMOS	0.5	8	1992		16,000	F
HMT	BRUGG	SWITZERLAND	NA	CONSUMER ICs	MOS		3			15,000	DFAT
HUGHES	GLENROTHES	SCOTLAND	NA	EPROM ASIC MIXED SIGNAL	CMOS MOS	2	4	1970		2,800	FRNATD
IBM	CORBEIL-ESSONNES	FRANCE		64Mb DRAM		0.35					F
IBM	CORBEIL-ESSONNES	FRANCE	NA	256K DRAM 64K SRAM	CMOS MOS	1	5			25,000	F
IBM	CORBEIL-ESSONNES	FRANCE	NA	ARRAYS LIN CUSTOM	BIP	2	5			40,000	F
IBM	CORBEIL-ESSONNES	FRANCE	NA	1Mb DRAM	CMOS	0.8	8	1989		7,000	P
IBM	HANNOVER	GERMANY	NA	DIS	BIP	3	4			20,000	F
IBM	SINDELFINGEN	GERMANY	NA	ARRAYS	BIP	2	5			15,000	F
IBM	SINDELFINGEN	GERMANY	NA	PWR DIS HYBRID	BIP	3	4			20,000	F
IBM	SINDELFINGEN	GERMANY	NA	DRAM SRAM DSP MPU CUSTOM	MOS	1.5	5			25,000	F
IBM	ZURICH	SWITZERLAND	NA	NA	GaAs CMOS		3				PR
IBM/PHILIPS	BOEBLINGEN	GERMANY	NA	4Mb DRAM	CMOS	0.8	8	1989		20,000	F
IBM/SIEMENS	CORBEIL-ESSONNES	FRANCE	ACL	16Mb DRAM	CMOS	0.4	8	1992	1,232	16,100	F
ICCE	BANEASA	ROMANIA	NA	OPTO LIN	BIP						FR
IMEC	PLIJM	BELGIUM		R&D PROTOTYPING	CMOS BICMOS NMOS/PMOS	0.25	6	1982	100	500	PR
INSTITUTE OF ELECTRON TECHNOLOGY	WARSAW	POLAND	R&D SILICON	ASIC MCU DSP OPTO	CMOS	3	4	1978	10,000	25,000	FRD
INTEGRAL	MINSK CITY	RUSSIA	NA	NA	BIP CMOS		6			75,000	F
INTEL	LEIXLIP	IRELAND	FAB 10	MPU (P5, DX4, P6)	BiCMOS	0.6	8	1994		20,000	F

(Continued)

Table 1 (Continued)
Europe, Africa, and Middle East Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
INTEL	MIGDAEL HEIMIK	ISRAEL	FAB 8	MPU (386E,486) MCU MPR	CMOS	0.8	6	1985		28,000	F
INTERNATIONAL RECTIFIER	TURIN	ITALY	BORGARO	RECTIFIER THYRISTOR	NA		4	1960		15,000	FAT
INTERNATIONAL RECTIFIER	TURIN	ITALY	VENARIA	RECTIFIER THYRISTOR	NA		4			10,000	DFAT
ISKRA	TRBOVLJE	SLOVENIA	NA	DIS	BIP		3			5,000	DPAT
ISOCOM	HARTLEPOOL	ENGLAND	NA	OPTO	GaAs						FAT
ITALTEL	ROME	ITALY	NA	NA	GaAs			1988			F
ITT	FREIBURG	GERMANY	IC FAB	MPU MCU DSP NVMEM	CMOS NMOS/ PMOS BIPOLAR	0.8	5	1990		16,800	FRDAT
ITT	FREIBURG	GERMANY	NA	DIS CUSTOM	BIPOLAR	5	4			16,500	FAT
IXYS SEMICONDUCTOR	LAMPERTHEIM	GERMANY	IXYS	DISCRETE DIODE THYRISTORS	BIPOLAR	4	5	1970	3,000	16,000	FRQD
LUCAS	SUTTON COLDFIELD	ENGLAND	NA	PWR DIS	GaAs						DFAT
MICROELECTRONICA S.A.	BANEASA	ROMANIA	NA	MPU 16K DRAM	MOS						F
MICROELECTRONICS - IME, LTD.	SOFIA	BULGARIA	NA	LIN	CMOS BICMOS	2	1			2,000	PDAT
MICROELECTRONICS - IME, LTD.	SOFIA	BULGARIA	NA	LIN	CMOS BICMOS	2	5			9,000	PDAT
MICRONAS, INC.	ESPOO	FINLAND	NA	LIN CBIC CUSTOM	CMOS M2	2	4	1986		4,000	PNATD
MICRONAS, INC. (ASCOM MICRO)	BEVAIX	SWITZERLAND	AM	ARRAYS CUSTOM	BIP	5	4	1990		4,000	PTDQR
MIETEC ALCATEL	OUDENAARDE	BELGIUM	FAB 1	CUSTOM MIXED SIGNAL ASIC	CMOS BiCMOS	1	4	1985	6,000	15,000	FQT
MIETEC ALCATEL	OUDENAARDE	BELGIUM	FAB 2	CUSTOM MIXED SIGNAL ASIC	CMOS BiCMOS	0.35	6	1993	2,000	12,000	FT
MIKROELEKTRONIK & TECHNOLOGIE GES.	DRESDEN	GERMANY	SMD	ASIC SRAM DSP	CMOS M2						PR
MOTOROLA	TOULOUSE	FRANCE	BIPOLAR 4	TELECOM OP ANALOG	BIP	2	4	1983		24,800	F
MOTOROLA	TOULOUSE	FRANCE	SMOS1	PWR TRAN SMARTMOS	CMOS	3	6	1969		10,000	F
MOTOROLA	TOULOUSE	FRANCE	TLS POWER	LOW FREQUENCY POWER	BIP MOS	1.5	5			14,000	F

(Continued)

Table 1 (Continued)
Europe, Africa, and Middle East Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Tech-nology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
MOTOROLA	TOULOUSE	FRANCE	TLS RECTI-FIER	RECTIFIERS	MOS		3			44,000	F
MOTOROLA	EAST KILBRIDE	SCOTLAND	MOS 1	MCU LOGIC	CMOS MOS	0.8	4	1969		56,000	FAT
MOTOROLA	EAST KILBRIDE	SCOTLAND	MOS 9	FSRAM DSP MCU	CMOS	0.35	6	1990		24,000	NFAT
MOTOROLA (Formerly Digital Equip.)	SOUTH QUEENS-FERRY	SCOTLAND	MOS 16	MPU ALPHA ANALOG	CMOS BICMOS	0.5	6	1990		7,200	F
MTG (THESYS GMBH)	ERFURT	GERMANY	NA	ASIC	CMOS BICMOS	1.5	6				F
NATIONAL S/C	GREENOCK	SCOTLAND	4	LOG LIN	CMOS M1	2.5	4	1981		25,000	FTD
NATIONAL S/C	GREENOCK	SCOTLAND	FAB 2	LAN	BIP	2	6	1984		21,000	DF
NATIONAL S/C	GREENOCK	SCOTLAND	LINEAR 4	LIN	BIP M1 M2	5	4	1977		37,000	F
NATIONAL S/C	GREENOCK	SCOTLAND	LINEAR 6	LIN	BIP		6	1993			F
NEC SEMICONDUCTOR	LIVINGSTON	SCOTLAND	1 Phase 1	DRAM SRAM MPU	CMOS	0.5	6	1987	9,000	25,000	F
NEWMARKET MICROSYS.	NEWMARKET	ENGLAND	NA	LIN DIS	BIP		4			10,000	FQ
NEWPORT WAFER FAB	NEWPORT	WALES	F21	FOUNDRY	CMOS	0.7	6	1982	10,000	23,000	F
NUOVA MISTRAL S.P.A.	SERMONETA (LA-TINA)	ITALY	NA	ZENER DIODE DIODES SST	NA	3	4	1983		15,000	DFAT
PHILIPS	HAZELGROVE, STOCKPORT	ENGLAND	BIPOLAR	TRAN DIODE RECTIFIER	BIP	10	4	1969		45,000	FTD
PHILIPS	HAZELGROVE, STOCKPORT	ENGLAND	POWER-MOS	DIODE PWR ICs	MOS M1	3	4	1987		10,000	FTD
PHILIPS	REDHILL	ENGLAND	NA	NA	GaAs		3				PR
PHILIPS	CAEN	FRANCE	NA	CONSUMER ICs	BIP	1.5	5			18,000	F
PHILIPS	HAMBURG	GERMANY	CONSUMER	CONSUMER ICs	BIP	1.2	5	1990		18,000	FT
PHILIPS	HAMBURG	GERMANY	DISCRETE	DIS	BIP	2	4	1957		22,000	FT
PHILIPS	HAMBURG	GERMANY	NA	8- 16-Bit MCU EEPROM ASIC	CMOS NMOS M1 M2	1	5	1980		12,500	FATD
PHILIPS	NIJMEGEN	NETHER-LANDS	MOS 3	CONSUMER ICs DIS	CMOS	0.7	6	1993		15,000	F
PHILIPS	NIJMEGEN	NETHER-LANDS	NA	LOG	CMOS	3	4	1984		26,000	F
PHILIPS	NIJMEGEN	NETHER-LANDS	NA	SRAM CONSUMER ICs	CMOS NMOS M2	0.8	6	1988		8,400	F
PHILIPS	NIJMEGEN	NETHER-LANDS	NA	DIS	MOS BICMOS BIP	1.5	5	1970		20,000	FT

(Continued)

Table 1 (Continued)
Europe, Africa, and Middle East Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
PHILIPS	STADSKANAAL	NETHER-LANDS	NA	RECTIFIER	BIP M3		4	1970		70,000	FATD
PHILIPS RESEARCH LABS	SILFORD	ENGLAND	NA	NA	GaAs		2				PR
PHILIPS RTC	PARIS	FRANCE	NA	TRAN	GaAs	5	5	1970		12,000	FTD
ROBERT BOSCH	REUTLINGEN	GERMANY	NA	LIN DIS CUSTOM	BiCMOS	0.6	6	1995		25,000	DFAT
ROBERT BOSCH	REUTLINGEN	GERMANY	RtW/FAW	LIN DIS CUSTOM	BIP BiCMOS	3	4			20,000	DFAT
SEAGATE MICROELECT.	LIVINGSTON	SCOTLAND	NA	LIN	BIP M2	3	4	1986		5,000	DFAT
SEMEFAB	GLENROTHES	SCOTLAND	NA	LIN DIS OPTO	BIP CMOS MOS	4	4			2,000	DP
SEMIKRON	NURNBERG	GERMANY	NA	DIS	BIP		5			10,000	FAT
SGS-THOMSON	CORBEVILLE	FRANCE	NA	NA	GaAs		3				PR
SGS-THOMSON	CROLLES	FRANCE	GNB92	ASIC ASSP MPU TELECOM DSP	CMOS BICMOS HFMOS	0.5	8	1993		20,000	PR
SGS-THOMSON	GRENOBLE	FRANCE	NA	LIN SMART PWR CUSTOM	BIP CMOS	1.5	4	1980		25,000	FDT
SGS-THOMSON	RENNES	FRANCE	NA	LINEAR TELECOM	BIPOLAR BiCMOS	2.5	5	1985	8,000	20,000	F
SGS-THOMSON	ROUSSET	FRANCE	MODULE 5	EPROM EEPROM MPU MCU TELECOM	CMOS NMOS	1.2	6	1987		26,000	FDT
SGS-THOMSON	TOURS	FRANCE	MESA	DIS	NA	10	4			60,000	FD
SGS-THOMSON	TOURS	FRANCE	PLANAR	DIS	NA	5	4			15,000	F
SGS-THOMSON	AGRATE	ITALY	R1	FLASH EPROM	CMOS	0.6	6	1991			PR
SGS-THOMSON	AGRATE (MILAN)	ITALY	FAB 8	EPROM ARRAYS MIXSIGASIC	CMOS	0.6	6	1987		25,000	FPRD
SGS-THOMSON	CASTALETTO	ITALY	NA	LIN	BIP CMOS	1.25	5			12,000	FR
SGS-THOMSON	CATANIA	ITALY	NA	LOG LIN CUSTOM SMART PWR	CMOS	1.5	5			25,000	FR
SIEMENS	VILLACH	AUSTRIA	VILLACH	LOG TELECOM	MOS BIP	1	4	1981		46,000	FRDT
SIEMENS	DRESDEN	GERMANY	NA	16Mb 64Mb DRAM	CMOS	0.35	8	1995		8,000	FDR
SIEMENS	REGENSBURG	GERMANY	REGENS-BURG	1Mb 4Mb DRAM MCU	CMOS	0.7	6	1986	22,400	40,000	F

(Continued)

Table 1 (Continued)
Europe, Africa, and Middle East Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
SOUTH AFRICAN MICROELECTRONIC SYSTEMS	PRETORIA	SOUTHAFRICA	NA	CBIC ASIC	CMOS	1.5	6	1992		5,000	PR
TAG	ZURICH	SWITZERLAND	NA	DIS	NA		3			10,000	DFT
TEMIC	HEILBRONN	GERMANY	NA	ANALOG DISCRETE	BIPOLAR	0.6	6	1994		14,000	F
TEMIC MATRA MHS S.A.	NANTES	FRANCE	FAB 1	256K SCRAM MCU RISC ASIC LIN	CMOS BiCMOS M2	0.5	6	1986		10,500	DFAT
TEMIC TELEFUNKEN ELECTRONIC	HEILBRONN	GERMANY	NA	ANALOG	BIPOLAR BiCMOS	0.8	6	1970		30,000	DFT
TEXAS INSTRUMENTS	FREISING	GERMANY	FRIS	MPR	CMOS BiCMOS	0.6	6	1977	4,100	22,300	F
TEXAS INSTRUMENTS	AVEZZANO	ITALY	AMOS	4Mb DRAM ASSP CBIC	CMOS	0.5	6	1991		13,500	FD
TEXET	NICE	FRANCE	NA	DIS	NA		4			10,000	DFAT
TOWER SEMICONDUCTOR	MIGDAL HAEMEK	ISRAEL	NA	MPU MCU MPR DSP ARRAYS CUSTOM	CMOS	0.8	6	1986	5,000	14,000	FNT
VAISALA	VANTAA	FINLAND	NA	LIN	CMOS	5	3			200	DPT
WESTCODE S/C	CHIPPENHAM	ENGLAND	NA	DIS	BIP		2	1977		10,000	DFAT
ZETEX	CHADDERTON LANCASHIRE	ENGLAND	NA	DISCRETE ANALOG	BIPOLAR NMOS/PMOS	2	4	1970	4,000	9,000	FR
ZMD GmbH	GRENZSTRASSE	GERMANY	ZVE 1	DRAM SRAM NVMEM ASIC ANALOG	CMOS NMOS/ PMOS	0.8	5	1983	8,500	17,000	FRQ

NA = Not applicable
Fab Types:
F = Production-Based Fab
R = Semiconductor R&D and/or Trial Production Facility
P = Pilot Line (Initial Production or Intended Low Volume)
T = Test and Assembly (Formerly A)
Q = Quick-Turn Fab
N = Nondedicated Foundry Service Available
D = Design Center
Source: Dataquest (December 1995)

Table 2
Europe, Africa, and Middle East Future Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
AMD	DRESDEN	GERMANY	NA	K5	CMOS	0.25	8	1997		15,000	F
ANALOG DEVICES	LIMERICK	IRELAND	NA	DSPs ANALOG	CMOS BiCMOS	0.6	6	1995		4,400	PR
ATMEL CORPORATION	AIX EN PROVENCE	FRANCE	AIX EN PROVENCE	CUSTOM MIXED SIGNAL ASICs	CMOS BiCMOS	0.4	6	1997	1,500	7,000	F
FRAUNHOFER INSTITUTE	ITZHOE	GERMANY	ITZHOE	ASIC	CMOS	0.8	6	1996			PR
FUJITSU	NEWTON AYCLIFFE	ENGLAND	FAB 2	16Mb 64Mb DRAM	CMOS	0.32	8	1997	10,000	30,000	F
GEC PLESSEY	ROBOROUGH	ENGLAND	NA	ASIC	CMOS	0.5	8	1996	2,000	24,000	F
INTEL	LEIXLIP	IRELAND	FAB 14	LOG MPU	BiCMOS	0.25	8	1998		20,000	F
INTEL	KIRYAT GAT	ISRAEL	FAB 18	FLASH	CMOS	0.35	8	1997		20,000	F
MITSUBISHI	Alsdorf	GERMANY	NA	16M DRAM	CMOS	0.35	8	1997	7,000	7,000	FAT
NEC SEMICONDUCTOR	LIVINGSTON	SCOTLAND	2 Phase 1	16M/64M DRAM	CMOS	0.35	8	1996	10,000	10,000	F
NEC SEMICONDUCTOR	LIVINGSTON	SCOTLAND	2 Phase 2	16M/64M DRAM	CMOS	0.35	8	1998	10,000	20,000	F
ORBIT SEMICONDUCTOR, INC	EILAT	ISRAEL	NA	ARRAYS CUSTOM MIXSIGASIC	CMOS	0.8	6	1996		2,000	FN
PHILIPS	NIJMEGEN	NETHER-LANDS	MOS 4	CONSUMER ICs	CMOS	0.35	8	1996		10,000	F
ROBERT BOSCH	REUTLINGEN	GERMANY	NA	LIN DIS CUSTOM	BiCMOS	0.6	6	1995		25,000	DFAT
SGS-THOMSON	ROUSSET	FRANCE	ROUSSET 2000	MCU EEPROM NVMEM	CMOS	0.35	8	1998		20,000	F
SGS-THOMSON	CATANIA	ITALY	NA	EPROM FLASH	CMOS	0.5	8	1996		20,000	F
SIEMENS	NEWCASTLE	ENGLAND	NA	ASIC	CMOS	0.35	8	1997		25,000	F
SIEMENS	DRESDEN	GERMANY	NA	16Mb 64Mb DRAM	CMOS	0.35	8	1995		8,000	FDR
TEMIC	NANTES	GERMANY	NA	SRAM MCU ASIC	CMOS	0.35	8	1996		10,000	F
TEXAS INSTRUMENTS	AVEZZANO	ITALY	PHASE 2	16Mb DRAM	CMOS	0.5	8	1996		20,000	F

NA = Not applicable
Fab Types:
F = Production-Based Fab
R = Semiconductor R&D and/or Trial Production Facility
P = Pilot Line (Initial Production or Intended Low Volume)
T = Test and Assembly (Formerly A)
Q = Quick-Turn Fab
N = Nondedicated Foundry Service Available
D = Design Center
Source: Dataquest (December 1995)

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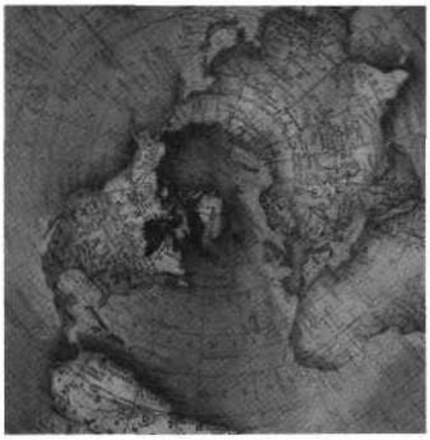

Dataquest

Japan Fab Database

Market Statistics

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
Product Code: SEMM-WW-MS-9504
Publication Date: December 25, 1995
Filing: Market Analysis

Japan Fab Database

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Table of Contents

List of Tables

Note: All tables show estimated data.

Japan Fab Database

Background

This document contains the Japan portion of Dataquest's wafer fab database. The Semiconductor Equipment, Materials, and Manufacturing Worldwide (SEMM) program uses both primary and secondary research to update this data. The tables in this report cover both merchant and captive production and pilot-line facilities, although our surveys and database also include R&D fabs.

Research Methodology

Dataquest conducts extensive annual surveys, complemented with quarterly secondary research. This data is then supplemented and cross-checked with various other information sources.

General Definitions

Fab line: A fab line is a semiconductor processing facility equipped for all front-end wafer manufacturing. Occasionally, there are two or more separate product-specific fab lines or wafer sizes in a single cleanroom. In this situation, Dataquest documents the cleanroom as separate fab lines if the company dedicates equipment to each wafer size or product line. Therefore, a company may operate many fab lines at one location.

Front-end wafer processing: Dataquest defines front-end wafer processing as all steps involved in semiconductor processing, beginning with initial oxide and ending at wafer probe.

Production fab: A wafer fab capable of front-end processing more than 1,250 wafers per week is a production fab (type = F).

Pilot fab: A wafer fab capable of front-end processing 1,250 or fewer wafers per week is a pilot fab (type = P).

Worldwide Geographic Region Definitions and Regional Roll-Ups

Americas
Includes Central America (all nations), Canada, Mexico, United States and Puerto Rico, and South America (all nations).

Japan
Japan is the only single-country region.

Europe, Africa, and Middle East
Includes Africa (all nations), Albania, Andorra, Armenia, Azerbaijan, Belarus, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Gibraltar, Hungary, Iceland, Israel, Italy, Kazakhstan, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Middle East (all nations), Moldova, Monaco,

Netherlands, Norway, Poland, Romania, Russia, San Marino, Scandinavia, Slovakia, Spain, Sweden, Sweden, Switzerland, Tajikistan, Turkey, Turkmenistan, Ukraine, United Kingdom, Uzbekistan, Vatican City, and Yugoslavia (all nations within the former Yugoslavia).

Asia/Pacific

Includes Australia, Bangladesh, Cambodia, China, Hong Kong, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, and Vietnam.

Definition of Table Columns

Products Produced contains details for seven product categories. The nomenclature used within the seven product groups of the fab database is as follows, with definitions where warranted:

- Analog
  - A/D D/A: Analog-to-digital, digital-to-analog converter
  - AUTOMOTIVE: Dedicated to automobile applications
  - CODEC: Coder/decoder
  - INTERFACE: Interface IC
  - LIN: Linear/analog device
  - MDIODE: Microwave diode
  - MESFET: Metal semiconductor field-effect transistor
  - MFET: Microwave field-effect transistor
  - MIXSIG ASIC: Mixed-signal/linear ASIC
  - MODEM: Modulator/demodulator
  - MMIC: Monolithic microwave IC
  - OP AMP: Operational amplifier
  - PWR IC: Power IC
  - REG: Voltage regulator
  - SMART PWR: Smart power
  - SWITCHES: Switching device
  - TELECOM: Telecommunications chip
- Memory
  - DRAM: Dynamic RAM
  - EEPROM or E2: Electrically erasable PROM
  - EPROM: Ultraviolet erasable PROM

- FERRAM: Ferroelectric RAM
- FIFO: First-in/first-out memory
- FLASH: Flash memory
- MEM: Memory
- NVMEM: Nonvolatile memory (ROM, PROM, EPROM, EEPROM, FERRAM)
- PROM: Programmable ROM
- RAM: Random-access memory
- ROM: Read-only memory
- SPMEM: Other specialty memory (such as dual-port, shift-register, color lookup)
- SRAM: Static RAM
- VRAM: Video RAM

■ Micrologic

- ASSP: Application-specific standard product
- BIT: Bit slice (subset of MPU functions)
- DSP: Digital signal processor
- LISP: 32-bit list instruction set processor for AI
- MCU: Microcontroller unit
- MPR: Microperipheral
- MPRCOM: MPR digital communication (ISDN, LAN, UART, modem)
- MPU: Microprocessor unit
- RISC: Reduced-instruction-set computation 32-bit MPU

■ Standard logic

- LOG or LOGIC: Standard logic

■ ASIC logic

- ARRAYS: Gate array
- ASIC: Application-specific IC
- CBIC: Cell-based IC
- CUSTOM: Full-custom IC (single user)
- FPGA: Field-programmable gate array
- PLD: Programmable logic device

- Discrete
  - DIODE
  - DIS or DISCRETE: Discrete
  - FET: Field-effect transistor
  - GTO: Gate turn-off thyristor
  - HEMT: High-electron-mobility transistor
  - IGBT: Insulated gate bipolar transistor
  - MOSFET: MOS-based field-effect transistor
  - PWR TRAN: Power transistor
  - RECTIFIER
  - RF: Radio frequency
  - SCR: Schottky rectifier
  - SENSOR
  - SST: Small-signal transistor
  - THYRISTOR
  - TRAN: Transistor
  - ZENER DIODE
- Optoelectronic
  - CCD: Charge-coupled device (imaging)
  - COUPLER: Photocoupler
  - IED: Infrared-emitting diode
  - IMAGE SENSOR
  - LASER: Semiconductor laser or laser IC
  - LED: Light-emitting diode
  - OPTO: Optoelectronic
  - PDIODE: Photo diode
  - PTRAN: Photo transistor
  - SAW: Surface acoustic wave device
  - SIT IMAGE SENSOR: Static induction transistor image sensor

Process Technology column lists four major types of technologies. This column also lists uncommon technologies with information on well types, logic structure, and number of metal levels. Definitions used in the "Process Technology" column are as follows:

- MOS (silicon-based)
  - CMOS: Complementary metal-oxide semiconductor

- MOS: N-channel metal-oxide semiconductor (NMOS) and p-channel metal-oxide semiconductor (PMOS).
- M1: Single-level metal
- M2: Double-level metal
- M3: Triple-level metal
- N-WELL
- P-WELL
- POLY1: Single-level polysilicon
- POLY2: Double-level polysilicon
- POLY3: Triple-level polysilicon

- BiCMOS (silicon-based)
  - BiCMOS: Bipolar and CMOS combined on a chip
  - BiMOS: Bipolar and MOS combined on a chip
  - ECL I/O: ECL input/output
  - TTL I/O: TTL input/output
- Bipolar (silicon-based)
  - BIP or BIPOLAR: Bipolar
  - ECL: Emitter-coupled logic
  - TTL: Transistor-transistor logic
  - STTL: Schottky TTL
- Gallium arsenide and other compound semiconductor materials
  - GaAs: Gallium arsenide
  - AlGaAs: Gallium aluminum arsenide
  - GaAs on Si: Gallium arsenide on silicon
  - GaP: Gallium phosphide
  - HgCdTe: Mercuric cadmium telluride
  - InAs: Indium arsenide
  - InGaAs: Indium gallium arsenide
  - InP: Indium phosphide
  - InSb: Indium antimony
  - LiNbO3: Lithium niobate
  - SOS: Silicon on sapphire

Minimum Geometry is the smallest feature attainable in production volumes, measured in microns, at the critical mask layers.

Wafer Diameter represents the wafer diameter usually expressed colloquially in inches. However, for wafers greater than 3 inches in diameter, the colloquial expression becomes grossly inaccurate. When calculating square inches, Dataquest uses the following approximations:

- Stated diameter 4 inches (100mm) = Approximate diameter 3.938 inches
- Stated diameter 5 inches (125mm) = Approximate diameter 4.922 inches
- Stated diameter 6 inches (150mm) = Approximate diameter 5.906 inches
- Stated diameter 8 inches (200mm) = Approximate diameter 7.87 inches

Estimated Maximum Wafer Starts per Month is the equipment-limited wafer start capacity per four-week period. Start capacity is limited only by the installed equipment in the fab and the complexity of the process it runs, not by current staffing or the number of shifts operating.

Table 1
Japan Existing Pilot and Production Fab Lines
(Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
AISHIN SEIKI	HANDA-SHI	JAPAN	HANDA	AUTOMOTIVE	NA		6	1991			F
AISHIN SEIKI	HEKINAN-SHI	JAPAN	SHINKAWA	AUTOMOTIVE	NA		3	1990			P
ASAHI KASEI MICRO SYSTEMS	ATSUGI-SHI	JAPAN	NA	TRAN CUSTOM	MOS		5	1987		4,000	PR
ASAHI KASEI MICRO SYSTEMS	NOBEOKA-SHI	JAPAN	NA	SRAM, FULL CUSTOM, OTHER MOS LOGIC	CMOS	0.8	6	1993	5,250	6,000	FAT
CANON	HIRATSUKA-SHI	JAPAN	NA	AMORPHOUS IMAGE SENSORS	GaAs		3				P
CANON	HIRATSUKA-SHI	JAPAN	NA	ASIC	CMOS		6		3,000	3,000	P
CANON DENSHI	CHICHIBU-SHI	JAPAN	NA	CCD	MOS	3	5	[illegible]	5,000	5,000	P
CASIO	HACHIOJI-SHI	JAPAN	NA	ASIC	NA		4		11,000	11,000	PAT
FUJI ELECTRIC	MATSUMOTO-SHI	JAPAN	NA	CUSTOM ASSP	MOS BiCMOS BIPOLAR	2	4			15,000	F
FUJI ELECTRIC	MATSUMOTO-SHI	JAPAN	NA	CUSTOM ASSP	CMOS BiCMOS BIPOLAR	0.8	6	1990		3,000	F
FUJI ELECTRIC	MATSUMOTO-SHI	JAPAN	NA	MOSFET IGBT High Voltage Diode	MOS BIPOLAR	3	5	1995		30,000	F
FUJI ELECTRIC	MATSUMOTO-SHI	JAPAN	NA	DIODE PWR TRAN MOSFET	BIPOLAR	6	4	1985		50,000	FAT
FUJI FILM MICRODEVICE	KUROKAWA-GUN	JAPAN	NA	CCD Converter Full-Custom	CMOS	1	6	1992	3,000	3,000	F
FUJI XEROX	SUZUKA-SHI	JAPAN	NA	PWR ICs IMAGE SENSOR LOG	CMOS	3	5	1986	3,000		P
FUJITSU	AIZU WAKAMATSU-SHI	JAPAN	BLDG. #1	ARRAYS LOGIC	CMOS BIPOLAR	1.2	6	1985		30,000	F
FUJITSU	AIZU WAKAMATSU-SHI	JAPAN	BLDG. #2	ARRAYS CBIC 32-Bit MCU	CMOS	0.7	6	1990		30,000	F
FUJITSU	AIZU WAKAMATSU-SHI	JAPAN	BLDG. #2-2	ARRAYS Logic CBIC MPU	CMOS	0.35	6	1995		35,000	F
FUJITSU	AIZU WAKAMATSU-SHI	JAPAN	VLSI 1	DIS A/D D/A	BIPOLAR	1.5	5	1983		30,000	FAT
FUJITSU	AIZU WAKAMATSU-SHI	JAPAN	VLSI 2	256K DRAM SRAM EPROM MPU	CMOS MOS	1	5	1984		40,000	FAT
FUJITSU	AIZU WAKAMATSU-SHI	JAPAN	VLSI 3	DRAM SRAM ROM	CMOS MOS	1	6	1988		20,000	F
FUJITSU	ISAWA-GUN	JAPAN	NO. 2	ROM EPROM	MOS	1.5	5	1984		32,000	FAT
FUJITSU	ISAWA-GUN	JAPAN	NO. 3	1Mb 4Mb DRAM, SRAM, ROM	CMOS MOS POLY3	0.8	6	1987		25,000	F
FUJITSU	ISAWA-GUN	JAPAN	NO. 4	4Mb/16Mb DRAM 1Mb/4Mb FLASH SRAM ASIC	CMOS MOS POLY3	0.5	6	1990		30,000	F

(Continued)

Table 1 (Continued)
Japan Existing Pilot and Production Fab Lines
(Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
FUJITSU	KAWASAKI-SHI	JAPAN	NA	3D ICs JOSEPHSON JUNCTION	NA	0.35	5	1988		5,000	P
FUJITSU	KUWANA-GUN	JAPAN	NO. 1	ARRAYS	CMOS MOS	1	6	1984		10,000	P
FUJITSU	KUWANA-GUN	JAPAN	NO. 2	LOG ARRAYS 4Mb DRAM	CMOS BIP	0.8	6	1987		10,000	PAT
FUJITSU	KUWANA-GUN	JAPAN	NO. 3 PHASE 1	4Mb/16Mb DRAM SRAM MPU	CMOS	0.5	6	1992		15,000	F
FUJITSU	KUWANA-GUN	JAPAN	NO. 3 PHASE 2	4Mb/16Mb DRAM	CMOS	0.25	8	1994		500	F
FUJITSU-AMD SEMICONDUCTOR	AIZU WAKAMATSU-SHI	JAPAN	Phase 1	4/16/32Mb Flash EPROM	CMOS	0.5	8	1994	5,000	10,000	F
FUJITSU-Quantum Device	NAKAKOMA-GUN	JAPAN	No.1	FET LIN OPTO HEMT	GaAs	1.5	4	1984		13,000	F
FUJITSU-Quantum Device	NAKAKOMA-GUN	JAPAN	No.2	HEMT ASIC	GaAs	1.5	4	1992		13,000	F
HAMAMATSU PHOTONICS	HAMAMATSU-SHI	JAPAN	NA	OPTO	NA		3		15,000	15,000	F
HITACHI	CHITOSE-SHI	JAPAN	Chitose 1F	4M DRAM MCU	CMOS	0.8	6	1988		15,000	F
HITACHI	CHITOSE-SHI	JAPAN	Chitose 2F	4M DRAM MCU	CMOS	0.8	6	1990		15,000	F
HITACHI	GOSHOGAWARA-SHI	JAPAN	NA	1M/4M DRAM	CMOS	0.8	6	1990		17,000	F
HITACHI	HITACHI-SHI	JAPAN	NA	PWR GTO THYRISTERS TTL	BIP	1.5	5	1983		20,000	F
HITACHI	HITACHINAKA-SHI	JAPAN	N1-1	1Mb/4Mb DRAM	CMOS	0.8	6	1983		15,000	F
HITACHI	HITACHINAKA-SHI	JAPAN	N2-1	16Mb DRAM	CMOS	0.5	8	1994	10,000	20,000	F
HITACHI	KODAIRA-SHI	JAPAN	NA	4Mb/16Mb DRAM	CMOS	0.8	6	1990		3,000	P
HITACHI	KODAIRA-SHI	JAPAN	R&D 1	MPU MEM CBIC	CMOS M2	1.2	5	1987		5,000	P
HITACHI	KODAIRA-SHI	JAPAN	R&D 2	MPU SRAM DRAM ARRAYS CBIC	CMOS M2	0.5	6	1985		3,000	P
HITACHI	KOMORO-SHI	JAPAN	KOMORO	LASER TELECOM	CMOS GaAs BiCMOS	1.5	3	1980		15,000	F
HITACHI	MOBARA-SHI	JAPAN	D1	ASIC MCU EPROM	MOS CMOS	1.3	5	1982		25,000	F
HITACHI	MOBARA-SHI	JAPAN	D3	4Mb DRAM	CMOS M2	0.8	6	1990		15,000	F
HITACHI	NAKAKOMA-GUN	JAPAN	K2-1F	4Mb DRAM SRAM MCU	CMOS	2	6	1990		25,000	F
HITACHI	NAKAKOMA-GUN	JAPAN	K2-2F	16Mb DRAM	CMOS	0.5	8	1995		10,000	F
HITACHI	NAKAKOMA-GUN	JAPAN	K4-1F	MROM MPU LOGIC	CMOS	1.3	5	1983		30,000	F
HITACHI	NAKAKOMA-GUN	JAPAN	K4-2F	MROM	CMOS	1	6	1988		20,000	F

(Continued)

Table 1 (Continued)
Japan Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
HITACHI	NAKAKOMA-GUN	JAPAN	K4-3	4Mb DRAM 1Mb SRAM EPROM	CMOS MOS	0.8	6	1989		10,000	F
HITACHI	OME-SHI	JAPAN	D4/D5	64M DRAM 64M Flash ASIC	CMOS	0.35	8	1994		5,000	PR
HITACHI	TAKASAKI-SHI	JAPAN	No. 1	DISCRETE BIP ANALOG OPTO	BIP MOS	2	5	1986		15,000	F
HITACHI	TAKASAKI-SHI	JAPAN	No. 2	MEM BIP LIN	BIP BICMOS CMOS	1.2	6	1988		15,000	F
HITACHI	TAKASAKI-SHI	JAPAN	No. 3	16Mb DRAM	CMOS	0.5	8	1995		10,000	F
HITACHI	TAKASAKI-SHI	JAPAN	No. 4	256K/1Mb SRAM	CMOS BICMOS	0.5	6	1992		20,000	F
HONDA	HAGA-GUN	JAPAN	Tochigi Lab	ENG. CONTROL SENSORS MMIC	GaAs		3	1990			P
IBM	YASU-GUN	JAPAN	NA	ARRAY 1Mb DRAM MPU ROM	CMOS	1	5			30,000	F
IBM	YASU-GUN	JAPAN	NA	4M/16M DRAM	CMOS	0.6	8	1990		6,000	F
IWATSU	HACHIOJI-SHI	JAPAN	NA	NA	CMOS	1.5	5	1986		6,000	P
JVC	YOKOSUKA-SHI	JAPAN	NA	1K ARRAYS DSP CUSTOM	CMOS	3	3		9,000	9,000	P
KAWASAKI STEEL	UTSUNOMIYA-SHI	JAPAN	NA	256K SRAM CBIC ARRAYS	CMOS	0.8	6	1991	6,000	6,000	NP
KODENSHI	UJI-SHI	JAPAN	PLANT 3	OPTO DISCRETE	GaAs GaP BIP				7,000	7,000	FAT
KONICA	NISHI-SHINJUKU	JAPAN	LAB	OPTO	NA		3	1984		7,000	PR
KTI SEMICONDUCTOR	NISHIWAKI-SHI	JAPAN	Fab 1	16M DRAM ASIC	CMOS	0.5	8	1992	7,000	10,000	FAT
KYOCERA	KANSAI-SHI	JAPAN	NA	NA	NA			1992			PR
KYOTO SEMICONDUCTOR	KYOTO-SHI	JAPAN	NA	LED TRAN IMAGE SENSOR	GaAs GaP						F
LSI LOGIC (NIHON S/C)	TSUKUBA-SHI	JAPAN	FAB 1	ASIC CBIC MPU MPR SRAM	CMOS BICMOS	1	6	1989	4,700	20,000	NF
LSI LOGIC (NIHON S/C)	TSUKUBA-SHI	JAPAN	FAB 2	ASIC CBIC MPU MPR SRAM	CMOS BICMOS	0.6	6	1993	6,000	8,000	F
MATSUSHITA	ARAI-SHI	JAPAN	FAB B	MCU LOGIC ASSP	BIP BiCMOS	1.5	5	1982		14,000	F
MATSUSHITA	ARAI-SHI	JAPAN	FAB C-1	Analog	BIP	2	5	1984		7,000	FAT
MATSUSHITA	ARAI-SHI	JAPAN	FAB C-2	CCD	CMOS	0.8	5	1984		7,000	FAT
MATSUSHITA	ARAI-SHI	JAPAN	FAB D-1	ANALOG	BIP	1.8	4	1985		22,000	F
MATSUSHITA	ARAI-SHI	JAPAN	FAB D-2	ANALOG	BIP	1.5	5	1985		18,000	F
MATSUSHITA	HIOKI-GUN	JAPAN	FAB A	ANALOG+E102	BIPOLAR BiCMOS	2	4	1980		28,000	F

(Continued)

Table 1 (Continued)
Japan Existing Pilot and Production Fab Lines
(Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
MATSUSHITA	HIOKI-GUN	JAPAN	NA	OPTO LED LASER	GaAs GaP	3	2	1974		1,000	F
MATSUSHITA	KADOMA-SHI	JAPAN	S/C R6	16Mb DRAM 64-bit MPU 64Mb DRAM	CMOS	0.35	6	1991		500	PRAT
MATSUSHITA	KYOTO-SHI	JAPAN	KAGOSHIMA	DISCRETE(SS Tr)	BIPOLAR	5	2	1978		18,000	F
MATSUSHITA	KYOTO-SHI	JAPAN	KYOTO R&D	DRAM	CMOS	0.35	8	1991		500	PR
MATSUSHITA	KYOTO-SHI	JAPAN	TOYODENPA	DISCRETE(SS Di)	BIP	5	4	1975		20,000	FAT
MATSUSHITA	NAGAOKAKYO-SHI	JAPAN	A	ANALOG	BIP	5	4	1967		15,000	F
MATSUSHITA	NAGAOKAKYO-SHI	JAPAN	B	Discrete (Small Signal)	BIP	4	4	1970		17,000	F
MATSUSHITA	NAGAOKAKYO-SHI	JAPAN	C	Discrete (Power)	BIP	3	4	1980		18,000	F
MATSUSHITA	NAGAOKAKYO-SHI	JAPAN	V	MCU LOGIC MOSFET	MOS CMOS	2	4	1982		19,000	F
MATSUSHITA	TONAMI-SHI	JAPAN	FAB 1	MCU ASIC	CMOS	0.5	6	1994	4,000	12,000	F
MATSUSHITA	UOZU-SHI	JAPAN	FAB A-1	MCU	CMOS	1.2	5	1985		34,000	F
MATSUSHITA	UOZU-SHI	JAPAN	FAB B	MCU DSP LOGIC ASSP	CMOS	0.8	6	1991		20,000	F
MATSUSHITA	UOZU-SHI	JAPAN	FAB B-2	MPU MCU	CMOS	0.8	6	1995		10,000	F
MATSUSHITA	UOZU-SHI	JAPAN	FAB C-1	MPU MCU LOGIC ASSP	CMOS	1	6	1987		27,000	F
MATSUSHITA	UOZU-SHI	JAPAN	FAB C-2	MCU	CMOS	0.6	6	1990		24,000	F
MATSUSHITA	UTSUNOMIYA-SHI	JAPAN	NA	DISCRETE (SS Tr, Varicap)	BIPOLAR	5	4	1983		10,000	PAT
MEIDENSHA	NUMAZU-SHI	JAPAN	NA	GTO THYRISTOR	NA		5	1985		7,000	P
MITSUBISHI	FUKUOKA-SHI	JAPAN	#1	PWR TRAN DIODE BIP	BIP MOS	3	4	1976		34,000	FAT
MITSUBISHI	FUKUOKA-SHI	JAPAN	#2	BIP LIN A/D D/A DIS Micro	BIP	1.5	5	1984		42,000	F
MITSUBISHI	ITAMI-SHI	JAPAN	NA	FET HEMT LAZRE DI	GaAs	0.35	3	1960	1,000	3,000	P
MITSUBISHI	ITAMI-SHI	JAPAN	ULSI	16Mb/64Mb/256Mb DRAM ASIC FLASH	CMOS	0.35	8	1993		10,000	PR
MITSUBISHI	KAMI-GUN	JAPAN	TA1	4Mb DRAM 1Mb SRAM ASSP	CMOS	0.7	6	1990		30,000	F
MITSUBISHI	KAMI-GUN	JAPAN	TA2	8b/16b/32b MCU ASIC	CMOS	0.5	6	1988		30,000	PAT
MITSUBISHI	KIKUCHI-GUN	JAPAN	B-1F	EPROM	CMOS	1.3	5	1970		30,000	F
MITSUBISHI	KIKUCHI-GUN	JAPAN	B-2F	ARRAYS MCU	CMOS	1	4	1975		52,000	F

(Continued)

Table 1 (Continued)
Japan Existing Pilot and Production Fab Lines
(Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
MITSUBISHI	KIKUCHI-GUN	JAPAN	C-1F	1Mb SRAM 1Mb ROM MCU FLASH	MOS CMOS	0.8	5	1989		25,000	F
MITSUBISHI	KIKUCHI-GUN	JAPAN	C-2F	EPROM MCU MPU	CMOS	1.3	5	1990		28,000	F
MITSUBISHI	KIKUCHI-GUN	JAPAN	D-1F	16Mb DRAM	CMOS	0.35	8	1994	8,000	10,000	F
MITSUBISHI	SAIJO-SHI	JAPAN	B	1Mb DRAM ANALOG	CMOS M1	0.9	5	1984		36,000	FAT
MITSUBISHI	SAIJO-SHI	JAPAN	C	DRAM 8b MCU ASIC	CMOS M2	0.8	5	1988		42,000	FAT
MITSUBISHI	SAIJO-SHI	JAPAN	SA2A	4Mb/16Mb DRAM	CMOS M2	0.5	6	1991		20,000	F
MITSUBISHI	SAIJO-SHI	JAPAN	SA2B	4Mb/16Mb DRAM	CMOS M2	0.5	8	1994		16,000	F
MITSUMI	ATSUGI-SHI	JAPAN	NA	LOG DIS	BIP		4	1984		30,000	FAT
MORIRICA ELECTRONICS	YOKOHAMA-SHI	JAPAN	NA	OPTO	GaP						F
MOTOROLA	YAMA-GUN	JAPAN	MOS 7A	LOGIC ANALOG	CMOS MOS BIPOLAR BiCMOS	0.8	6	1994		50,000	FAT
MURATA MANUFACTURING	YASU-GUN	JAPAN	Yasu	FET MMIC	GaAs	0.8		1993			RP
NEC	HIGASHI HIROSHIMA-SHI	JAPAN	Dif-1	4Mb DRAM SRAM MPU 4Mb ROM	CMOS	0.6	6	1990		30,000	FAT
NEC	HIGASHI HIROSHIMA-SHI	JAPAN	Dif-3	16Mb/64Mb DRAM ASIC RISC	CMOS	0.35	8			10,000	F
NEC	KAWASAKI-SHI	JAPAN	NA	ASIC EPROM MCU MPU OPTO	CMOS MOS	1.4	5	1985		20,000	PFAT
NEC	SAGAMIHARA-SHI	JAPAN	BLDG. UL	EPROM ASIC MPU MCU	CMOS	1.2	5	1985		12,000	FAT
NEC	SAGAMIHARA-SHI	JAPAN	G-1	16Mb DRAM ASIC MPU 4Mb ROM	CMOS BiCMOS	0.8	6	1988		10,000	PAT
NEC	SAGAMIHARA-SHI	JAPAN	G-2	16Mb/64Mb DRAM ASIC MPU	CMOS	0.35	8	1990		3,000	F
NEC	TSURUOKA-SHI	JAPAN	TSURUOKA Works 1	BIP LOG LIN DIS	BIP	1	4	1976		20,000	FAT
NEC	TSURUOKA-SHI	JAPAN	TSURUOKA Works 2	LOG LIN	BIP	0.8	6	1993		20,000	F
NEC	ASA-GUN	JAPAN	Dif-1	4Mb DRAM 1Mb SRAM MPU CBIC	CMOS BiCMOS	0.8	6	1988		45,000	FAT
NEC	ASA-GUN	JAPAN	Dif-2 (Bldg.C)	4Mb/16Mb DRAM ASIC	CMOS	0.5	6	1993		45,000	F
NEC	KUMAMOTO-SHI	JAPAN	Dif-3	EPROM ROM	CMOS MOS	2	5	1974		20,000	F

(Continued)

Table 1 (Continued)
Japan Existing Pilot and Production Fab Lines
(Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
NEC	KUMAMOTO-SHI	JAPAN	Dif-4	BIP LIN MEM ASIC	BIP	1.4	5	1983		25,000	F
NEC	KUMAMOTO-SHI	JAPAN	Dif-5	LOGIC DRAM	CMOS MOS	1.2	5	1978		20,000	F
NEC	KUMAMOTO-SHI	JAPAN	Dif-6	1Mb DRAM MPU ARRAYS	CMOS MOS POLY2	1	6	1987		30,000	F
NEC	KUMAMOTO-SHI	JAPAN	Dif-7	MCU 4Mb DRAM ASIC	CMOS BICMOS	0.8	6	1988		30,000	F
NEC	KUMAMOTO-SHI	JAPAN	Dif-8 -1	16Mb DRAM 4Mb SRAM RISC MPU	CMOS	0.35	8	1994	5,000	15,000	F
NEC	OTSU-SHI	JAPAN	Dif-1	PWR TRAN LINEAR	BIP	2	4	1978		25,000	FAT
NEC	OTSU-SHI	JAPAN	Dif-2	MCU LCD Driver	CMOS MOS	1	6	1981	12,000	16,000	F
NEC	OTSU-SHI	JAPAN	Dif-3	SRAM 4Mb DRAM MICRO ASIC	CMOS MOS	1	6	1983	16,000	17,000	F
NEC	OTSU-SHI	JAPAN	Dif-4	16bit MCU LCD Driver ASIC	CMOS	0.8	6	1989		20,000	FAT
NEC	OTSU-SHI	JAPAN	GaAs	DIODE OPTO	GaAs	3	4	1988	1,500	2,000	P
NEW JAPAN RADIO	KAMIFUKUOKA-SHI	JAPAN	FAB 1	ANALOG OP AMP OPTO	BIP	4	3	1977		21,000	F
NEW JAPAN RADIO	KAMIFUKUOKA-SHI	JAPAN	FAB 2	ANALOG A/D D/A	BIP	2.5	4	1981		35,000	NF
NEW JAPAN RADIO	KAMIFUKUOKA-SHI	JAPAN	FAB 3	LOGIC ANALOG MCU	CMOS BIP BiCMOS	0.8	5	1986		19,000	NFAT
NEW JAPAN RADIO	KAMIFUKUOKA-SHI	JAPAN	GaAs	ANALOG DISCRETE OPTO	GaAs GaAlAs	0.5	3	1984		200	FR
NIPPON PRECISION CIRCUITS	NASU-GUN	JAPAN	Bldg H	A/D D/A DSP LOG ASSP	CMOS	0.8	6	1990		6,000	F
NIPPON PRECISION CIRCUITS	NASU-GUN	JAPAN	Bldg S	LOG LIN A/D D/A MODEM	CMOS	2	4	1984		15,000	F
NIPPON STEEL	SAGAMIHARA-SHI	JAPAN	S/C DEVICE R&D CTR.	ASIC	NA	0.8	6	1991			DP
NIPPONDENSO	KARIYA-SHI	JAPAN	BLDG. 1	LOG CUSTOM MCU OPTO	MOS	1.5	5	1987	2,000	2,000	PF
NIPPONDENSO	NUKATA-GUN	JAPAN	705	MCU CUSTOM	MOS	1.5	6	1993	10,000	10,000	FAT
NISSAN	YOKOSUKA-SHI	JAPAN	R&D Center	MCU CUSTOM	CMOS	2	5	1987	500	500	PAT
NITTETSU SEMICONDUCTOR	TATEYAMA-SHI	JAPAN	M1	MCU Logic (LCD Driver)	CMOS	1.2	5	1985			OFAT
NITTETSU SEMICONDUCTOR	TATEYAMA-SHI	JAPAN	M2	1Mb/4Mb DRAM FLASH Logic	CMOS M1	0.8	6	1988		12,000	OFAT

(Continued)

Table 1 (Continued)
Japan Existing Pilot and Production Fab Lines
(Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
NITTETSU SEMICONDUCTOR	TATEYAMA-SHI	JAPAN	M3	1Mb/4Mb DRAM	CMOS	0.5	6	1990		15,000	OF
NKK	AYASE-SHI	JAPAN	Phase 1	256K/1Mb/4Mb SRAM Flash MROM RISC MPU ASIC	CMOS	0.5	8	1992	3,000	6,000	P
OKI	HACHIOJI-SHI	JAPAN	H1	Micro Logic Analog	CMOS BiCMOS BIP	3	2	1988	20,000	30,000	NFAT
OKI	HACHIOJI-SHI	JAPAN	U1	64M/256M DRAM Micro Logic	CMOS BiC Compound	0.3	6	1992	1,000	1,000	F
OKI	HACHIOJI-SHI	JAPAN	V3	16M/64M DRAM Micro Gate Array	CMOS BiC Compound	0.5	6	1989	1,000	2,000	F
OKI	KUROKAWA-GUN	JAPAN	S1	4Mb DRAM VRAM 1Mb SRAM 16M MROM	CMOS	0.5	6	1981	25,000	30,000	FAT
OKI	MIYAZAKI-GUN	JAPAN	M1	Micro Logic	CMOS BiCMOS	2	4	1984	30,000	50,000	NFAT
OKI	MIYAZAKI-GUN	JAPAN	M2	1Mb DRAM 256k SRAM 4M MROM	CMOS	0.8	5	1991	20,000	60,000	NFT
OKI	MIYAZAKI-GUN	JAPAN	M3	16M DRAM 4M DRAM	CMOS	0.4	6	1967	25,000	30,000	FAT
OLYMPUS	HACHIOJI-SHI	JAPAN	NA	IC	CMOS						P
OLYMPUS	KAMIINA-GUN	JAPAN	S/C Technology Cente	SIT IMAGE SENSOR	CMOS	3	5	1986		5,000	P
OMRON	KOUKA-GUN	JAPAN	NA	OPTO IMAGE SENSOR	BIP GaP		4	1975		20,000	F
OMRON	KOUKA-GUN	JAPAN	NA	OPTO IMAGE SENSOR	BIP GaP	3	4	1987		1,000	PA
ORIGIN ELECTRIC	OYAMA-SHI	JAPAN	NA	TRAN DIODE DIS	BIP		4			17,000	FAT
PIONEER VIDEO	KOFU-SHI	JAPAN	NA	MPR ASIC Analog	CMOS	0.8	5	1985	8,000	8,000	PFAT
RICOH	IKEDA-SHI	JAPAN	Fab 1	256k ROM G/A CBIC Vol.Reg.	CMOS Bip	1.5	6	1982		5,000	FDN
RICOH	IKEDA-SHI	JAPAN	Fab 2	1Mb ROM 8b MCU G/A CBIC	CMOS	0.8	4	1986		5,000	FDN
RICOH	KATO-GUN	JAPAN	Fab 3	4M/8Mb ROM 16b MCU G/A CBIC	CMOS	1.5	6	1990		12,000	FDN
ROHM	CHIKUGO-SHI	JAPAN	APOLLO ELECTRONICS	TRAN DIS	BIP	3	4	1981	20,000	20,000	FAT
ROHM	KASAOKA-SHI	JAPAN	Wako	LINEAR epi	BIP	1.2	4	1968	20,000	20,000	FA

(Continued)

Table 1 (Continued)
Japan Existing Pilot and Production Fab Lines
(Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
ROHM	KYOTO-SHI	JAPAN	LSI R&D 1	MPU LASER MODEM TRAN LED	CMOS	0.8	6	1989	13,000	13,000	DPAT
ROHM	KYOTO-SHI	JAPAN	LSI R&D 2	MCU GA	CMOS BiCMOS	0.5	6	1994	3,000	3,000	DPAT
ROHM	KYOTO-SHI	JAPAN	NA	MCU ARRAYS SRAM EEPROM	CMOS BICMOS	0.8	6	1989	15,000	15,000	F
ROHM	KYOTO-SHI	JAPAN	NA	DISCRETE OPTO	BIP GaAs	3	4			15,000	FAT
ROHM	KYOTO-SHI	JAPAN	NA	LASER OPTO	BIP GaAs	3	4		25,000	25,000	FAT
SANKEN	HIGASHINE-SHI	JAPAN	NA	PWR TRAN DIODE LED	Bip		5	1981		10,000	FAT
SANKEN	HIGASHINE-SHI	JAPAN	NA	PWR TRAN DIODE	Bip		4	1989		10,000	FAT
SANKEN	NIIZA-SHI	JAPAN	NA	PWR TRAN DIODE LED	Bip		3	1970		15,000	F
SANKEN	NIIZA-SHI	JAPAN	NA	PWR TRAN DIODE LED	Bip		5	1986		6,000	P
SANKEN	NIHONMATSU-SHI	JAPAN	NA	LED	Compound		3	1991		10,000	FAT
SANYO	ANPACHI-GUN	JAPAN	C 3	SRAM, EEPROM, Logic (CD-ROM LSI), Custom, CCD	CMOS	0.8	5	1986	28,000	30,000	NFQ
SANYO	ANPACHI-GUN	JAPAN	Microelectronics	SRAM, Custom, CCD	CMOS	0.4	6	1990	1,000	1,000	PR
SANYO	OJIYA-SHI	JAPAN	A 1	1M/4Mb DRAM, 4/8b MCU, DSP	CMOS	0.8	5	1985	16,000	35,000	NFAT
SANYO	OJIYA-SHI	JAPAN	B 1	EEPROM FLASH LOGIC ASSP	CMOS	0.7	6	1989	16,000	28,000	NFAT
SANYO	OJIYA-SHI	JAPAN	B 2	ANALOG	BiCMOS, Bipolar	1	5	1987	27,000	30,000	NF
SANYO	OJIYA-SHI	JAPAN	C	DRAM	CMOS	0.6	6	1994	20,000	20,000	NFAT
SANYO	OURA-GUN	JAPAN	Bip 1	Analog	Bipolar	2	2	1967	3,000	20,000	NF
SANYO	OURA-GUN	JAPAN	Bip 2	Analog	Bipolar	1.6	3	1981	20,000	45,000	NF
SANYO	OURA-GUN	JAPAN	Bip 3	Analog	Bipolar	1.2	4	1991	24,000	40,000	NF
SANYO	OURA-GUN	JAPAN	MOS 2	Logic ASSP MCU	CMOS, MOS	1	5	1984	16,000	25,000	NF
SANYO	OURA-GUN	JAPAN	R&D 1	Memory, Logic	Bipolar	1.8	4	1984	4,500	5,000	PR
SANYO	OURA-GUN	JAPAN	R&D 2	Memory, Logic	CMOS	0.6	6	1984	4,500	5,000	PR
SANYO	OURA-GUN	JAPAN	Tr	Logic	CMOS, MOS	1.2	4	1980	22,000	30,000	NF
SANYO	OURA-GUN	JAPAN	Tr 1	TRAN (SST, Pw.T)	MOS, Bipolar	1	4		10,000	100,000	NF
SANYO	OURA-GUN	JAPAN	Tr 2	TRANSISTORS SST POWER	MOS, BIPOLAR	2	4	1980	10,000	60,000	NF
SANYO	TOTTORI-SHI	JAPAN	Tottori	LED, Laser diode	Compound	2	3		10,000	40,000	NF

(Continued)

Table 1 (Continued)
Japan Existing Pilot and Production Fab Lines
(Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
SEIKO EPSON	SAKATA-SHI	JAPAN	Bldg 3	FPGA PLD CBIC	CMOS	0.65	6	1991	10,000	10,000	NF
SEIKO EPSON	SUWA-GUN	JAPAN	BLDG. A	ARRAYS 256K SRAM EPROM	CMOS	1.5	5	1985	30,000	30,000	NF
SEIKO EPSON	SUWA-GUN	JAPAN	BLDG. B	ARRAYS CBIC SRAM EEPROM	CMOS MOS	2.5	4	1981	40,000	40,000	NF
SEIKO EPSON	SUWA-GUN	JAPAN	BLDG. D	1Mb SRAM ASIC	CMOS BICMOS	0.8	6	1989	5,000	5,000	F
SEIKO INSTRUMENTS	MATSUDO-SHI	JAPAN	BLDG. B	TELECOM	CMOS	2	4	1983	10,000	10,000	NF
SEIKO INSTRUMENTS	MATSUDO-SHI	JAPAN	NA	SRAM ARRAYS CBIC EEPROM	CMOS	0.8	6	1987	3,000	3,000	NF
SHARP	FUKUYAMA-SHI	JAPAN	FACTORY 1	MROM 8bit MCU ARRAYS CBIC	CMOS	0.8	5	1985	14,000	30,000	NF
SHARP	FUKUYAMA-SHI	JAPAN	FACTORY 2	16Mb MROM, DRAM, SRAM	CMOS	0.6	6	1989	20,000	35,000	NFAT
SHARP	FUKUYAMA-SHI	JAPAN	FACTORY 3	Flash, 32M MROM, SRAM	CMOS	0.6	8	1991	6,000	15,000	F
SHARP	KITA KATSURAGI-GUN	JAPAN	NA	Optocoupler	GaAs	0	3	1981	25,000	25,000	NFAT
SHARP	TENRI-SHI	JAPAN	FACTORY 2	SRAM, MROM, MCU, LCD	CMOS BIP	1.2	5	1977	20,000	25,000	NF
SHARP	TENRI-SHI	JAPAN	FACTORY 3	SRAM, MROM, MCU, ASIC	CMOS BIP	0.35	5	1980	20,000	22,000	NFAT
SHARP	YAMATO KORIYAMA-SHI	JAPAN	NA	LASER, LED, OPTO	GaAs		3		22,000	22,000	FAT
SHIMADZU	ATSUGI-SHI	JAPAN	Atsugi	Laser Diode	Compound		4				FAT
SHINDENGEN	HANNO-SHI	JAPAN	R&D Center	PWR MOSFET HYBRID	MOS BIP	5	4	1989	500	1,000	DPAT
SHINDENGEN	HANNO-SHI	JAPAN	Trial	PWR MOSFET HYBRID	MOS BIP	5	4	1991	500	1,000	PAT
SHINDENGEN	HIGASHINE-SHI	JAPAN	BLDG. 1	TRANSISTOR	MOS BIP	10	3	1985	1,000	10,000	F
SHINDENGEN	HIGASHINE-SHI	JAPAN	BLDG. 2	MOSFET	MOS BIP	10	3	1987	1,000	20,000	F
SHINDENGEN	HIGASHINE-SHI	JAPAN	BLDG. 3	POWER TRAN	MOS BIP	10	4	1993	1,000	5,000	F
SHINDENGEN	HONJO-SHI	JAPAN	Ohura -1	DIODE THYRISTOR	BIP	10	2	1972	10,000	70,000	FAT
SHINDENGEN	HONJO-SHI	JAPAN	Ohura -2	DIODE THYRISTOR	BIP	10	2	1983	5,000	50,000	F
SONY	ATSUGI-SHI	JAPAN	NA	LIN	BIP	2	4			400	F
SONY	ATSUGI-SHI	JAPAN	NA	EEPROM 4Mb VRAM 4Mb SRAM	CMOS	0.8	6	1987		10,000	F
SONY	ATSUGI-SHI	JAPAN	NA	FET LASER CCD HEMT	GaAs		3	1988			PAT

(Continued)

Table 1 (Continued)
Japan Existing Pilot and Production Fab Lines
(Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
SONY	ISAHAYA-SHI	JAPAN	1G	1Mb SRAM LOG	CMOS	1	6	1989		14,000	F
SONY	ISAHAYA-SHI	JAPAN	2G	CCD 256Kb SRAM 1Mb SRAM	CMOS	0.8	6	1989		17,000	F
SONY	ISAHAYA-SHI	JAPAN	3G	1Mb SRAM 4Mb VRAM CCD	CMOS	0.5	6	1991		45,000	F
SONY	KOKUBU-SHI	JAPAN	#2 PHASE1	DIS	BIP	3	4	1975		30,000	F
SONY	KOKUBU-SHI	JAPAN	#2 PHASE2	LIN A/D D/A	BIP	2	5	1976		25,000	F
SONY	KOKUBU-SHI	JAPAN	#4	SRAM MCU CCD	MOS CMOS	1.3	5	1978		28,000	FAT
SONY	KOKUBU-SHI	JAPAN	#6	LOG MEM MCU LIN	CMOS BiCMOS	0.8	6	1992		30,000	FAT
SONY	KOKUBU-SHI	JAPAN	NA	CCD	CMOS	0.6	5	1973		20,000	F
STANLEY	HADANO-SHI	JAPAN	NA	LASER LED	Compound		4	1986		10,000	F
STANLEY		JAPAN	NA	LED	Compound			1993			F
SUMITOMO METAL INDUSTRIES	AMAGASAKI-SHI	JAPAN	NA	4Mb DRAM ARRAYS	NA	0.8	6	1991	300	300	P
TEXAS INSTRUMENTS	HATOGAYA-SHI	JAPAN	Hato	Analog LCD Driver ASSP	CMOS NMOS	1	5	1982		17,700	FAT
TEXAS INSTRUMENTS	HAYAMI-GUN	JAPAN	Hiji 1	Logic Linear G/A	BIP	1	5	1974		8,000	F
TEXAS INSTRUMENTS	HAYAMI-GUN	JAPAN	Hiji 8	4M/16M DRAM	CMOS BiCMOS	0.8	6			10,000	F
TEXAS INSTRUMENTS	INASHIKI-GUN	JAPAN	Miho 5	ASSP ASIC MPU DSP CBIC	MOS	1	5	1982		29,000	F
TEXAS INSTRUMENTS	INASHIKI-GUN	JAPAN	Miho 6	1M/4M DRAM ASSP MPU	CMOS BiCMOS	0.8	6			15,000	FAT
TOHOKU SEMICONDUCTOR	SENDAI-SHI	JAPAN	STEP 1	1Mb DRAM MCU MPU	CMOS	1	6	1988		7,500	FAT
TOHOKU SEMICONDUCTOR	SENDAI-SHI	JAPAN	STEP 2	4Mb DRAM MPU MCU	CMOS BICMOS	0.8	6	1991		10,000	F
TOHOKU SEMICONDUCTOR	SENDAI-SHI	JAPAN	STEP 3	16Mb/64Mb DRAM	CMOS	0.35	8	1995	15,000	15,000	F
TOKIN	SENDAI-SHI	JAPAN	NA	POWER SIT	BIP		3			10,000	P
TOKO	IRUMA-GUN	JAPAN	NA	NA	MOS	3	5	1990		15,000	F
TOKO	IRUMA-GUN	JAPAN	NA	A/D D/A TELECOM DIODE	BIP	3.5	5	1990		20,000	FAT
TOSHIBA	HIMEJI-SHI	JAPAN	No.1	PWR FET TRAN DIODE	MOS BIP	2	4	1990		45,000	FAT
TOSHIBA	HIMEJI-SHI	JAPAN	No.2	TRAN DIODE	BIP NMOS	2	5	1982		30,000	F

(Continued)

Table 1 (Continued)
Japan Existing Pilot and Production Fab Lines
(Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
TOSHIBA	KAWASAKI-SHI	JAPAN	Bldg.108 D-1	PWR TRAN LIN	BIP BICMOS GaAs	2	5	1970		15,000	F
TOSHIBA	KAWASAKI-SHI	JAPAN	Bldg.108 D-2	16Mb/64Mb DRAM FLASH	CMOS	0.35	8	1990		1,300	P
TOSHIBA	KITA KYUSHU-SHI	JAPAN	Kubik 1	BIP Analog Opto	BIP GaAs	1.5	4	1986		36,000	F
TOSHIBA	KITA KYUSHU-SHI	JAPAN	Kubik 2	BIP Analog	BICMOS BIP	1.2	5	1988		30,000	NF
TOSHIBA	KITA KYUSHU-SHI	JAPAN	Kubik 3	Analog	BIP BICMOS	1	6	1993		30,000	F
TOSHIBA	KITAKAMI-SHI	JAPAN	Bldg.101, D-1	CCD ASIC MPU MCU MROM	CMOS	1	5	1984		40,000	FAT
TOSHIBA	KITAKAMI-SHI	JAPAN	Bldg.101, D-2	CCD ASIC MPU MCU MROM	CMOS	1	5	1986		40,000	F
TOSHIBA	KITAKAMI-SHI	JAPAN	Bldg.102, D-3	ASIC	CMOS	1	6	1989		15,000	FAT
TOSHIBA	KITAKAMI-SHI	JAPAN	Bldg.102, D-4	EPROM MROM MPU ASIC	CMOS	0.8	6	1991		15,000	F
TOSHIBA	KITAKAMI-SHI	JAPAN	Bldg.106, D-5	EPROM MROM MPU ASIC	BICMOS CMOS	0.8	6	1993		24,000	F
TOSHIBA	NOMI-GUN	JAPAN	NA	PWR TRAN	BIP	2	4	1992		30,000	FAT
TOSHIBA	OITA-SHI	JAPAN	C-CUBED 1	MCU SRAM LOGIC	CMOS	1.2	4	1986		33,000	F
TOSHIBA	OITA-SHI	JAPAN	C-CUBED 2	MCU SRAM LOGIC	CMOS	1.2	5	1987		32,000	F
TOSHIBA	OITA-SHI	JAPAN	C-CUBED 3	MCU ASIC DRAM SRAM	CMOS	1	5	1989		32,000	F
TOSHIBA	OITA-SHI	JAPAN	C-CUBED 4	4Mb/16MDRAM	CMOS	0.5	6	1991		40,000	F
TOSHIBA	YOKKAICHI-SHI	JAPAN	Y-CUBED, #1-Mod 1	4Mb/16Mb DRAM	CMOS	0.5	8	1993	9,000	10,000	F
TOSHIBA	YOKKAICHI-SHI	JAPAN	Y-CUBED, #1-Mod 2	4Mb/16Mb DRAM	CMOS	0.35	8	1994	9,000	10,000	F
TOSHIBA COMPONENTS	KIMITSU-SHI	JAPAN	PHASE 1 & 2	DIODE RECTIFIER THYRISTOR	BIP	4	4	1970		44,000	FAT
TOYODA AUTOMATIC LOOM WORKS	OBU-SHI	JAPAN	KYOWA	POWER TRAN	Bip		4	1990	0		FAT
TOYODA GOSEI	INAZAWA-SHI	JAPAN	Technology Center	LED	COMPOUND	25	2	1993	0		PF
TOYODA MACHINE WORKS	KARIYA-SHI	JAPAN	HIGASHI KARIYA	ASIC	CMOS		5	1990	0		F
TOYOTA MOTOR	TOYOTA-SHI	JAPAN	ME	MCU PWR ICs CUSTOM	CMOS BIP	2	5	1990	500	500	PFAT
UNIZON	ITAMI-SHI	JAPAN	NA	ZENER DIODE REG ARRAYS	BIP		5		3,000	10,000	F

(Continued)

Table 1 (Continued)
Japan Existing Pilot and Production Fab Lines
(Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
YAMAHA	AIRA-GUN	JAPAN	Fab 1	LIN ROM CBIC ASSP MPR	CMOS MOS	0.65	5	1988	8,000	15,000	NF
YAMAHA	AIRA-GUN	JAPAN	Fab 2	ROM CBIC ASSP	CMOS	0.65	6	1995	10,000	10,000	NF
YAMAHA	IWATA-GUN	JAPAN		CBIC LOG	CMOS	0.8	6	1986	6,000	6,000	NP
YAMAHA	TOYOOKA-MURA	JAPAN	Building 11	ASIC MPR	CMOS M2/M3	0.5	6	1990	5,000	5,000	F
YOKOGAWA IMT	KAMI INA-GUN	JAPAN	NA	TRAN DIODE OPTO Analog	BIP CMOS	3	4	1988	7,000	7,000	FAT

NA = Not applicable
Fab Types:
F = Production-Based Fab
R = Semiconductor R&D and/or Trial Production Facility
P = Pilot Line (Initial Production or Intended Low Volume)
T = Test and Assembly (Formerly A)
Q = Quick-Turn Fab
N = Nondedicated Foundry Service Available
D = Design Center
Source: Dataquest (December 1995)

Table 2
Japan Future Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
FUJI ELECTRIC	MATSUMOTO-SHI	JAPAN	NA	MOSFET IGBT High Voltage Diode	MOS BIPOLAR	3	5	1995		30,000	F
FUJITSU	AIZU WAKAMATSU-SHI	JAPAN	BLDG. #2-2	ARRAYS Logic CBIC MPU	CMOS	0.35	6	1995		35,000	F
FUJITSU	AIZU WAKAMATSU-SHI	JAPAN	BLDG. #2-3	ARRAYS Logic CBIC MPU	CMOS	0.35	8	1996	10,000	10,000	F
FUJITSU	AKIKAWA	JAPAN	NA		CMOS	0.3	8	1996		1,000	F
FUJITSU	ISAWA-GUN	JAPAN	NO. 4-2	16Mb DRAM	CMOS	0.35	8	1996	10,000	20,000	F
FUJITSU-AMD SEMICONDUCTOR	AIZU WAKAMATSU-SHI	JAPAN	Phase 2	16/32Mb Flash	CMOS	0.35	8	1997	10,000	10,000	F
HITACHI	CHITOSE-SHI	JAPAN	Chitose 2	64Mb DRAM	CMOS	0.35	8	1998		10,000	F
HITACHI	HITACHINAKA-SHI	JAPAN	N2-2	16Mb/64Mb DRAM	CMOS	0.35	8	1996	10,000	20,000	F
HITACHI	NAKAKOMA-GUN	JAPAN	K2-2F	16Mb DRAM	CMOS	0.5	8	1995		10,000	F
HITACHI	TAKASAKI-SHI	JAPAN	No.3	16Mb DRAM	CMOS	0.5	8	1995		10,000	F
KAWASAKI STEEL	UTSUNOMIYA-SHI	JAPAN	PHASE 2	DRAM SRAM ARRAYS	CMOS	0.5	8	1996		20,000	F
KTI SEMICONDUCTOR	NISHIWAKI-SHI	JAPAN	Fab 2	16M/64M DRAM ASIC	CMOS	0.35	8	1997	15,000	15,000	F
MATSUSHITA	TONAMI-SHI	JAPAN	FAB 2	16Mb DRAM ASIC	CMOS	0.35	8	1996	10,000	20,000	F
MATSUSHITA	UOZU-SHI	JAPAN	FAB B-2	MPU MCU	CMOS	0.8	6	1995		10,000	F
MITSUBISHI	KIKUCHI-GUN	JAPAN	D-1F-2	16Mb DRAM	CMOS	0.35	8	1996		10,000	F
MITSUBISHI	SAIJO-SHI	JAPAN	SA2F	16Mb 64Mb DRAM	CMOS M2	0.35	8	1998	10,000	20,000	F
NEC	HIGASHI HIROSHIMA-SHI	JAPAN	Dif-2	16Mb DRAM ASIC RISC	CMOS	0.35	8	1996		10,000	F
NEC	KUMAMOTO-SHI	JAPAN	Dif-8 -2	64M/256M DRAM	CMOS	0.25	8	1998		30,000	F
OKI	KUROKAWA-GUN	JAPAN	S2	16M/64M DRAM	CMOS	0.4	8	1996	5,000	15,000	NFAT
TOHOKU SEMICONDUCTOR	SENDAI-SHI	JAPAN	STEP 3	16Mb/64Mb DRAM	CMOS	0.35	8	1995	15,000	15,000	F
TOSHIBA	YOKKAICHI-SHI	JAPAN	Y-CUBED, #2	16Mb/64Mb DRAM	CMOS	0.35	8	1996		40,000	F
YAMAHA	AIRA-GUN	JAPAN	Fab 2	ROM CBIC ASSP	CMOS	0.65	6	1995	10,000	10,000	NF
YAMAHA	TOYOOKA-MURA	JAPAN	Building 11-2	ASIC MPR	CMOS M2/M3	0.5	6	1996	5,000	5,000	F

NA = Not applicable
Fab Types:
F = Production-Based Fab
R = Semiconductor R&D and/or Trial Production Facility
P = Pilot Line (Initial Production or Intended Low Volume)
T = Test and Assembly (Formerly A)
Q = Quick-Turn Fab
N = Nondedicated Foundry Service Available
D = Design Center
Source: Dataquest (December 1995)

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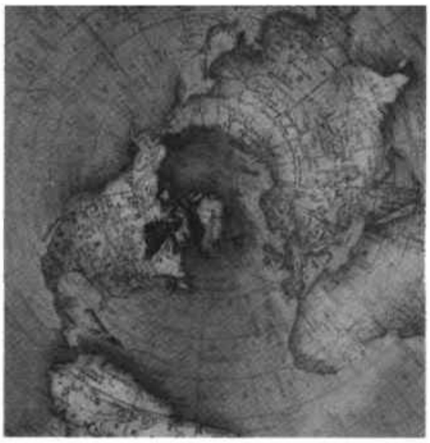

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Americas Fab Database

Market Statistics

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
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Table of Contents

List of Tables

Note: All tables show estimated data.

Americas Fab Database

Background

This document contains the Americas portion of Dataquest's wafer fab database. The Semiconductor Equipment, Materials, and Manufacturing Worldwide (SEMM) program uses both primary and secondary research to update this data. The tables in this report cover both merchant and captive production and pilot-line facilities, although our surveys and database also include R&D fabs.

Research Methodology

Dataquest conducts extensive annual surveys, complemented with quarterly secondary research. This data is then supplemented and cross-checked with various other information sources.

General Definitions

Fab line: A fab line is a semiconductor processing facility equipped for all front-end wafer manufacturing. Occasionally, there are two or more separate product-specific fab lines or wafer sizes in a single cleanroom. In this situation, Dataquest documents the cleanroom as separate fab lines if the company dedicates equipment to each wafer size or product line. Therefore, a company may operate many fab lines at one location.

Front-end wafer processing: Dataquest defines front-end wafer processing as all steps involved in semiconductor processing, beginning with initial oxide and ending at wafer probe.

Production fab: A wafer fab capable of front-end processing more than 1,250 wafers per week is a production fab (type = F).

Pilot fab: A wafer fab capable of front-end processing 1,250 or fewer wafers per week is a pilot fab (type = P).

Worldwide Geographic Region Definitions and Regional Roll-Ups

Americas
Includes Central America (all nations), Canada, Mexico, United States and Puerto Rico, and South America (all nations).

Japan
Japan is the only single-country region.

Europe, Africa, and Middle East
Includes Africa (all nations), Albania, Andorra, Armenia, Azerbaijan, Belarus, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Gibraltar, Hungary, Iceland, Israel, Italy, Kazakhstan, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Middle East (all nations), Moldova, Monaco,

Netherlands, Norway, Poland, Romania, Russia, San Marino, Scandinavia, Slovakia, Spain, Sweden, Sweden, Switzerland, Tajikistan, Turkey, Turkmenistan, Ukraine, United Kingdom, Uzbekistan, Vatican City, and Yugoslavia (all nations within the former Yugoslavia).

Asia/Pacific

Includes Australia, Bangladesh, Cambodia, China, Hong Kong, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, and Vietnam.

Definition of Table Columns

Products Produced contains details for seven product categories. The nomenclature used within the seven product groups of the fab database is as follows, with definitions where warranted:

- Analog
  - A/D D/A: Analog-to-digital, digital-to-analog converter
  - AUTOMOTIVE: Dedicated to automobile applications
  - CODEC: Coder/decoder
  - INTERFACE: Interface IC
  - LIN: Linear/analog device
  - MDIODE: Microwave diode
  - MESFET: Metal semiconductor field-effect transistor
  - MFET: Microwave field-effect transistor
  - MIXSIG ASIC: Mixed-signal/linear ASIC
  - MODEM: Modulator/demodulator
  - MMIC: Monolithic microwave IC
  - OP AMP: Operational amplifier
  - PWR IC: Power IC
  - REG: Voltage regulator
  - SMART PWR: Smart power
  - SWITCHES: Switching device
  - TELECOM: Telecommunications chip
- Memory
  - DRAM: Dynamic RAM
  - EEPROM or E2: Electrically erasable PROM
  - EPROM: Ultraviolet erasable PROM

- FERRAM: Ferroelectric RAM
- FIFO: First-in/first-out memory
- FLASH: Flash memory
- MEM: Memory
- NVMEM: Nonvolatile memory (ROM, PROM, EPROM, EEPROM, FERRAM)
- PROM: Programmable ROM
- RAM: Random-access memory
- ROM: Read-only memory
- SPMEM: Other specialty memory (such as dual-port, shift-register, color lookup)
- SRAM: Static RAM
- VRAM: Video RAM

- Micrologic
  - ASSP: Application-specific standard product
  - BIT: Bit slice (subset of MPU functions)
  - DSP: Digital signal processor
  - LISP: 32-bit list instruction set processor for AI
  - MCU: Microcontroller unit
  - MPR: Microperipheral
  - MPRCOM: MPR digital communication (ISDN, LAN, UART, modem)
  - MPU: Microprocessor unit
  - RISC: Reduced-instruction-set computation 32-bit MPU
- Standard logic
  - LOG or LOGIC: Standard logic
- ASIC logic
  - ARRAYS: Gate array
  - ASIC: Application-specific IC
  - CBIC: Cell-based IC
  - CUSTOM: Full-custom IC (single user)
  - FPGA: Field-programmable gate array
  - PLD: Programmable logic device

- Discrete
  - DIODE
  - DIS or DISCRETE: Discrete
  - FET: Field-effect transistor
  - GTO: Gate turn-off thyristor
  - HEMT: High-electron-mobility transistor
  - IGBT: Insulated gate bipolar transistor
  - MOSFET: MOS-based field-effect transistor
  - PWR TRAN: Power transistor
  - RECTIFIER
  - RF: Radio frequency
  - SCR: Schottky rectifier
  - SENSOR
  - SST: Small-signal transistor
  - THYRISTOR
  - TRAN: Transistor
  - ZENER DIODE
- Optoelectronic
  - CCD: Charge-coupled device (imaging)
  - COUPLER: Photocoupler
  - IED: Infrared-emitting diode
  - IMAGE SENSOR
  - LASER: Semiconductor laser or laser IC
  - LED: Light-emitting diode
  - OPTO: Optoelectronic
  - PDIODE: Photo diode
  - PTRAN: Photo transistor
  - SAW: Surface acoustic wave device
  - SIT IMAGE SENSOR: Static induction transistor image sensor

Process Technology column lists four major types of technologies. This column also lists uncommon technologies with information on well types, logic structure, and number of metal levels. Definitions used in the "Process Technology" column are as follows:

- MOS (silicon-based)
  - CMOS: Complementary metal-oxide semiconductor

- MOS: N-channel metal-oxide semiconductor (NMOS) and p-channel metal-oxide semiconductor (PMOS).
- M1: Single-level metal
- M2: Double-level metal
- M3: Triple-level metal
- N-WELL
- P-WELL
- POLY1: Single-level polysilicon
- POLY2: Double-level polysilicon
- POLY3: Triple-level polysilicon

■ BiCMOS (silicon-based)

- BiCMOS: Bipolar and CMOS combined on a chip
- BiMOS: Bipolar and MOS combined on a chip
- ECL I/O: ECL input/output
- TTL I/O: TTL input/output

■ Bipolar (silicon-based)

- BIP or BIPOLAR: Bipolar
- ECL: Emitter-coupled logic
- TTL: Transistor-transistor logic
- STTL: Schottky TTL

■ Gallium arsenide and other compound semiconductor materials

- GaAs: Gallium arsenide
- AlGaAs: Gallium aluminum arsenide
- GaAs on Si: Gallium arsenide on silicon
- GaP: Gallium phosphide
- HgCdTe: Mercuric cadmium telluride
- InAs: Indium arsenide
- InGaAs: Indium gallium arsenide
- InP: Indium phosphide
- InSb: Indium antimony
- LiNbO3: Lithium niobate
- SOS: Silicon on sapphire

Minimum Geometry is the smallest feature attainable in production volumes, measured in microns, at the critical mask layers.

Wafer Diameter represents the wafer diameter usually expressed colloquially in inches. However, for wafers greater than 3 inches in diameter, the colloquial expression becomes grossly inaccurate. When calculating square inches, Dataquest uses the following approximations:

- Stated diameter 4 inches (100mm) = Approximate diameter 3.938 inches
- Stated diameter 5 inches (125mm) = Approximate diameter 4.922 inches
- Stated diameter 6 inches (150mm) = Approximate diameter 5.906 inches
- Stated diameter 8 inches (200mm) = Approximate diameter 7.87 inches

Estimated Maximum Wafer Starts per Month is the equipment-limited wafer start capacity per four-week period. Start capacity is limited only by the installed equipment in the fab and the complexity of the process it runs, not by current staffing or the number of shifts operating.

Table 1
Americas Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	State	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
ADAMS-RUSSELL COMPANY	BURLINGTON	MA	U.S.A.	NA	MESFET MMIC RAD-HARD	GaAs	0.5	3	1984		400	NFAT
ADVANCED POWER TECHNOLOGY INC. (APT)	BEND	OR	U.S.A.	FAB 1	DISCRETE	NMOS/PMOS	2	4	1989	1,000	5,000	PR
ALLEGRO MICRO SYSTEMS	WILLOW GROVE	PA	U.S.A.	NA	SRAM ROM Analog	CMOS Bip		4	1982		12,800	NFT
ALLIED SIGNAL AEROSPACE	COLUMBIA	MD	U.S.A.	MICROELECTRONICS CTR	SRAM MPU MIXSIG ASIC CUSTOM	CMOS BiCMOS MOS	1.2	4	1985		1,400	PRNADT
ALPHA INDUSTRIES	WOBURN	MA	U.S.A.	NA	RF TRAN LIN	GaAs	0.5	3	1987		160	NF
AMD	AUSTIN	TX	U.S.A.	FAB 10	512K EPROM PLD SLAC ASIC	CMOS NMOS	0.8	5	1981	20,000	20,000	F
AMD	AUSTIN	TX	U.S.A.	FAB 14	1Mb 2Mb FLASH	CMOS	0.8	6	1984	800	13,200	F
AMD	AUSTIN	TX	U.S.A.	FAB 15	AM386 MPU MCU MPR DSPs	CMOS	0.7	6	1985		14,000	F
AMD	AUSTIN	TX	U.S.A.	FAB 25	K5 MPU	CMOS	0.35	8	1995	200	28,000	FR
AMD	SUNNYVALE	CA	U.S.A.	SDC (FAB 17)	2Mb FLASH 4Mb FLASH 4Mb EPROM 1Mb EPROM	CMOS	0.5	6	1990		10,000	FRDT
AMERICAN MICROSYSTEMS INC.	POCATELLO	ID	U.S.A.	FAB 1	ARRAYS PLD CBIC CUSTOM MIXSIG ASIC EEPROM	CMOS	0.8	5	1985		20,000	NFQRATD
ANADIGICS	WARREN	NJ	U.S.A.	NA	OP AMP MMIC ASIC	GaAs	0.3	3	1988		1,500	PR
ANALOG DEVICES	SAN JOSE	CA	U.S.A.	NA	LINEAR REGULATORS TEMPERATURE CONTROLLERS	CMOS BiCMOS BIPOLAR	2	4	1979	3,000	8,000	FR
ANALOG DEVICES	WILMINGTON	MA	U.S.A.	WILMINGTON FAB	ANALOG LIN AMP A/D D/A	CMOS BiCMOS BIPOLAR	0.8	4	1979	1,000	16,000	FRQ
APPLIED MICROCIRCUITS CORPORATION (AMCC)	SAN DIEGO	CA	U.S.A.	NA	ARRAYS CBIC MEM	BIP BiCMOS	1	4	1982		3,000	PAT
ARMY ETDL	FORT MONMOUTH	NJ	U.S.A.	NA	NA	NA		5	1987		5,000	P
AT&T BELL LABORATORIES	MURRAY HILL	NJ	U.S.A.	VLSI RESEARCH LAB	SRAM ASIC OPTO	MOS CMOS BIPOLAR BiCMOS		5	1975		4,000	PR
AT&T MICROELECTRONICS	ALLENTOWN	PA	U.S.A.	BIC II	ASIC ARRAYS CBIC CUSTOM ANALOG	BIPOLAR	1	4	1976	6,000	10,000	FTD
AT&T MICROELECTRONICS	ALLENTOWN	PA	U.S.A.	MOS II	ASIC ANALOG DSPs	CMOS	1.25	5	1981	10,400	16,800	F
AT&T MICROELECTRONICS	ALLENTOWN	PA	U.S.A.	MOS-V	DSP FPGA CBIC ASSP MIXSIG ASIC LIN	CMOS	0.55	5	1985	20,000	34,000	FADT
AT&T MICROELECTRONICS	LEE'S SUMMIT	MO	U.S.A.	NA	DIODES TRAN DIS MOD ASIC	BIPOLAR	1.5	5	1967		10,000	FRN
AT&T MICROELECTRONICS	ORLANDO	FL	U.S.A.	OR-1	ASIC DSP PLD FP	CMOS	0.6	6	1987		5,400	FNT
AT&T MICROELECTRONICS	READING	PA	U.S.A.	HIGH VOLTAGE - II	POWER	CMOS	3	5	1985	6,000	15,000	FR
AT&T MICROELECTRONICS	READING	PA	U.S.A.	LINEAR - I	LINEAR ANALOG	BIPOLAR	1.5	5	1975		16,000	FR
ATMEL CORPORATION	COLORADO SPRINGS	CO	U.S.A.	FAB 3	EPROM EEPROM FLASH MCU ASIC	CMOS BiCMOS	0.6	6	1989	4,000	24,400	FRQN
ATMEL CORPORATION	COLORADO SPRINGS	CO	U.S.A.	FAB 5	FLASH EPROM	CMOS	0.5	6	1994	6,000	28,000	FR

(Continued)

Table 1 (Continued)
Americas Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	State	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
AVANTEK	NEWARK	CA	U.S.A.	NA	MMIC FET DIS	GaAs		3	1588		900	F
BALL AEROSPACE	BOULDER	CO	U.S.A.	NA	MILITARY AEROSPACE	NA	1.2	6	1989		5,000	P
BELL NORTHERN RESEARCH	OTTAWA, ONTARIO	CN	U.S.A.	NA	NA	GaAs						PR
BIPOLARICS INC.	LOS GATOS	CA	U.S.A.	NA	DISCRETE MICROWAVE TRANSISTORS	BIPOLAR	0.5	4	1988	1,000	3,000	FR
BURR-BROWN CORPORATION	TUCSON	AZ	U.S.A.	MICROTECH	HYBRID ANALOG	BIPOLAR	3	4	1984	1,500	10,000	FRTD
CALIFORNIA MICRODEVICES	MILPITAS	CA	U.S.A.	THIN FILMS	DISCRETE	BIPOLAR	3	4	1985	100	6,200	FQRTD
CALIFORNIA MICRODEVICES	TEMPE	AZ	U.S.A.	MICRO DIV	MIXSIG ASIC CUSTOM MPU MCU MPR NVMEM	BiCMOS M2 POLY2 CMOS M2 POLY2	1	6	1978		6,500	NFRAT
CALOGIC	FREMONT	CA	U.S.A.	NA	A/D D/A	BIP MOS	3	4	1985		3,600	NP
CELERITEK INC.	SAN JOSE	CA	U.S.A.	NA	FET AMP	GaAs		3	1985			P
CHERRY SEMICONDUCTOR	EAST GREENWICH	RI	U.S.A.	BIPOLAR	DISCRETE	BIPOLAR BiCMOS	1.5	6	1982		22,000	FR
COMMODORE SEMICONDUCTORS	NORRISTOWN	PA	U.S.A.	FAB 1	ASIC	CMOS BiCMOS Mini Displays	0.8	5	1986	1,000	20,000	NFR
COMPENSATED DEVICES	MELROSE	MA	U.S.A.	NA	DISCRETE DIODE ZENER DIODE	BIPOLAR	3	3	1974	300	800	FRD
CRAY RESEARCH	CHIPPEWA FALLS	WI	U.S.A.	NA	ARRAYS	BiCMOS CMOS	0.8	8	1993		5,000	P
CRAY RESEARCH	CHIPPEWA FALLS	WI	U.S.A.	NA	ARRAYS	METAL	1.5	4				PR
CRYSTALONICS	CAMBRIDGE	MA	U.S.A.	NA	CAP REG DIODE HYBRID	BIP CMOS	3	4	1970		2,000	FP
CYPRESS SEMICONDUCTOR	BLOOMINGTON	MN	U.S.A.	FAB 3	SRAM	CMOS	0.65	6	1990	1,500	34,000	FR
CYPRESS SEMICONDUCTOR	BLOOMINGTON	MN	U.S.A.	FAB 4	SRAM EPROM FPGA	CMOS	0.5	8	1995		20,000	F
CYPRESS SEMICONDUCTOR	ROUNDROCK	TX	U.S.A.	FAB 2	SRAM EEPROM EPROM	CMOS BiCMOS	0.65	6	1986	1,500	36,000	FR
CYPRESS SEMICONDUCTOR	SAN JOSE	CA	U.S.A.	FAB 1	SRAM LOGIC MPU MPR	BiCMOS CMOS	0.5	6	1984	300	9,450	PRT
DALLAS SEMICONDUCTOR	DALLAS	TX	U.S.A.	FAB 10	SRAM RANDOM LOGIC	CMOS	0.8	6	1987	1,000	7,000	FRDT
DALLAS SEMICONDUCTOR	DALLAS	TX	U.S.A.	FAB 11	SRAMs RANDOM LOGIC	CMOS	0.4	6	1994	1,000	10,000	FRDT
DAVID SARNOFF LABS	PRINCETON	NJ	U.S.A.	SILICON IC CENTER	MMEM BIP MICROCOMPONENTS MOS MPR CUSTOM POWER ICs	CMOS BiCMOS MOS BIP	0.5	4	1983		1,000	PRDT
DELCO ELECTRONICS CORPORATION	KOKOMO	IN	U.S.A.	FAB 1	SENSORS DISCRETE	BIPOLAR	6	4	1968		15,800	F
DELCO ELECTRONICS CORPORATION	KOKOMO	IN	U.S.A.	FAB 2	ASIC ANALOG POWER ICs	BiCMOS NMOS/PMOS BIPOLAR	2.5	5	1981	4,000	14,000	FN
DELCO ELECTRONICS CORPORATION	KOKOMO	IN	U.S.A.	FAB 3	ASIC MPU LINEAR POWER	CMOS BIPOLAR	1	5	1985		22,400	F
DIGITAL EQUIPMENT CORPORATION	HUDSON	MA	U.S.A.	FAB 4	MCU ALPHA	NA	0.5	6	1988		20,000	P
DIGITAL EQUIPMENT CORPORATION	HUDSON	MA	U.S.A.	FAB 6	MPU ALPHA	CMOS	0.12	8	1995		20,000	F
DIGITAL EQUIPMENT CORPORATION	HUDSON	MA	U.S.A.	PILOT	MPU MCU MPR CBIC CUSTOM	CMOS	1.5	6	1989		1,600	P

(Continued)

Table 1 (Continued)
Americas Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	State	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
DIONICS INC.	WESTBURY	NY	U.S.A.	NA	PWR TRAN OPTO	BIPOLAR	5	3	1969	2,000	5,000	PR
ECI SEMICONDUCTOR	SANTA CLARA	CA	U.S.A.	NA	ANALOG ASIC DISCRETE OPTP POWER	BIPOLAR CMOS	3	5	1974	4,000	17,000	FN
EG&G RETICON	SUNNYVALE	CA	U.S.A.	4 INCH FAB	ANALOG DRIVERS OPTO CCD	CMOS NMOS/ PMOS	2.5	4	1981	800	2,000	PRNTD
EG&G VACTEC	ST. LOUIS	MO	U.S.A.	NA	PDIODE PTRAN	BIP	6	3	1973		16,000	F
ELANTEC	MILPITAS	CA	U.S.A.	DI FAB	ANALOG MONOLITHIC ICs	BIPOLAR	2	4	1984	500	2,500	PR
EXEL	SAN JOSE	CA	U.S.A.	NA	64K EEPROM PLD SRAM MCU	CMOS BIP	1.3	3	1987	10,000	10,000	FR
FLUKE CORP.	EVERETT	WA	U.S.A.	NA	ASIC	CMOS BiCMOS	1.8	4	1981		8,000	FRT
FOXBORO ICT	SAN JOSE	CA	U.S.A.	NA	DIS PRESSURE SENSORS	BIP	3	3	1982		24,000	FAT
FREQUENCY SOURCES	LOWELL		U.S.A.	NA	DISCRETE ASIC	CMOS	1	4	1986	800	1,000	FRTD
FUJITSU	GRESHAM	OR	U.S.A.	No. 1	ASIC 1Mb/4Mb DRAM	CMOS	0.8	6	1990		13,000	F
GE CORPRATE R&D	SCHENECTADY	NY	U.S.A.	PSF	SMART PWR	BiCMOS BIP	2	4	1985		1,600	PR
GE ELECT. LAB	SYRACUSE	NY	U.S.A.	MMIC FAB	MMIC	GaAs	0.5	4	1986		2,000	PAT
GENNUM CORP.	BURLINGTON, ONTARIO	CN	U.S.A.	LANDMARK	ANALOG AMPS FILTERS DRIVERS	BIPOLAR	1.5	4	1974		1,500	PR
GERMANIUM POWER DEVICES	ANDOVER	MA	U.S.A.	NA	OPTO DIS	NA		3	1974		10,000	F
HANSCORN AFB	LEXINGTON	MA	U.S.A.	NA	CUSTOM MIL STD	BIP CMOS MOS		4	1986		8,000	FAT
HARRIS SEMICONDUCTOR	FINDLAY	OH	U.S.A.	FAB 1 & 2	MPU MCU MPR ASIC	CMOS BiCMOS	1.2	4	1969		16,000	FR
HARRIS SEMICONDUCTOR	FINDLAY	OH	U.S.A.	FAB 3 & 4	MPR ANALOG MIXED SIGNAL POWER DRIVERS	BiCMOS MOS BIPOLAR	1.2	4	1971		12,000	FR
HARRIS SEMICONDUCTOR	FINDLAY	OH	U.S.A.	FAB 5	MPR MCU DSP POWER ICs	CMOS BiCMOS	1.2	5	1984	400	9,000	FR
HARRIS SEMICONDUCTOR	MELBOURNE	FL	U.S.A.	54E (FAB A)	BIP MIC MOS MPU LIN CUSTOM ASIC	BIP CMOS M2 BiCMOS M2	3	4	1983		7,225	PQ
HARRIS SEMICONDUCTOR	MELBOURNE	FL	U.S.A.	FAB 54W (FAB C)	MPU MPR ANALOG ASIC	CMOS BIPOLAR	2	4	1978		12,000	F
HARRIS SEMICONDUCTOR	MELBOURNE	FL	U.S.A.	FAB 59(VHSIC)	MPU ASIC DSPs SRAM	CMOS BiCMOS	0.8	6	1985		1,600	PR
HARRIS SEMICONDUCTOR	MELBOURNE	FL	U.S.A.	FAB D	LINEAR	BIP MOS BiCMOS	3	4	1970		9,000	NPT
HARRIS SEMICONDUCTOR	MOUNTAINTOP	PA	U.S.A.	FAB 6	DISCRETE POWER	CMOS	1.5	6	1989	3,000	14,000	FR
HEWLETT-PACKARD	CORVALLIS	OR	U.S.A.	4-INCH	CBIC	CMOS	1	4	1979		10,000	FAT
HEWLETT-PACKARD	CORVALLIS	OR	U.S.A.	6-INCH	ASIC MPR DSP RISC	CMOS	0.8	6	1990		12,500	NF
HEWLETT-PACKARD	FORT COLLINS	CO	U.S.A.	FTC	MPU ASIC	CMOS BIPOLAR	0.5	6	1978	500	14,000	FQRTD
HEWLETT-PACKARD	PALO ALTO	CA	U.S.A.	HSDL	ASIC OPTO	GaAs		2	1984			FA
HEWLETT-PACKARD	PALO ALTO	CA	U.S.A.	NA	NA	CMOS M3 BiCMOS	0.55	6	1993		2,000	RP
HEWLETT-PACKARD	SAN JOSE	CA	U.S.A.	BIPOLAR	TRAN	GaAs	0.5	2	1981		200	PAT
HEWLETT-PACKARD	SAN JOSE	CA	U.S.A.	DIODE	DIODE	BIPOLAR	3	2	1981		2,400	PAT
HEWLETT-PACKARD	SAN JOSE	CA	U.S.A.	OED	OPTO	GaAs	5	3	1984		2,050	PAT

(Continued)

Table 1 (Continued)
Americas Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	State	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
HEWLETT-PACKARD	SANTA CLARA	CA	U.S.A.	GaAs	DISCRETE POWER	GaAs	0.15	3		250	600	PR
HEWLETT-PACKARD	SANTA CLARA	CA	U.S.A.	NA	LOGIC ASIC	BIPOLAR	1.5	3			1,600	P
HEWLETT-PACKARD	SANTA ROSA	CA	U.S.A.	NA	ANALOG DISCRETE	GaAs BIPOLAR	0.25	2	1976	50	1,000	PR
HEWLETT-PACKARD	SANTA ROSA	CA	U.S.A.	NA	ANALOG	GaAs	0.25	3	1994	50	500	PR
HITACHI	IRVING	TX	U.S.A.	U1	1Mb 4Mb DRAM 256K SRAM MPU	CMOS	0.6	6	1990	4,200	16,500	F
HOLT INTEGRATED CIRCUITS	IRVINE	CA	U.S.A.	NA	OP AMP EEPROM LOG ASIC	CMOS MOS	2.5	4			10,000	NFAT
HONEYWELL OPTOELECTRONICS	RICHARDSON	TX	U.S.A.	GaAs OPTO	OPTOELECTRONICS	GaAs	10	2	1985	100	400	PR
HONEYWELL OPTOELECTRONICS	RICHARDSON	TX	U.S.A.	SENSOR FAB	ANALOG OPTO	BIPOLAR	3	4	1985	3,000	10,000	PRTD
HONEYWELL SOLID STATE	PLYMOUTH	MN	U.S.A.	VHSIC	SRAM ASIC ANALOG DISCRETE	CMOS BIPOLAR	0.65	4	1970		1,800	PR
HUGHES	CARLSBAD	CA	U.S.A.	HTC	MIL STD OPTO ASIC LIN	BiCMOS CMOS MOS	1.5	4	1987		8,800	P
HUGHES	NEWPORT BEACH	CA	U.S.A.	FAB 2	ASIC LIN	CMOS	3	4	1973		4,000	NPAT
HUGHES	TORRANCE	CA	U.S.A.	GaAs	MMIC	GaAs	0.25	3	1977		240	PRAT
HUGHES AIRCRAFT COMPANY	NEWPORT BEACH	CA	U.S.A.	SPC-FAB 3	ARRAYS CUSTOM MIX SIGNAL ASIC	CMOS	0.6	4	1983	1,000	6,000	FR
IBM	ESSEX JUNCTION	VT	U.S.A.	BLDG. 963	4Mb DRAM, MPU	CMOS	0.5	5	1989		16,000	FN
IBM	ESSEX JUNCTION	VT	U.S.A.	BLDG. 970	4Mb DRAM	CMOS	0.8	8	1988		24,000	F
IBM	ESSEX JUNCTION	VT	U.S.A.	BLDG. 973	16Mb DRAM	CMOS	0.5	8	1989		20,000	F
IBM	HOPEWELL JUNCTION	NY	U.S.A.	ASTC	64Mb 256Mb	CMOS	0.35	8	1989		10,000	F
IBM	HOPEWELL JUNCTION	NY	U.S.A.	BLDG 322	LOG	CMOS, BiCMOS	0.8	8	1992		20,000	F
IC SENSORS	MILPITAS	CA	U.S.A.	NA	MCU MPU DSP MPR	BIPOLAR CMOS	0.5	4	1988		17,600	FR
IDT	SALINAS	CA	U.S.A.	FAB 2	FAST 16K 64K 256K SRAM	CMOS	1	6	1985		13,500	FT
IDT	SANTA CLARA	CA	U.S.A.	FAB 3	SRAM MPU RISC LOGIC	BiCMOS CMOS	0.8	6	1990		15,000	FT
IMP	SAN JOSE	CA	U.S.A.	NA	ASIC ANALOG MPR	CMOS BiCMOS NMOS/PMOS	0.8	5	1982	2,000	2,500	PFQRNTD
INTEGRATED CIRCUIT WORKS	SAN JOSE	CA	U.S.A.	NA	3.3 VOLT SRAM	CMOS BiCMOS	0.8	6	1984		8,000	FN
INTEL	ALOHA	OR	U.S.A.	D1A1	MPU (P6, P7)	BiCMOS	0.4	8	1993		5,000	FDPR
INTEL	ALOHA	OR	U.S.A.	FAB 4	MCU	CMOS MOS	1.5	4	1976		52,000	F
INTEL	ALOHA	OR	U.S.A.	FAB 5	486 MPU	CMOS BiCMOS	0.6	6	1978		15,000	F
INTEL	CHANDLER	AZ	U.S.A.	FAB 6	MCU	CMOS BiCMOS	1	6	1982		24,000	F
INTEL	RIO RANCHO	NM	U.S.A.	FAB 11.1	MPU (P5, DX4)	BiCMOS	0.6	8	1994	5,000	10,000	F
INTEL	RIO RANCHO	NM	U.S.A.	FAB 11.2	MPU (P5, P6)	BiCMOS	0.4	8	1995	5,000	33,000	F
INTEL	RIO RANCHO	NM	U.S.A.	FAB 7	FLASH MEMORY	CMOS	0.6	6	1984		23,000	F

(Continued)

Table 1 (Continued)
Americas Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	State	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
INTEL	RIO RANCHO	NM	U.S.A.	FAB 9	MPU (P5 i960 486) MCU MPR	CMOS BiCMOS	0.8	6	1988		48,000	F
INTEL	SANTA CLARA	CA	U.S.A.	D2	MPU (P5, P6)	BiCMOS	0.6	8	1991		11,000	FPR
INTERNATIONAL MICROCIRCUITS INC.	MILPITAS	CA	U.S.A.	NA	ASIC	CMOS	1	5	1991	400	800	PQ
INTERNATIONAL RECTIFIER	EL SEGUNDO	CA	U.S.A.	PPD4	PWR TRANS MOSFET SCR	CMOS MOS	5	4	1983		13,000	FRATD
INTERNATIONAL RECTIFIER	TEMECULA	CA	U.S.A.	HEXFET	PWR TRANS MOSFET	CMOS MOS	5	5	1986		42,000	FAT
INTERNATIONAL RECTIFIER	TEMECULA	CA	U.S.A.	HEXFET-2	PWR TRANS MOSFET	CMOS MOS	2	6	1995		10,000	F
ITT	ROANOKE	VA	U.S.A.	DARPA	LIN PWR IC DIS MIL STD	GaAs	0.25	3	1984		400	P
KODAK	ROCHESTER	NY	U.S.A.	NA	IMAGING ARRAYS CBIC CCD	BIP CMOS MOS	1.5	4	1984		5,000	PR
KULITE	LEONIA	NJ	U.S.A.	NA	DISCRETE	BIP	3	4			24,000	F
LAWRENCE LIVERMORE LABS	LIVERMORE	CA	U.S.A.	NA	WAFER-SCALE COMPUTER	CMOS MOS	0.25	6	1987		2,000	PR
LINEAR TECHNOLOGY	MILPITAS	CA	U.S.A.	FAB 1	LINEAR INTERFACE A/D D/A	BIP CMOS BiCMOS	3	4	1982		8,790	FATD
LINEAR TECHNOLOGY	MILPITAS	CA	U.S.A.	FAB 2	LINEAR	BIP CMOS BiCMOS	2	4	1992		5,790	F
LINFINITY MICROELECTRONICS INC.	GARDEN GROVE	CA	U.S.A.	NA	LINEAR ANALOG	BIPOLAR CMOS	2.5	4	1982		2,000	FRNTD
LITTON MICROWAVE	SAN JOSE	CA	U.S.A.	NA	FET AMP	GaAs		3				F
LITTON SOLID STATE	SANTA CLARA	CA	U.S.A.	NA	MMIC CCD	GaAs	0.5	3			100	NP
LOCKHEED	SYRACUSE		U.S.A.	E LAB	ANALOG DISCRETE PHEMTs	GaAs	0.1	3	1983		3,600	PR
LOCKHEED-MARTIN	SANDERS NASHUA		U.S.A.	SANDERS NASHUA	ANALOG MMICs	GaAs	0.15	3	1985	1,440	19,200	PR
LOCKHEED	FORT WORTH	TX	U.S.A.	NA	NA	MOS	0.8	4			5,000	F
LOCKHEED	SUNNYVALE	CA	U.S.A.	113	ASIC MIL STD RAD-HARD	CMOS	1.5	5	1988		640	P
LORAL ELECTRONICS	LOWELL	MA	U.S.A.	S/C	RF & MICROWAVE DIODES	BIP		3	1985		2,000	PRADT
LSI LOGIC	FREMONT	CA	U.S.A.	FREMONT FAB	ASIC	CMOS	1.5	6			6,000	PRQ
LSI LOGIC	MILPITAS	CA	U.S.A.	MILPITAS FAB	ARRAYS CUSTOM	CMOS	0.5	6	1982		6,000	PRQ
LSI LOGIC	SANTA CLARA	CA	U.S.A.	R&D PILOT	ASIC MPU	CMOS	0.5	6	1989		5,000	PR
M/A-COM	BURLINGTON	MA	U.S.A.	NA	MMIC DIODE TRAN	GaAs MOS	0.3	3	1971		4,000	NFAT
M/A-COM	BURLINGTON	MA	U.S.A.	NA	DISCRETE	COMPOUND GaAs	0.35	4	1984		1,800	PRTD
M/A-COM	LOWELL	MA	U.S.A.	ADV. S/C	MMIC	GaAs	0.25	3	1985		800	NPAT
MAGNOVOX	FORT WAYNE	IN	U.S.A.	NA	ARRAYS CBIC HYBRID	CMOS	5	3	1976		400	DPAT
MASS. MICROELECTRONICS CENTER (M2C)	WESTBOROUGH	MA	U.S.A.	ICFF	ASIC	MOS BiCMOS M2	2	5	1989		1,200	PNADT
MATSUSHITA	PUYALLUP	WA	U.S.A.	PUYALLUP	1Mb/4Mb DRAM 4bit 8bit MCU	CMOS	0.8	6	1985	10,000	19,000	FNAT
MAXIM INTEGRATED PRODUCTS	SUNNYVALE	CA	U.S.A.	NA	OP AMPS A/D D/A	CMOS	3	4	1990		4,000	P

(Continued)

Table 1 (Continued)
Americas Existing Pilot and Production Fab Lines
(Including Fabs Beginning Operation during 1995)

Company	City or District	State	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
MCDONNELL DOUGLAS	HUNTINGTON BEACH	CA	U.S.A.	3PILOT	4K 16K SRAM 6K ARRAY MPU	GaAs	1	3	1985		400	NPAT
MCDONNELL DOUGLAS	HUNTINGTON BEACH	CA	U.S.A.	DVLPMNT	MPU LOG ASIC DIS	GaAs	1	3	1988			P
MEDTONIC/MICRO-REL	TEMPE	AZ	U.S.A.	NA	BIP CUSTOM MOS CUSTOM ASIC MIXSIG ASIC	BIP M1 CMOS M2 POLY1	1.5	4	1984		4,000	FRNADT
MICRO POWER SYSTEMS	SANTA CLARA	CA	U.S.A.	NA	LIN CUSTOM	BiCMOS CMOS BIP	4	3	1975		15,000	FAT
MICRO QUALITY S/C	GARLAND	TX	U.S.A.	NA	RECTIFIER MULTIPLIER	BIP		4			10,000	F
MICRO SEMI	TORRANCE	CA	U.S.A.	NA	MIL STD DIS	BIP	12	3			4,800	P
MICRO-CIRCUIT ENG	WEST PALM BEACH	FL	U.S.A.	NA	CUSTOM	MOS	4	4	1979		12,000	NDF
MICROCHIP TECHNOLOGY	CHANDLER	AZ	U.S.A.	CHANDLER 1	MCU EEPROM	CMOS	0.9	6	1986	5,000	16,000	FD
MICROCHIP TECHNOLOGY	TEMPE	AZ	U.S.A.	T1	MCU EEPROM	CMOS	0.8	6	1994	2,000	20,000	F
MICRON TECHNOLOGY	BOISE	ID	U.S.A.	FAB 1	256K DRAM 1Mb DRAM 256K SRAM	CMOS MOS	1.2	6	1981		32,000	FPRAT
MICRON TECHNOLOGY	BOISE	ID	U.S.A.	FAB 2	1Mb DRAM 256K SRAM VRAM	CMOS	0.5	6			14,400	F
MICRON TECHNOLOGY	BOISE	ID	U.S.A.	FAB 3	1Mb DRAM 4Mb DRAM 16Mb DRAM	CMOS	0.5	8	1991		40,000	F
MICROPAC INDUSTRIES	GARLAND	TX	U.S.A.	NA	MIL STD OPTO HYBRID	NA		4			3,000	PAT
MICROSEMI CORP.	BROOMFIELD	CO	U.S.A.	NA	SCHOTTKY DIODE RECTIFER	MOS	5	4	1981		8,800	FT
MICROWAVE TECH.	FREMONT	CA	U.S.A.	NA	MMIC AMP FET	GaAs	0.5	2	1983			FAT
MITEL SEMICONDUCTOR	BROMONT, QUEBEC	CN	CANADA	FAB 1	TELECOM A/D D/A	CMOS NMOS PMOS	0.8	4	1982	4,800	12,000	FNRT
MITSUBISHI	NORTH DURHAM	NC	U.S.A.	NA	1Mb/4Mb DRAM	CMOS	0.6	6	1990		7,800	F
MOTOROLA	GUADALAJARA		MEXICO	GUAD POWER	THYRISTOR			3			36,000	F
MOTOROLA	AIZU		U.S.A.	MOS 7	DISCRETE LOGIC ANALOG	CMOS MOS	1.8	4	1972		50,000	FAT
MOTOROLA	AUSTIN	TX	U.S.A.	APRDL	MPU ASIC MEM	CMOS MOS	1	5	1984		36,550	FR
MOTOROLA	AUSTIN	TX	U.S.A.	MOS 13/14	MPU MCU RISC	CMOS BiCMOS HCMOS	0.25	8	1995		7,200	FR
MOTOROLA	AUSTIN	TX	U.S.A.	MOS 2	LOG A/D MCU	CMOS MOS	1	4	1983		50,000	F
MOTOROLA	AUSTIN	TX	U.S.A.	MOS 3	MCU	CMOS MOS	1.2	4	1983		50,000	NF
MOTOROLA	AUSTIN	TX	U.S.A.	MOS 8	MCU PSRAM DSP LIN RISC	CMOS	0.65	5	1988		20,800	F
MOTOROLA	CHANDLER	AZ	U.S.A.	MOS 12	MCU MPU	CMOS BiCMOS HCMOS	0.65	8	1994		16,800	F
MOTOROLA	IRVINE	CA	U.S.A.	MOS 10	DSP MDAD	CMOS HCMOS BiCMOS	0.55	6	1982		12,000	FDT
MOTOROLA	MESA	AZ	U.S.A.	BIPOLAR 1	TELECOM OP AMP AUTOMOTIVE ANALOG	BIP BiCMOS	3	4	1983		36,000	NF
MOTOROLA	MESA	AZ	U.S.A.	BIPOLAR 2	LOGIC	BIP	2.5	4	1983		36,040	F
MOTOROLA	MESA	AZ	U.S.A.	BIPOLAR 3	ANALOG GATE ARRAYS	BIP BiCMOS	1.25	4	1983		16,000	F

(Continued)

Table 1 (Continued)
Americas Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

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MOTOROLA	MESA	AZ	U.S.A.	MOS 5	MCU	CMOS MOS	0.8	5	1988		22,000	F
MOTOROLA	MESA	AZ	U.S.A.	MOS 6	ASIC ANALOG LOG	CMOS BiCMOS	0.35	6	1988		8,000	F
MOTOROLA	OAKHILL	TX	U.S.A.	MOS 11	SRAM DSP MCU MPU RISC	CMOS BiCMOS	0.35	8	1992		15,700	F
MOTOROLA	PHOENIX		U.S.A.	COM 1	RF POWER	LD MOS		6	1995		2,400	P
MOTOROLA	PHOENIX		U.S.A.	OPTO	OPTO	GaAs		2			8,000	P
MOTOROLA	PHOENIX	AZ	U.S.A.	BIPOLAR 5	RF PWR SMALL SIGNAL OPTO	BIP	1.25	5	1983		26,000	F
MOTOROLA	PHOENIX	AZ	U.S.A.	DFS	RECTIFIERS			3			14,400	F
MOTOROLA	PHOENIX	AZ	U.S.A.	MOS 4	MOSFET SMART PWR DISCRETE	BIP	3	6	1986		18,000	F
MOTOROLA	PHOENIX	AZ	U.S.A.	PHOENIX POWER	PWR TRAN	BIP	10	5			30,000	F
MOTOROLA	PHOENIX	AZ	U.S.A.	ZENER/RECTIFIER	ZENER DIODE RECTIFIER	BIP	10	4			56,000	F
MOTOROLA	RESEARCH TRIANGLE PARK	NC	U.S.A.	MOS 15	8 Bit MCU LOGIC	CMOS	0.8	6	1984		12,000	F
MOTOROLA	TEMPE	AZ	U.S.A.	CS-1 PHASE 1	ANALOG RF	GaAs	0.35	4	1991		1,600	P
N-CHIP	SAN JOSE	CA	U.S.A.	NA	MCM	CMOS MOS	3	5	1986		1,000	P
NATIONAL S/C	ARLINGTON	TX	U.S.A.	CMOS 1	ARRAYS MCU EEPROM MPRCOM	CMOS M2 POLY1	1.2	6	1986		18,000	NF
NATIONAL S/C	ARLINGTON	TX	U.S.A.	FAB 2	ARRAYS MCU	CMOS	0.65	6	1993		3,500	FN
NATIONAL S/C	SANTA CLARA	CA	U.S.A.	ANALOG 5	ANALOG	BIPOLAR	2.5	5	1985		28,000	PQRN
NATIONAL S/C	SANTA CLARA	CA	U.S.A.	ATG 6	NONVOLATILE MEM MPR MCU MPU DSP ASIC	CMOS BiCMOS BIPOLAR	0.65	6	1990		26,000	PQRN
NATIONAL S/C	SANTA CLARA	CA	U.S.A.	ATG 8	MPR MCU MPR DSP ASIC	CMOS BiCMOS	0.35	8	1995		13,000	PRQN
NATIONAL S/C	SOUTH PORTLAND	ME	U.S.A.	BIPOLAR	LOG	BIP CMOS BiCMOS	2.5	4	1967		43,520	FADT
NATIONAL S/C	SOUTH PORTLAND	ME	U.S.A.	CMOS	LOG ARRAY	CMOS BiCMOS	1	5	1985		5,500	FATD
NATIONAL S/C	WEST JORDAN	UT	U.S.A.	MOS 3	EPROM EEPROM EMBEDDED CONTROLLERS ANALOG DISCRETE	CMOS MOS	0.6	6	1985	9,000	15,000	FNRTD
NATL. SECURITY ADMIN.	FORT MEADE	MD	U.S.A.	NA	CUSTOM MIL STD	BIP CMOS MOS	1	6	1988		10,000	F
NATL. SECURITY ADMIN.	FORT MEADE	MD	U.S.A.	NA	MIL STD	CMOS	0.8	6	1990		5,000	P
NAVAL OCEAN SYS. CTR.	SAN DIEGO	CA	U.S.A.	NA	NA	NA		4	1988		5,000	P
NEC ELECTRONICS	ROSEVILLE	CA	U.S.A.	K-LINE	256K SRAM 256K DRAM ASIC MCU	NMOS CMOS	1	5	1984		25,000	FAT
NEC ELECTRONICS	ROSEVILLE	CA	U.S.A.	M-LINE	4Mb/16Mb DRAM	CMOS	0.5	6	1991		30,000	FAT
NORTHERN TELECOM	NEPEAN, ONTARIO	CN	CANADA	MOD4	CBIC CUSTOM	MOS		6	1990		6,000	FATDR
NOVASENSOR	FREMONT	CA	U.S.A.	NA	Si-BASED PRESSURE SENSORS	CMOS	2	4	1987		3,000	PRQ
OPTEK TECHNOLOGY, INC.	CARROLLTON	TX	U.S.A.	FAB 1	MIL STD PWR ICs	MOS		4	1987		15,000	F
OPTEK TECHNOLOGY, INC.	CARROLLTON	TX	U.S.A.	FAB 2	MIL STD PWR ICs	MOS		5	1987		15,000	F
OPTO DIODE	NEWBURY PARK	CA	U.S.A.	NA	OPTO DIODE	GaAs			1981			F

(Continued)

Table 1 (Continued)
Americas Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	State	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
ORBIT SEMICONDUCTOR INC	SUNNYVALE	CA	U.S.A.	FAB 1	ARRAYS CUSTOM MIXSIG ASIC ASIC	CMOS	1.2	4	1991	1,000	9,600	FNQRTD
ORBIT SEMICONDUCTOR INC	SUNNYVALE	CA	U.S.A.	FAB 1	FOUNDRY	CMOS	0.8	6	1995		2,000	FNQRTD
PARADIGM TECHNOLOGY INC.	SAN JOSE	CA	U.S.A.	SRAM FAB	256K, 1Mb, 4Mb SRAM	CMOS	0.55	6	1990	3,000	6,000	FR
PERFORMANCE S/C	SUNNYVALE	CA	U.S.A.	FAB 1	SRAM ARRAYS MIPS RISC MPU	CMOS	1	6	1986		5,600	P
PERFORMANCE S/C	SUNNYVALE	CA	U.S.A.	FAB 2	SRAM MPU ASIC	BiCMOS CMOS	0.7	6	1990		7,000	P
PHILIPS SEMICONDUCTORS	ALBUQUERQUE	NM	U.S.A.	FAB 22	EPROM MCU MPR DSP ANALOG	CMOS BiCMOS MOS BIPOLAR	1.2	4	1980	6,000	25,000	F
PHILIPS SEMICONDUCTORS	ALBUQUERQUE	NM	U.S.A.	FAB 23	MCU MPR ASIC ANALOG DISCRETE OPTO POWER ICs	CMOS BiCMOS	0.8	6	1988	4,000	17,000	FR
PHILIPS/SIGNETICS	SUNNYVALE	CA	U.S.A.	FAB 1	LIN SMART PWR OP AMPS	BIP	2.5	4	1987		20,000	F
POWEREX	YOUNGWOOD		U.S.A.	H PWR SCR/DIODE	DISCRETE POWER DIODES SCR GTO	BIPOLAR	50	3	1988	20,000	40,000	FR
POWEREX	YOUNGWOOD	PA	U.S.A.	PLANAR TRANSISTOR	DISCRETE DIODE PWR TRAN THYRISTOR	BIPOLAR	5	4	1988	2,000	5,000	PR
PRECISION MONO.	SANTA CLARA	CA	U.S.A.	FAB 1	ASIC	CMOS	3	4	1985		1,600	PAT
PRECISION MONO.	SANTA CLARA	CA	U.S.A.	FAB 2	CUSTOM	BIP	2.5	4			3,200	PAT
PROTECT DEVICES	TEMPE	AZ	U.S.A.	NA	DIODE	BIP	25	3	1968		19,200	PAT
RAMTRON INTERNATIONAL CORP.	COLORADO SPRINGS	CO	U.S.A.	NORTHGATE	4K SERIAL/PARALLEL 64K PARALLEL NVMEM (FERRAM)	CMOS	1	6	1993	1,000	15,000	PRDT
RAYTHEON	ANDOVER	MA	U.S.A.	GaAs	NA	GaAs	0.5	3	1989		800	F
RAYTHEON	ANDOVER	MA	U.S.A.	NA	ARRAYS CUSTOM	CMOS	0.9	5	1985		3,500	FRAT
RAYTHEON	MOUNTAIN VIEW	CA	U.S.A.	LINEAR	LIN ASIC DIS TRAN SST	BIP	5	4	1979		6,400	F
RAYTHEON	MOUNTAIN VIEW	CA	U.S.A.	LSI ARAY	20K ARRAYS	BIP CMOS	1	4	1987		10,000	F
RAYTHEON	WALTHAM	MA	U.S.A.	NA	MMIC	GaAs		3	1988		400	NP
ROCKWELL	NEWBURY PARK	CA	U.S.A.	GaAs WAFER FAB	MOSFET HBT MEM ASIC	GaAs	0.7	4	1985		2,000	PRADT
ROCKWELL	NEWPORT BEACH	CA	U.S.A.	FAB 1	MODEM TELECOM	CMOS MOS	2	4	1979		25,000	FPRDT
ROCKWELL	NEWPORT BEACH	CA	U.S.A.	FAB 4	TELECOM INTERFACE	CMOS MOS	2	4	1987		25,000	FPRDT
ROCKWELL	NEWPORT BEACH	CA	U.S.A.	Fab V	TELECOM CHIPS ANALOG	CMOS GaAs	0.5	8	1995		11,000	F
ROCKWELL(FORMERLY UTMC)	COLORADO SPRINGS	CO	U.S.A.	UTMC	TELECOM CHIPS ANALOG	BIP CMOS	0.8	5	1986		3,200	NP
ROHM	SUNNYVALE	CA	U.S.A.	KIFER PLANT	CUSTOM Mixed-Signal ASIC	BIPOLAR	3	5	1989		15,000	F
SAMSUNG MICROWAVE	MILPITAS	CA	U.S.A.	GaAs	GaAs FET MMIC	GaAs	0.25	4	1982		3,500	NPATD
SANDERS ASSOCIATES	NASHUA	NH	U.S.A.	GaAs	LIN MMIC	GaAs	0.5	3	1985		400	PAT
SANDIA NATIONAL LABS	ALBUQUERQUE	NM	U.S.A.	RHIC-1	MPU LOG SRAM ASIC	CMOS	1.5	4	1981		1,200	PRAT
SANTA BARBARA RSCH.	GOLETA	CA	U.S.A.	SBRC	MIL STD INFRARED DETECTOR	HgCdTe InSb		4	1987		1,000	P
SEMATECH	AUSTIN	TX	U.S.A.	ATDF		CMOS	0.35	8	1988		5,000	PR

(Continued)

Table 1 (Continued)
Americas Existing Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	State	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
SEMICOA	COSTA MESA	CA	U.S.A.	NA	CUSTOM HI-REL PWR PHOTO	BIP	7	3	1969		12,000	F
SEMTECH CORPORATION	CORPUS CHRISTI	TX	U.S.A.	CORPUS CHRISTI	ANALOG DISCRETE	BIPOLAR	5	4	1974		8,000	FRD
SEMTECH CORPORATION	NEWBURY PARK	CA	U.S.A.	NEWBURY PARK	DISCRETE RECTIFIER ZENER DIODE	BIPOLAR		2	1968		10,000	FRAT
SENSOR SOLID STATE	QUAKERTOWN	PA	U.S.A.	NA	CUSTOM DIS SENSORS	MOS NMOS/ PMOS	3	4	1969		500	P
SENSYM INC	MILPITAS	CA	U.S.A.	FAB 1	SOLID STATE SENSORS ANALOG	BIPOLAR	3	4	1993	300	1,500	PFR
SGS-THOMSON	CARROLLTON	TX	U.S.A.	FAB 4	SRAM ASIC EPROM EEPROM	CMOS	1.2	4	1987		26,000	FNAT
SGS-THOMSON	CARROLLTON	TX	U.S.A.	FAB 6	1Mb SRAM ARRAYS	CMOS	0.7	6	1989		20,000	FRAT
SGS-THOMSON	PHILADELPHIA	PA	U.S.A.	NA	DIS, RF	BIP	5	4			12,000	F
SGS-THOMSON	PHOENIX	AZ	U.S.A.	PHOENIX FAB	MPU SRAM	CMOS	0.5	8	1995		14,000	F
SGS-THOMSON	SAN DIEGO	CA	U.S.A.	NA	ASIC LOG	CMOS BiCMOS	2	4	1981		14,000	FR
SID MICROELECT.	CONTAGEM		BRAZIL	NA	LIN PWR TRAN SST PWR ICs	BIP	30	3	1984		12,000	F
SID MICROELECT.	CONTAGEM		BRAZIL	NA	PWR ICs	CMOS	2	4	1990		13,000	F
SIEMENS	CUPERTINO	CA	U.S.A.	NA	LED COUPLERS OPTO	GaAs MOS						F
SILICON SYSTEMS (TDK)	SANTA CRUZ	CA	U.S.A.	FAB III	MIXED SIGNAL ASIC	CMOS BiCMOS BIPOLAR	0.8	6	1992	1,500	3,400	FR
SILICON TRANSISTOR	CHELMSFORD	MA	U.S.A.	BIPOLAR	DISCRETE POWER	BIPOLAR	4	4	1980	10,000	50,000	PR
SILICONIX INCORPORATED	SANTA CLARA	CA	U.S.A.	FAB 2	SMART PWR A/D D/A	CMOS	3	4			8,000	F
SILICONIX INCORPORATED	SANTA CLARA	CA	U.S.A.	FAB 3	PWR SMART PWR	CMOS	1.5	6	1986		4,000	P
SIPEX CORPORATION	MILPITAS	CA	U.S.A.	FAB 1	ASIC MIXED SIGNAL	BIPOLAR BiCMOS	3	4	1987	1,500	4,000	PR
SOLID POWER CO.	FARMINGDALE	NY	U.S.A.	NA	PWR TRAN	BIP	20	2	1967		24,000	FAT
SOLID STATE DEVICES	LA MIRADA	CA	U.S.A.	NA	HI-REL CUSTOM	BIP		4			4,000	P
SOLITRON DEVICES	WEST PALM BEACH	FL	U.S.A.	NA	DISCRETE	BIPOLAR	2	3	1992	200	1,000	PRATD
SONY	SAN ANTONIO	TX	U.S.A.	Fab 11	SRAM	CMOS	0.5	6	1991		16,000	F
SONY	SAN ANTONIO	TX	U.S.A.	Fab 12	ASIC PLD	BIPOLAR	1.25	6	1982		12,800	F
SPECTRA DIODE LABS	SAN JOSE	CA	U.S.A.	SDL	LASER DIODE	GaAs GaAlAs		3	1987			FR
SPECTRO LABS (HUGHES)	SYLMAR	CA	U.S.A.	NA	SOLAR CELL ARRAYS	NA		4	1982		24,000	FAT
SPRAGUE (ALLEGRO)	WILLOW GROVE	PA	U.S.A.	NA	SRAM ROM PROM	CMOS	2.2	4	1982		12,800	NFT
SPRAGUE (ALLEGRO)	WORCESTER	MA	U.S.A.	NA	CUSTOM DIS	BiCMOS BIP	4	4	1987		19,200	F
STANDARD MICROSYSTEMS	HAUPPAUGE	NY	U.S.A.	NA	CUSTOM CBIC	CMOS MOS	1.25	4	1984		19,200	NFAT
SUPERTEX	SUNNYVALE	CA	U.S.A.	NA	ANALOG POWER	CMOS MOS	4	4	1976		82,000	FR
SYMBIOS LOGIC (Formerly Hyundai (NCR))	COLORADO SPRINGS	CO	U.S.A.	COLORADO SPRINGS 4	MPR MIXED SIGNAL ASIC	CMOS	0.7	4	1982		7,400	PFQR
SYMBIOS LOGIC (Formerly Hyundai (NCR))	COLORADO SPRINGS	CO	U.S.A.	COLORADO SPRINGS 8	MPR ASIC ANALOG	CMOS	0.5	8	1994		10,200	PFQR

(Continued)

Table 1 (Continued)
Americas Existing Pilot and Production Fab Lines
(Including Fabs Beginning Operation during 1995)

Company	City or District	State	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
SYMBIOS LOGIC (Formerly Hyundai [NCR])	FORT COLLINS	CO	U.S.A.	FT. COLLINS (4)	ARRAYS CBIC	CMOS	1.5	4	1979		8,000	PFQN
SYMBIOS LOGIC (Formerly Hyundai [NCR])	FORT COLLINS	CO	U.S.A.	FT. COLLINS (6)	ARRAYS CBIC	CMOS	1	6	1986		4,400	FQ
SYNERGY SEMICONDUCTOR	SANTA CLARA	CA	U.S.A.	CORVEN FAB	FAST-SRAM MPR ASIC	BIPOLAR BiCMOS	1	4	1989	250	400	P
SYPEX	MILPITAS	CA	U.S.A.	FAB 1	OP AMP CBIC CUSTOM	CMOS	4	4	1986		1,600	NPAT
TECCOR ELECTRONICS	IRVING	TX	U.S.A.	SIDEATOR	ASIC ANALOG	BIPOLAR	0.24	3	1969	1,000	10,000	FRTD
TECCOR ELECTRONICS	IRVING	TX	U.S.A.	TRIACS STAND	DISCRETE THYRISTOR	BIPOLAR	0.35	3	1986	1,000	16,000	FRTD
TEKTRONIX MICROELECTRONICS	BEAVERTON	OR	U.S.A.	BIPOLAR	TELECOM A/D ARRAYS CUSTOM	BIP	1	4	1984		4,000	NPAT
TELCOM DEVICES	CAMARILLO	CA	U.S.A.	NA	PDIODE LED	GaAs		2	1993		800	FRADT
TELEDYNE MICROELECT.	LOS ANGELES	CA	U.S.A.	NA	HI-REL HYBRID & A/D D/A	BIP		4			5,000	P
TELEDYNE MICROWAVE	MOUNTAIN VIEW	CA	U.S.A.	GaAs	FET	GaAs	0.5	3			80	PAT
TELEDYNE S/C	MOUNTAIN VIEW	CA	U.S.A.	NA	PWR ICs PWR MOSFET HYBRIDS	BIP BiCMOS CMOS		4	1972		5,000	P
TEXAS INSTRUMENTS	DALLAS	TX	U.S.A.	DLIN	LIN	BIP BiCMOS	1	6	1989		27,000	F
TEXAS INSTRUMENTS	DALLAS	TX	U.S.A.	DLOG	LIN ASSP	MOS CMOS	0.8	6	1989		16,000	F
TEXAS INSTRUMENTS	DALLAS	TX	U.S.A.	DMOS	LOG MPU	CMOS	0.6	6	1985		29,200	F
TEXAS INSTRUMENTS	DALLAS	TX	U.S.A.	DMOS 5	16Mb DRAM	CMOS	0.5	8	1995		16,000	F
TEXAS INSTRUMENTS	DALLAS	TX	U.S.A.	SPDL	16Mb, 64Mb DRAM ASSP	CMOS	0.6	6	1986		300	FR
TEXAS INSTRUMENTS	HOUSTON	TX	U.S.A.	H-FAB	ADV BIP ASSP ASIC	BIP CMOS	1	5	1984		25,466	F
TEXAS INSTRUMENTS	LUBBOCK	TX	U.S.A.	LMOS	EPROM MPU MCU DSPs	CMOS	0.6	6	1978	15,000	25,000	F
TEXAS INSTRUMENTS	SHERMAN	TX	U.S.A.	S-FAB	LOG MPR	BIP TTL	1	5	1980		51,600	F
TRIQUINT	BEAVERTON	OR	U.S.A.	NA	MMIC LIN OPTO CBIC ARRAYS	GaAs	0.7	4	1985		2,300	OFA
TRW	MANHATTAN BEACH	CA	U.S.A.	NA	LIN TRAN PWR TRAN HYBRD	MOS		4	1982		5,000	P
TRW	REDONDO BEACH	CA	U.S.A.	D1	VHSIC MIL STD FERRAM	CMOS MOS	0.5	4	1986		6,400	FAT
TRW	REDONDO BEACH	CA	U.S.A.	D1	LIN TRAN PWR TRAN HYBRD	BIP CMOS	1.5	4	1985		1,600	PAT
TRW	REDONDO BEACH	CA	U.S.A.	NA	RF PWR	GaAs	0.5	3	1971		200	P
TRW SYSTEMS	LA JOLLA	CA	U.S.A.	NA	A/D D/A MULTIPLIERS	CMOS BIP		4	1987		5,000	PR
UNITRODE	WATERTOWN	MA	U.S.A.	NA	HYBRID DIS	BIP		4			10,000	F
UNITRODE INTEGRATED CIRCUITS CORPORATION	MERRIMACK	NH	U.S.A.	NA	LIN SMART PWR CUSTOM	BIP	5	4	1987		4,000	PAT
UNIVERSAL SEMICONDUCTOR	SAN JOSE	CA	U.S.A.	NA	LINEAR ARRAYS ASIC POWER ICs	CMOS BiCMOS BIPOLAR	2	4	1980	4,000	10,000	PRNTD
VITESSE SEMICONDUCTOR	CAMARILLO	CA	U.S.A.	CAMARILLO FAB	GaAs ARRAYS ASIC MPR	GaAs	0.5	4	1986	500	5,000	PQRNTD
VLSI TECHNOLOGY	SAN ANTONIO	TX	U.S.A.	MODULE A	ARRAYS CBIC MPU MPR	CMOS M3 POLY1	1	6	1989		12,000	FQR

(Continued)

Table 1 (Continued)
Americas Existing Pilot and Production Fab Lines
(Including Fabs Beginning Operation during 1995)

Company	City or District	State	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
VLSI TECHNOLOGY	SAN ANTONIO	TX	U.S.A.	MODULE B	ARRAYS CBIC MPU MPR	CMOS M3	0.8	6	1991		5,400	F
VLSI TECHNOLOGY	SAN ANTONIO	TX	U.S.A.	MODULE C	ARRAYS CBIC SRAM MPU E2	CMOS M3	0.8	6	1994		6,400	F
VLSI TECHNOLOGY	SAN JOSE	CA	U.S.A.	SAN JOSE	PLD ARRAYS CBIC MPR	CMOS MOS	0.8	5	1982		15,000	FQ
WESTINGHOUSE	BALTIMORE	MD	U.S.A.	GaAs	POWER MMICs	GaAs	0.2	4	1991	80	225	PRNTD
WESTINGHOUSE	BALTIMORE	MD	U.S.A.	SILICON	ASIC DISCRETE OPTO RAD HARD MEM	CMOS BiCMOS BIPOLAR	0.6	6	1984	100	2,000	PQRNTD
XEROX PALO ALTO RSCH.	PALO ALTO	CA	U.S.A.	NA	CUSTOM IMAGE PROCESSING	SOI		4	1982			PR
XICOR	MILPITAS	CA	U.S.A.	PHASE 2	EEPROM	CMOS NMOS/PMOS	0.5	6	1981	5,000	6,000	PFR
ZENITH MICROCIRC.	ELK GROVE	IL	U.S.A.	HVSR	HIGH-VOLT DIODE TRIODE	BIP	20	2	1981		16,000	FAT
ZILOG	NAMPA	ID	U.S.A.	MODULE 1	MPU MCU CUSTOM	NMOS	1.2	5	1988		15,000	NFAT
ZILOG	NAMPA	ID	U.S.A.	MODULE 2	Z80,OOO MPU MCU CUSTOM	CMOS NMOS BiCMOS	0.65	5	1988		10,200	NFAT
ZILOG	NAMPA	ID	U.S.A.	MODULE 3	MPU MCU CUSTOM	CMOS	0.6	8	1994		8,000	F

NA = Not applicable
Fab Types:
F = Production-Based Fab
R = Semiconductor R&D and/or Trial Production Facility
P = Pilot Line (Initial Production or Intended Low Volume)
T = Test and Assembly (Formerly A)
Q = Quick-Turn Fab
N = Nondedicated Foundry Service Available
D = Design Center
Source: Dataquest (December 1995)

Table 2
Americas Future Pilot and Production Fab Lines (Including Fabs Beginning Operation during 1995)

Company	City or District	State	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
AMD	AUSTIN	TX	U.S.A.	FAB 25	K5 MPU	CMOS	0.35	8	1995	200	28,000	FR
AMERICAN MICROSYSTEMS INC.	POCATELLO	ID	U.S.A.	FAB 2	ARRAYS PLD CBIC CUSTOM MIXSIG ASIC	CMOS	0.5	8	1996	6,500	20,000	FN
CYPRESS SEMICONDUCTOR	BLOOMINGTON	MN	U.S.A.	FAB 4	SRAM EPROM FPGA	CMOS	0.5	8	1995		20,000	F
DIGITAL EQUIPMENT CORPORATION	HUDSON	MA	U.S.A.	FAB 6	MPU ALPHA	CMOS	0.12	8	1995		20,000	F
FUJITSU	GRESHAM	OR	U.S.A.	No 2-2	16Mb 64Mb DRAM	CMOS	0.32	8	1997	5,000	10,000	F
HARRIS SEMICONDUCTOR	MOUNTAINTOP	PA	U.S.A.	POWER MOS 8	DISCRETE POWER	CMOS MOS BIPOLAR		8	1997			F
HITACHI	IRVING	TX	U.S.A.	U2	MCU	CMOS	0.35	8	1997		10,000	F
HYUNDAI	EUGENE	OR	U.S.A.	OREGON FAB	16Mb 64Mb DRAM	CMOS	0.35	8	1997		30,000	F
IBM/TOSHIBA	MANASSAS	VA	U.S.A.	NA	16Mb/64Mb DRAM DSP	CMOS	0.35	8	1997	15,000	28,000	F
IDT	HILLSBORO	OR	U.S.A.	NA	LOGIC SRAM	CMOS	0.5	8	1996		10,000	F
INTEL	ALOHA	OR	U.S.A.	D1A2	MPU (P6, P7)	BiCMOS	0.25	8	1996		3,000	P
INTEL	CHANDLER	AZ	U.S.A.	FAB 12	MPU (P6)	BiCMOS	0.4	8	1996		24,000	F
INTEL	HILLSBORO	OR	U.S.A.	NA	LOGIC MPU	CMOS	0.25	12	1998		5,000	P
INTEL	RIO RANCHO	NM	U.S.A.	FAB 11.2	MPU (P5, P6)	BiCMOS	0.4	8	1995	5,000	33,000	F
INTERNATIONAL RECTIFIER	TEMECULA	CA	U.S.A.	HEXFET-2	PWR TRANS MOSFET	CMOS MOS	2	6	1995		10,000	F
LINEAR TECHNOLOGY	CAMAS	WA	U.S.A.	FAB 3	LINEAR	BIP CMOS BICMOS		6	1996		10,000	F
LSI LOGIC	GRESHAM	OR	U.S.A.	FAB 1	ASIC CBIC MPU MPR SRAM	CMOS BICMOS	0.35	8	1997		15,000	F
MEDTONIC/MICRO-REL	TEMPE	AZ	U.S.A.	NA	NA	BIP M1 CMOS M2 POLY1	0.8	6	1997			FRNADT
MICRON TECHNOLOGY	LEHI	UT	U.S.A.	NA	16Mb 64Mb 256Mb DRAM	CMOS	0.25	8	1998		40,000	F
MOTOROLA	AUSTIN	TX	U.S.A.	MOS 13/14	MPU MCU RISC	CMOS BICMOS HCMOS	0.25	8	1995		7,200	FR
MOTOROLA	MESA	AZ	U.S.A.	MOS 21	LOGIC ASIC ANALOG DISCRETE	CMOS BICMOS	0.8	8	1996		9,200	F
MOTOROLA	PHOENIX		U.S.A.	COM 1	RF POWER	LD MOS		6	1995		2,400	P
MOTOROLA	PHOENIX		U.S.A.	POWER RECT	RECTIFIERS			6	1998		6,000	F
MOTOROLA	RESEARCH TRIANGLE PARK	NC	U.S.A.	MOS 19	MPU MCU LOGIC	CMOS BiCMOS	0.35	8	1999		4,800	F
MOTOROLA	WEST CREEK	VA	U.S.A.		PowerPC MPU	CMOS	0.35	8	1998		25,000	F
NATIONAL SEMICONDUCTOR					ANALOG LOGIC ASICs	BiCMOS CMOS	0.35	8	1997		10,000	F
NATIONAL SEMICONDUCTOR	ARLINGTON	TX	U.S.A.	FAB 3	ARRAYS MCU	CMOS	0.25	6	1997			F
NATIONAL SEMICONDUCTOR	SANTA CLARA	CA	U.S.A.	ATG 8	MPR MCU MPR DSP ASIC	CMOS BiCMOS	0.35	8	1995		13,000	PRQN
NATIONAL SEMICONDUCTOR	SOUTH PORTLAND	ME	U.S.A.	NA	LOG ARRAY	BiCMOS	0.25	8	1997			F
ORBIT SEMICONDUCTOR INC	SUNNYVALE	CA	U.S.A.	FAB 1	FOUNDRY	CMOS	0.8	6	1995		2,000	FNQRTD
ORBIT SEMICONDUCTOR INC	SUNNYVALE	CA	U.S.A.	FAB 2	ARRAYS CUSTOM MIXSIG ASIC	CMOS	0.8	6	1996	1,000	1,000	FN
ROCKWELL	NEWPORT BEACH	CA	U.S.A.	Fab V	TELECOM CHIPS ANALOG	CMOS GaAs	0.5	8	1995		11,000	F
ROCKWELL	NEWPORT BEACH	CA	U.S.A.	Fab VI	TELECOM CHIPS ANALOG	CMOS GaAs	0.35	8	1997		5,000	F

(Continued)

Table 2 (Continued)
Americas Future Pilot and Production Fab Lines (Including Fabs Beginning Operation During 1995)

Company	City or District	State	Country	Fab Name	Products Produced	Process Technology	Est. Minimum Geometry (Microns)	Wafer Diameter (In.)	Year of Initial Production	Initial Wafer Starts per Month	Est. Maximum Wafers per Month	Fab Type
SAMSUNG	AUSTIN	TX	U.S.A.	NA	64Mb DRAM	CMOS	0.35	8	1997		30,000	F
SGS-THOMSON	PHOENIX	AZ	U.S.A.	PHOENIX FAB	MPU SRAM	CMOS	0.5	8	1995		14,000	F
SONY	SAN ANTONIO	TX	U.S.A.	NA	HS SRAM ASIC LOGIC (ASSPs)	CMOS	0.35	6	1996		10,000	F
TEXAS INSTRUMENTS	DALLAS	TX	U.S.A.	DMOS 5	16Mb DRAM	CMOS	0.5	8	1995		16,000	F
TEXAS INSTRUMENTS	DALLAS	TX	U.S.A.	DMOS 5 PHASE 2	64Mb, 256Mb DRAM	CMOS	0.35	8	1997		16,000	FR
TSMC-JV1	NA	NA	U.S.A.	NA	LOG CUSTOM MPU MEM FOUNDRY	CMOS	0.35	8	1998		25,000	FN
TWINSTAR SEMICONDUCTOR	RICHARDSON	TX	U.S.A.	TWINSTAR	16M/64M DRAM	CMOS	0.3	8	1996	10,000	15,000	F
VLSI TECHNOLOGY	SAN ANTONIO	TX	U.S.A.	MODULE D	ARRAYS CBIC SRAM MPU E2	CMOS M3	0.6	6	1996		6,400	F

NA = Not applicable
Fab Types:
F = Production-Based Fab
R = Semiconductor R&D and/or Trial Production Facility
P = Pilot Line (Initial Production or Intended Low Volume)
T = Test and Assembly (Formerly A)
Q = Quick-Turn Fab
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Source: Dataquest (December 1995)

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Market Analysis

Semiconductor Equipment, Manufacturing, and Materials Worldwide

Market Analysis

Lithography Stepper Capacity: Bottleneck of Semiconductor Production

Abstract: *Semiconductor manufacturing's unprecedented and sustained growth of the past several years has put a significant strain on the infrastructure of the markets that support it. In manufacturing semiconductors, lithography defines capacity and technical capability. The capacity constraints of the suppliers in this critical lithography stepper market are discussed in this article by looking at each stepper supplier.*
By Nader Pakdaman

Stepper Suppliers Step Up Capacity

Nikon recently announced expansion of its stepper production facility in Kumagaya, Japan. The company will increase output at its main plant to nearly 1,000 steppers per year from a current capacity of about 650 units. The primary emphasis will be on the high-end i-line systems (NSR-2205i11D and beyond) and the newly announced scanning stepper (NSR-S201A deep-UV system). Full capacity will be reached gradually through 1996.

At about the same time, Ultratech Stepper and ASM Lithography (ASML) announced that they are holding preliminary discussions to form a strategic alliance. Ultratech and ASML will offer their clients the option of mixing and matching their respective noncritical and critical resolution steppers. The primary goal of the discussions is to focus on developing faster responses to capacity constraints.

Dataquest Analysis

The news releases on both of these announcements were short but significant. Without steppers, one cannot build a fab and expect to pattern the

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circuits on the silicon. Concerns about infrastructure constraints in the semiconductor industry are mounting. Could the current undercapacity in manufacturing curtail the semiconductor industry's goal of surpassing $300 billion by the end of the century? These concerns are balanced by warnings of historical overinvestment patterns that have taken the industry through some very hard times. There is merit to both of these arguments. As usual, the reality will probably lie somewhere in between and be more complex than either.

In a recent update of the semiconductor revenue forecast, Dataquest increased its forecast of average growth rates for the industry to over 20 percent until the end of the decade. Growth rates had been just over 15 percent for the first half of the decade. We believe this increase is a fundamental indicator of the growing prevalence of semiconductors in our lives. From set-top boxes to PCs and communications applications, semiconductors are changing all facets of our lives at home and work.

The other fundamental aspect of the industry is the cyclical nature of the markets and investment patterns that have produced cycles of relatively stronger and slower years. As the industry migrates to a new device generation, the cycle begins with investment to address undercapacity. Then, as device shrinks take hold and yield increases, demand is met and a period of overcapacity may occur. This cyclical pattern is seen very clearly in the DRAM market.

In short, we are experiencing a fundamentally stronger demand for semiconductors that the industry is addressing by unprecedented increases in capacity. However, the central cyclical drivers still exist in the market. In Dataquest's view, the issue of over- and undercapacity will not prevail uniformly in all markets and for all ICs. The Dataquest forecasts for the semiconductor market and the directly related manufacturing equipment and materials market reflect both the growth in demand and the cyclical nature of the market.

Since 1993, megafab announcements have become daily news. Capital spending figures for fabs ranging from $1 billion to $2 billion are now taken as ordinary events. The technology and capacity of these fabs are defined by the number and capabilities of their lithography steppers.

The lithography tools supply-demand equation has been producing backlogs extending into the first quarter of 1997. This may sound fantastic, but if these backlogs are not addressed in a timely fashion by stepper suppliers, it could spell disaster. As both technology and users' needs evolve, these extended delivery times could translate into changing specifications. Changes in the market over such an extended period could even spur cancellations. A more balanced supply-demand picture with realistic backlogs would make planning and investment for stepper manufacturers and semiconductor manufacturers a more reasonable and less chaotic exercise.

All of the major stepper manufacturers (ASML, Canon, Nikon, SVG Lithography, and Ultratech Stepper) are facing historic capacity demands. Inability to address the problem could spell loss of market share in a segment that accounts for over 15 percent of the total front-end equipment market, on average. Dataquest estimated the stepper market at $1.8 billion in 1994.

Current estimates call for this market to reach $5 billion by the end of the decade.

Nikon has led the stepper market with shares about and above 50 percent in the last several years. Nikon's current capacity is approximately 650 stepper units a year. For 1995, this capacity should preserve the company's position in a market that we estimate will surpass 1,000 steppers for the first time, with over 1,200 steppers shipped to manufacturers. Nikon plans to sustain and even gain market share by quickly increasing capacity in a market that is highly cyclical. The peak and trough years of the stepper market are very steep. But we estimate that the growing demand in production will not be met by capacity until 1997, at least, and that the slowdowns that follow will not be as severe as those of previous cycles. Nikon's lens capacity, or the better availability of glass, is even more critical. It takes over a year to anneal the quartz material used in the optical train of the steppers. We must assume that Nikon has been planning this increase for many months and that its glass capacity will match its 1,000-stepper goal.

Nikon's Japanese counterpart, Canon, has been increasing capacity since early 1994. By our estimate, Canon is now running at a capacity of over 400 steppers per year. We expect Canon to increase its capacity to preserve and perhaps increase its share of about 25 percent of the stepper market. Canon is on a very aggressive product introduction path as it tries to reestablish itself as a leader for 0.25-micron deep-UV lithography scanning tools.

The Ultratech and ASML announcement is also directly related to the capacity issue. ASML has been working hard with its optical shop, the lens supplier Zeiss of Germany, to increase capacity for its systems. Sophisticated tools and major investments are required to process the glass and manufacture and test the optical train for all stepper manufacturers. Based on announcements made by ASML and Zeiss, Dataquest estimates their lens capacity at fewer than 180 units for 1995. This figure could easily grow in the next several years.

ASML's primary strategy is to compete with Canon and Nikon on the high-resolution stepper front as the industry moves to 0.35-micron and smaller geometries. However, resolution is not the only measure of steppers and equipment. Cost-effectiveness and productivity must match technical capabilities. Because of this, stepper manufacturers have introduced mix-and-match lithography as a means of reducing cost and increasing throughput.

Ultratech has led the way in matching its high-throughput systems in a mix with high-resolution steppers on the fab floor. Canon, ASML, and Nikon have all followed suit with their high-throughput systems. By our estimates, Ultratech shipped nearly 70 steppers for semiconductor manufacturing in 1994. The company has been growing strongly in all regions of the world with its i-line steppers for mix and match. Unlike other players in the market, which have product lead times of 18 months or more, Ultratech enjoys turnaround times of six to nine months. This is primarily because of the relatively simple optical design of the Ultratech steppers.

The agreement between Ultratech and ASML translates into a marketing strategy that would allow semiconductor manufacturers to choose between two mix-and-match scenarios. ASML and Ultratech will each propose two mix-and-match packages to the customer. ASML will offer one package pairing its high-resolution stepper with its own high-throughput system and one with the Ultratech companion. Ultratech will offer its system partnered with ASML's equivalent to the high-resolution stepper (which the prospective client may have already chosen) or with the non-ASML stepper.

Discussions between the companies are still in the preliminary stages. Both will benefit from this agreement even if cooperation goes no further than the outlines of their announcement. Most Ultratech high-throughput steppers are matched with Canon and Nikon steppers because of the massive installed base of these two vendors. Ultratech will be well positioned to enjoy the benefits of ASML's client base and to further solidify its position in the critical mix-and-match arena. In turn, ASML will get much-needed capacity relief for its high-resolution steppers.

It will be interesting to see what other synergy may exist between these two players. In 1994, ASML and Ultratech together held over 18 percent of a market that totaled more than $1.8 billion. Each has been growing over 60 to 70 percent per year in the past several years. Ultratech's presence in Japan may compensate for ASML's lack of visibility in this critical market. From a manufacturing point of view, both companies rely heavily on their external suppliers in strategic OEM agreements. Could this similarity and flexibility in manufacturing strategy and this partnership in mix and match lead to cooperation and exchange of technology?

We cannot close this discussion without mentioning the other critical player in the market, SVG Lithography (SVGL). For SVGL, more than any other company in the market, capacity does not merely translate into market share but may determine its future. SVGL's deep-UV Micrascan has led lithography's foray into sub-0.5 micron deep-UV scanning lithography. Dataquest estimates that SVGL holds over 25 percent of the installed base of deep-UV steppers, trailing only Nikon's near-40 percent share of installed deep-UV systems.

Nikon's shipment earlier this year of the first NSR-S201A 0.25-micron deep-UV scanning system to IBM's East Fishkill, New York, plant has the market awaiting SVGL's next stepper—the Micrascan III. However, semiconductor manufacturers are also interested in seeing how SVGL will build the infrastructure needed to support the deep-UV market into the next century. SVGL has benefited from the approval and financial backing of several U.S. semiconductor manufacturers and SEMATECH. Nobody doubts that SVGL's position in technology is formidable, but annual unit shipments now in the low teens would have to increase to levels of deep-UV stepper capacity comparable to SVGL's competitors—ASML, Canon, and Nikon.

Semiconductor revenue and the ensuing growth in capital spending have translated into long backlogs for equipment suppliers, particularly for stepper manufacturers. If stepper undersupply is gating the supply of chips, the market's ability to spur demand by producing in volume and at lower cost will be greatly inhibited. We believe that by mid-1996, even at the current high rate of demand, increases in stepper capacity will relieve the pressure on the market. Through adoption of mix-and-match lithography strategies and/or faster shrinks of IC designs, semiconductor manufacturers will address the growing demand for their products.

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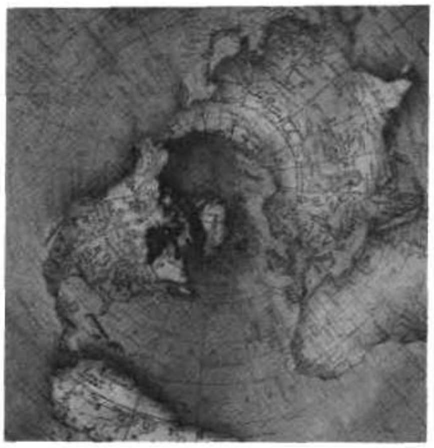

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1994 Silicon Wafer Market Share Estimates

Market Statistics

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Table of Contents

List of Tables

Note: All tables show estimated data.

List of Tables (Continued)

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1994 Silicon Wafer Market Share Estimates

Section 1. Introduction

Dataquest's Semiconductor Equipment, Manufacturing, and Materials service tracks the silicon wafer industry by examining the merchant silicon and epitaxial wafer market, captive silicon production, wafer price trends, and silicon square-inch consumption.

The information in this document is focused on the silicon and epitaxial wafers used in the manufacturing of integrated circuits.

Definitions and Conventions

The calendar year sales of merchant silicon and epitaxial wafer suppliers are estimated in U.S. dollars and converted to millions of square inches using an average selling price for each region. Currency fluctuations over the last several years affect the dollar value of wafer sales of Japanese and European companies. Dataquest uses average exchange rates supplied by the International Monetary Fund (IMF) to convert from local currency to U.S. dollars. The average exchange rates for the Japanese yen and German deutsche mark for 1990 through 1994 are shown in Table 1-1.

Table 1-1
Japanese and German Exchange Rates

	1990	1991	1992	1993	1994
Japanese Yen/U.S.$1	144	135	126	111	102
German Deutsche Mark/U.S.$1	1.62	1.66	1.55	1.65	1.62

Source: Dataquest (June 1995)

Please note the convention that the regional designation "United States" includes Canadian semiconductor manufacturing activities.

Silicon Products

The merchant silicon wafer market is categorized into two product segments—silicon wafers and silicon epitaxial wafers. Silicon wafers include prime, test, and monitor wafers grown by both Czochralski and float zone methods. In the silicon database, Dataquest does not include sales of polysilicon, single-crystal silicon ingots (unless noted), silicon materials used in solar applications, or compound semiconductor material substrates such as gallium arsenide.

Silicon Producers

Companies that produce silicon and epitaxial wafers are defined as either merchant silicon companies or captive silicon producers. Merchant silicon companies are suppliers such as Shin-Etsu Handotai (SEH) of Japan and Wacker of Germany.

Silicon also is produced, to a lesser extent, by both merchant and captive semiconductor manufacturers. These semiconductor manufacturers collectively are referred to as captive silicon producers because they grow single-crystal silicon to produce wafers for their own internal consumption. Examples of captive producers with significant internal silicon production include AT&T, Motorola, and Texas Instruments in the United States and Hitachi in Japan.

Merchant or Captive?

Some captive silicon producers have sold small amounts of material on the merchant silicon market. These producers have sold wafers to ensure that internal production methods continue to produce material of competitive quality and cost. Dataquest estimates that merchant sales for these companies historically have represented a small percentage of their total captive silicon production; these companies are therefore identified as captive rather than merchant silicon producers.

Dataquest identifies Toshiba Ceramics, a subsidiary of Toshiba Corporation, as a merchant silicon company even though a substantial amount of its silicon production is consumed by its semiconductor parent. However, because Toshiba Ceramics is actively marketing its material on the merchant market, it is considered a merchant rather than a captive silicon producer. Toshiba Corporation is considered a customer of Toshiba Ceramics.

Merchant Silicon and Epitaxial Wafer Suppliers

Table 1-2 contains a list of merchant silicon manufacturers that were active in the worldwide market in 1994. This table, organized by region of corporate ownership, summarizes whether a company offers silicon and/or epitaxial wafers.

Table 1-2
Worldwide Merchant Silicon and Epitaxial Companies, 1994

Companies	Silicon Wafers	Epitaxial Wafers
U.S. Companies		
Crysteco Inc.	X	
Epitaxy Inc.		X
General Instrument		
Power Semiconductor Division		X
M/A-COM Semiconductor Products		X
Moore Technologies		X
Pure Sil (Formerly Pensilco)	X	
Spire Corporation		X
Unisil	X	X
Virginia Semiconductor	X	
Japanese Companies		
Kawasaki Steel		
Kawatec	X	X
Komatsu Electronic Metals	X	X
Mitsubishi Materials		
Mitsubishi Materials Silicon	X	X
Siltec Corporation	X	X
NSC Electron Corporation (Nittetsu Denshi)	X	X
Sumitomo SiTix (formerly Osaka Titanium Company)	X	X
Shin-Etsu Handotai	X	X
Showa Denko	X	X
Toshiba Ceramics	X	X
European Companies		
Epitech		X
Huls		
MEMC Electronic Materials	X	X
Okmetic	X	
Siltronix SA	X	
Topsil Semiconductor Materials A/S	X	
Wacker	X	X
Rest of World Companies		
Korea		
Posco-Huls (incl in MEMC Electronic Mat'ls summary)	X	
Siltron (formerly Lucky Advanced Materials Inc.)	X	
Taiwan		
Episil Technologies Inc. (Hermes Epitaxy affiliate)		X
Sino-America	X	
Tatung Company	X	

Source: Dataquest (June 1995)

Section 2. Historical MSI by Region by Product, 1990-1994

Table 2-1
Shipments of Merchant and Captive Silicon Wafers* and Merchant Epitaxial Wafers to Each Region, 1990-1994 (Millions of Square Inches)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
North America	640.2	605.2	650.9	720.0	832.1	6.8
Growth (%)	10.0	-5.5	7.6	10.6	15.6	
Japan	991.9	1,038.5	972.8	1,127.3	1,279.7	6.6
Growth (%)	8.7	4.7	-6.3	15.9	13.5	
Europe	235.4	212.2	235.0	291.2	351.2	10.5
Growth (%)	1.8	-9.9	10.7	23.9	20.6	
Asia/Pacific-ROW	180.8	189.8	238.0	311.2	456.0	26.0
Growth (%)	39.2	5.0	25.4	30.8	46.5	
Worldwide	2,048.3	2,045.7	2,096.7	2,449.7	2,919.0	9.3
Growth (%)	10.4	-0.1	2.5	16.8	19.2	

*Includes prime, virgin test, and monitor wafers
Source: Dataquest (June 1995)

Table 2-2
Shipments of Merchant Epitaxial Wafers to Each Region, 1990-1994 (Millions of Square Inches)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
North America	88.1	84.2	128.1	154.5	190.2	21.2
Growth (%)	7.8	-4.4	52.1	20.6	23.1	
Japan	92.9	104.0	87.0	89.0	119.5	6.5
Growth (%)	11.8	11.9	-16.3	2.3	34.3	
Europe	18.9	23.0	23.9	36.1	54.5	30.3
Growth (%)	8.0	21.7	3.9	51.0	51.0	
Asia/Pacific-ROW	4.6	8.3	9.5	13.0	19.5	43.5
Growth (%)	2.2	80.4	14.5	36.8	50.0	
Worldwide	204.5	219.5	248.5	292.6	383.7	17.0
Growth (%)	9.5	7.3	13.2	17.7	31.1	

Source: Dataquest (June 1995)

Table 2-3
Shipments of Merchant and Captive Silicon Wafers* to Each Region, 1990-1994 (Millions of Square Inches)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
North America	552.1	521.0	522.8	565.5	641.9	3.8
Growth (%)	10.4	-5.6	0.3	8.2	13.5	
Japan	899.0	934.5	885.8	1,038.3	1,160.2	6.6
Growth (%)	8.4	3.9	-5.2	17.2	11.7	
Europe	216.5	189.2	211.1	255.1	296.7	8.2
Growth (%)	1.3	-12.6	11.6	20.8	16.3	
Asia/Pacific-ROW	176.2	181.5	228.5	298.2	436.5	25.5
Growth (%)	40.5	3.0	25.9	30.5	46.4	
Worldwide	1,843.8	1,826.2	1,848.2	2,157.1	2,535.3	8.3
Growth (%)	10.5	-1.0	1.2	16.7	17.5	

*Includes prime, virgin test, and monitor wafers
Source: Dataquest (June 1995)

Table 2-4
Shipments of Captive Silicon Wafers* to Each Region, 1990-1994 (Millions of Square Inches)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
North America	80.0	70.0	72.0	78.0	90.0	3.0
Growth (%)	-2.4	-12.5	2.9	8.3	15.4	
Japan	46.0	40.0	37.0	35.0	35.0	-6.6
Growth (%)	24.3	-13.0	-7.5	-5.4	0	
Europe	8.0	5.0	5.0	5.0	5.0	-11.1
Growth (%)	60.0	-37.5	0	0	0	
Asia/Pacific-ROW	0	0	6.0	7.0	7.0	NM
Growth (%)	NM	NM	NM	16.7	0	
Worldwide	134.0	115.0	120.0	125.0	137.0	0.6
Growth (%)	8.1	-14.2	4.3	4.2	9.6	

*Includes prime, virgin test, and monitor wafers
NM = Not meaningful
Source: Dataquest (June 1995)

Table 2-5
Shipments of Merchant Silicon Wafers* to Each Region, 1990-1994 (Millions of Square Inches)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
North America	472.1	451.0	450.8	487.5	551.9	4.0
Growth (%)	12.9	-4.5	0	8.1	13.2	
Japan	853.0	894.5	848.8	1,003.3	1,125.2	7.2
Growth (%)	7.6	4.9	-5.1	18.2	12.1	
Europe	208.5	184.2	206.1	250.1	291.7	8.8
Growth (%)	-0.1	-11.7	11.9	21.3	16.6	
Asia/Pacific-ROW	176.2	181.5	222.5	291.2	429.5	25.0
Growth (%)	40.5	3.0	22.6	30.9	47.5	
Worldwide	1,709.8	1,711.2	1,728.2	2,032.1	2,398.3	8.8
Growth (%)	10.7	0.1	1.0	17.6	18.0	

*Includes prime, virgin test and monitor wafers

Source: Dataquest (June 1995)

Table 2-6
Shipments of Merchant Test and Monitor Wafers to Each Region, 1990-1994 (Millions of Square Inches)

	1990	1991	1992	1993	1994
North America	94.4	90.2	90.2	102.4	121.4
Japan	170.6	178.9	169.8	203.2	230.7
Europe	41.7	36.8	41.2	50.0	61.3
Asia/Pacific-ROW	35.2	36.3	44.5	59.7	92.3
Worldwide	342.0	342.2	345.6	415.3	505.7
Growth (%)	10.7	0.1	1.0	20.1	21.8

Source: Dataquest (June 1995)

Section 3. Historical Wafer Size Distribution by Region, 1990-1994

Table 3-1
Worldwide Wafer Size Distribution, 1987-1994
(Percent Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (sq.in.)	1987	1988	1989	1990	1991	1992	1993	1994
Percent Square Inches by Diameter									
2 inches	3.14	0.5	0.4	0.3	0.3	0.2	0.2	0.1	0.1
3 inches	7.07	3.5	3.0	3.7	3.0	2.5	2.1	1.6	1.4
100mm	12.17	30.1	28.0	26.1	23.4	20.3	18.7	16.1	14.8
125mm	19.02	45.1	43.4	40.0	37.4	34.8	33.0	28.8	24.7
150mm	27.38	20.5	24.4	29.1	34.2	39.7	43.3	49.6	48.0
200mm	48.67	0.3	0.8	0.9	1.7	2.4	2.7	3.6	11.0
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total - MSI		1,354	1,603	1,856	2,048	2,046	2,097	2,450	2,919
Growth (%)		6.9	18.5	15.7	10.4	-0.1	2.5	16.8	19.2
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 inches	3.14	2.3	2.3	1.6	1.7	1.5	1.0	1.0	1.1
3 inches	7.07	6.7	6.9	9.8	8.8	7.3	6.3	5.6	5.7
100mm	12.17	33.5	36.9	39.8	39.3	34.1	32.3	32.5	35.5
125mm	19.02	32.1	36.5	39.0	40.3	37.5	36.3	37.1	37.9
150mm	27.38	10.1	14.3	19.7	25.6	29.7	33.2	44.4	51.2
200mm	48.67	0.1	0.3	0.3	0.7	1.0	1.2	1.8	6.6
Total Wafers (M)		84.8	97.1	110.2	116.4	111.1	110.3	122.5	138.0
Avg Wafer Diam (")		4.51	4.58	4.63	4.73	4.84	4.92	5.05	5.19

Source: Dataquest (June 1995)

Table 3-2
North American Wafer Size Distribution, 1987-1994
(Percent Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (sq.in.)	1987	1988	1989	1990	1991	1992	1993	1994
Percent Square Inches by Diameter									
2 inches	3.14	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
3 inches	7.07	3.3	2.2	3.2	1.8	1.5	1.3	1.2	1.1
100mm	12.17	36.3	33.4	31.6	28.8	26.8	26.3	22.4	20.1
125mm	19.02	40.1	41.9	36.7	35.4	32.5	31.9	26.5	21.7
150mm	27.38	19.4	20.7	26.9	30.5	35.6	36.5	44.0	42.2
200mm	48.67	0.7	1.7	1.5	3.4	3.5	3.9	5.8	14.8
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total - MSI		442	546	582	640	605	651	720	832
Growth (%)		8.9	23.7	6.5	10.0	-5.5	7.6	10.6	15.6
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 inches	3.14	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3
3 inches	7.07	2.1	1.7	2.6	1.6	1.3	1.2	1.2	1.3
100mm	12.17	13.2	15.0	15.1	15.2	13.3	14.1	13.3	13.7
125mm	19.02	9.3	12.0	11.2	11.9	10.3	10.9	10.0	9.5
150mm	27.38	3.1	4.1	5.7	7.1	7.9	8.7	11.6	12.8
200mm	48.67	0.1	0.2	0.2	0.4	0.4	0.5	0.9	2.5
Total Wafers (M)		27.9	33.2	35.1	36.5	33.4	35.6	37.2	40.2
Avg Wafer Diam (")		4.49	4.58	4.60	4.73	4.80	4.83	4.97	5.14

Source: Dataquest (June 1995)

Table 3-3
Japan Wafer Size Distribution, 1987-1994
(Percent Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (sq.in.)	1987	1988	1989	1990	1991	1992	1993	1994
Percent Square Inches by Diameter									
2 inches	3.14	0.2	0.1	0.1	0.1	0.1	0	0	0
3 inches	7.07	2.8	2.8	2.6	2.3	2.0	1.7	1.5	1.4
100mm	12.17	22.4	21.4	20.2	17.9	15.6	13.2	11.5	10.8
125mm	19.02	53.0	48.1	46.5	42.9	39.3	36.7	32.2	29.9
150mm	27.38	21.5	27.4	30.3	36.4	41.6	46.9	53.3	51.6
200mm	48.67	0.1	0.2	0.3	0.5	1.5	1.5	1.5	6.3
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total - MSI		670	777	913	992	1,039	973	1,127	1,280
Growth (%)		4.4	16.0	17.5	8.7	4.7	-6.3	15.9	13.5
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 inches	3.14	0.4	0.2	0.3	0.3	0.3	0	0	0
3 inches	7.07	2.7	3.1	3.4	3.2	2.9	2.3	2.4	2.5
100mm	12.17	12.3	13.7	15.2	14.6	13.3	10.6	10.7	11.4
125mm	19.02	18.7	19.6	22.3	22.4	21.5	18.8	19.1	20.1
150mm	27.38	5.3	7.8	10.1	13.2	15.8	16.7	21.9	24.1
200mm	48.67	0	0	0.1	0.1	0.3	0.3	0.3	1.7
Total Wafers (M)		39.4	44.4	51.3	53.8	54.1	48.6	54.4	59.8
Avg Wafer Diam (")		4.66	4.72	4.76	4.85	4.94	5.05	5.14	5.22

Source: Dataquest (June 1995)

Table 3-4
European Wafer Size Distribution, 1987-1994
(Percent Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (sq.in.)	1987	1988	1989	1990	1991	1992	1993	1994
Percent Square Inches by Diameter									
2 inches	3.14	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.1
3 inches	7.07	5.9	5.0	4.3	3.7	3.1	2.5	1.7	0.7
100mm	12.17	44.9	40.1	35.9	32.5	29.1	25.9	22.0	20.5
125mm	19.02	33.9	34.3	33.0	31.9	30.8	30.5	30.1	21.7
150mm	27.38	14.9	19.5	24.4	28.3	32.3	36.7	42.3	43.0
200mm	48.67	0	0.7	2.0	3.3	4.4	4.1	3.7	14.0
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total - MSI		172	196	231	235	212	235	291	351
Growth (%)		11.0	14.0	17.9	1.7	-9.7	10.7	23.9	20.6
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 inches	3.14	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.1
3 inches	7.07	1.4	1.4	1.4	1.2	0.9	0.8	0.7	0.3
100mm	12.17	6.3	6.5	6.8	6.3	5.1	5.0	5.3	5.9
125mm	19.02	3.1	3.5	4.0	3.9	3.4	3.8	4.6	4.0
150mm	27.38	0.9	1.4	2.1	2.4	2.5	3.1	4.5	5.5
200mm	48.67	0	0	0.1	0.2	0.2	0.2	0.2	1.0
Total Wafers (M)		12.0	13.1	14.7	14.3	12.3	13.2	15.5	16.9
Avg Wafer Diam (")		4.27	4.37	4.48	4.58	4.68	4.77	4.89	5.14

Source: Dataquest (June 1995)

Table 3-5
Asia/Pacific-ROW Wafer Size Distribution, 1987-1994
(Percent Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (sq.in.)	1987	1988	1989	1990	1991	1992	1993	1994
Percent Square Inches by Diameter									
2 inches	3.14	7.0	6.0	2.0	1.6	1.2	0.8	0.6	0.5
3 inches	7.07	6.0	6.0	13.0	10.5	8.1	5.6	2.9	2.4
100mm	12.17	28.0	25.5	25.1	22.1	15.5	13.7	13.0	12.0
125mm	19.02	28.0	30.0	21.2	21.8	22.4	23.1	20.8	17.8
150mm	27.38	31.0	32.5	38.7	43.3	51.0	54.1	56.3	52.3
200mm	48.67	0	0	0	0.7	1.8	2.7	6.4	15.0
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total - MSI		70	84	130	181	190	238	311	456
Growth (%)		9.4	20.0	54.8	39.2	4.9	25.4	30.8	46.5
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 inches	3.14	1.6	1.6	0.8	0.9	0.7	0.6	0.6	0.7
3 inches	7.07	0.6	0.7	2.4	2.7	2.2	1.9	1.3	1.5
100mm	12.17	1.6	1.8	2.7	3.3	2.4	2.7	3.3	4.5
125mm	19.02	1.0	1.3	1.4	2.1	2.2	2.9	3.4	4.3
150mm	27.38	0.8	1.0	1.8	2.9	3.5	4.7	6.4	8.7
200mm	48.67	0	0	0	0	0.1	0.1	0.4	1.4
Total Wafers (M)		5.6	6.4	9.2	11.9	11.2	12.9	15.4	21.2
Avg Wafer Diam (")		3.99	4.09	4.24	4.41	4.65	4.85	5.07	5.24

Source: Dataquest (June 1995)

Section 4. Historical Market Share by Company, by Region, and by Product, 1990-1994

Table 4-1
Top 15 Merchant Silicon and Epitaxial Wafer Manufacturing Companies Comparison of 1994 and 1993 Ranking by Worldwide Revenue (End-User Revenue in Millions of U.S. Dollars)

	1994	1994 Rank	1993	1993 Rank	Percent Change
All Companies	4,591.9		3,554.3		29
Shin-Etsu Handotai	1,174.3	1	895.7	1	31
MEMC Electronic Materials + Joint Ventures	757.6	2	569.8	2	33
Sumitomo SiTix	582.4	3	443.6	3	31
Wacker Chemitronic + Siltronic	500.4	4	401.2	4	25
Mitsubishi Materials Silicon	475.2	5	363.6	6	31
Komatsu Electronic Metals	452.9	6	377.3	5	20
Toshiba Ceramics	275.0	7	209.1	7	32
Nittetsu Denshi	105.8	8	84.5	8	25
Lucky Advanced Materials Inc.	89.8	9	61.0	9	47
UniSil Corp.	40.0	10	22.3	10	79
Showa Denko	20.7	11	16.4	13	26
Topsil	20.1	12	18.5	11	9
Okmetic	19.0	13	16.7	12	14
Crysteco Inc.	17.9	14	14.8	14	21
Episil	15.7	15	13.1	15	20
All Other Companies	45.1		46.7		-3

Source: Dataquest (June 1995)

Table 4-2
Each Company's Revenue from Shipments of Merchant Silicon Wafers* and Epitaxial Wafers to the World, 1990-1994 (End-User Revenue in Millions of U.S. Dollars)

Company	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
United States-Based Companies						
Crysteco	14.1	16.8	16.3	14.8	17.9	
Epitaxy Inc.	10.7	10.7	10.6	12.5	14.8	
Unisil	12.5	16.6	17.6	22.3	40.0	
Other U.S. Companies	22.6	11.9	13.1	16.5	20.0	
Total	59.9	56.0	57.6	66.1	92.7	11.5
Japan-Based Companies						
Kawatec	11.0	11.3	13.9	8.7	0.0	
Komatsu Electronic Metals	279.0	332.6	317.8	377.3	452.9	
Mitsubishi Materials Silicon	317.4	326.4	306.5	363.6	475.2	
NSC Electron Corporation	32.0	56.4	72.0	84.5	105.8	
Sumitomo SiTix Silicon[1]	348.1	382.1	370.9	443.6	582.4	
Shin-Etsu Handotai	691.5	768.5	780.4	895.7	1,174.3	
Showa Denko	10.2	11.9	13.9	16.4	20.7	
Toshiba Ceramics	129.7	148.2	140.7	209.1	275.0	
Total	1,818.9	2,037.4	2,016.1	2,398.9	3,086.3	14.1
Europe-Based Companies						
MEMC Electronic Materials[2]	410.9	446.6	483.7	552.5	660.8	
Okmetic	5.0	4.5	5.9	16.7	19.0	
Topsil	15.5	19.5	17.3	18.5	20.1	
Wacker	313.6	295.9	337.3	401.2	500.4	
Other European Companies	1.4	2.0	2.0	2.2	2.6	
Total	746.4	768.5	846.2	991.1	1,202.9	12.7
ROW-Based Companies						
Episil	3.0	3.2	11.2	13.1	15.7	
Posco-Huls	0	0	0	17.3	96.8	
Siltron	26.2	35.4	48.1	61.0	89.8	
Other ROW Companies	10.0	12.5	12.2	6.8	7.7	
Total	39.2	51.1	71.5	98.2	210.0	52.1
Total Sales—World	2,664.4	2,913.0	2,991.4	3,554.3	4,591.9	14.6

*Includes prime, test, and monitor wafers

[1]U.S. Semiconductor included from 1987 onward; Cincinnati Milacron included from 1989 onward

[2]Monsanto Electronic Materials included from 1989 onward; DNS Electronic Materials included from 1989 onward; Kawatec included from 1994 onward

Source: Dataquest (June 1995)

Table 4-3
Each Company's Revenue from Shipments of Merchant Silicon Wafers* to the World, 1990-1994 (End-User Revenue in Millions of U.S. Dollars)

Company	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
United States-Based Companies						
Crysteco	14.1	16.8	16.3	14.8	17.9	
Epitaxy Inc.	0	0	0	0	0	
Unisil	12.5	16.6	17.6	22.3	40.0	
Other U.S. Companies	14.1	5.6	4.5	4.9	5.9	
Total	40.7	39.0	38.4	42.0	63.8	11.9
Japan-Based Companies						
Kawatec	10.7	10.3	11.3	5.5	0.0	
Komatsu Electronic Metals	225.2	261.9	258.5	295.4	343.1	
Mitsubishi Materials Silicon	227.2	233.0	218.9	282.1	342.2	
NSC Electron Corporation	32.0	56.4	72.0	84.5	105.8	
Sumitomo SiTix Silicon[1]	272.7	283.0	265.4	307.5	373.0	
Shin-Etsu Handotai	499.9	554.6	562.3	643.1	882.0	
Showa Denko	10.2	11.9	13.9	16.2	19.6	
Toshiba Ceramics	80.8	90.7	91.9	151.2	203.3	
Total	1,358.7	1,501.8	1,494.2	1,785.5	2,269.0	13.7
Europe-Based Companies						
MEMC Electronic Materials[2]	320.9	346.5	373.8	403.1	440.5	
Okmetic	5.0	4.5	5.9	16.7	19.0	
Topsil	15.5	19.5	17.3	18.5	20.1	
Wacker	220.3	217.4	214.8	224.1	270.3	
Other European Companies	1.4	2.0	2.0	2.2	2.6	
Total	563.1	589.9	613.8	664.6	752.5	7.5
ROW-Based Companies						
Episil	0	0	0	0	0	
Posco-Huls	0	0	0	17.3	96.8	
Siltron	26.2	35.4	48.1	61.0	89.8	
Other ROW Companies	10.0	12.5	12.2	6.8	7.7	
Total	36.2	47.9	60.3	85.1	194.3	52.2
Total Sales—World	1,998.7	2,178.6	2,206.7	2,577.2	3,279.6	13.2

*Includes prime, test, and monitor wafers
[1]U.S. Semiconductor included from 1987 onward; Cincinnati Milacron included from 1989 onward
[2]Monsanto Electronic Materials included from 1989 onward; DNS Electronic Materials included from 1989 onward; Kawatec included from 1994 onward
Source: Dataquest (June 1995)

Table 4-4
Each Company's Revenue from Shipments of Merchant Epitaxial Wafers to the World, 1990-1994 (End-User Revenue in Millions of U.S. Dollars)

Company	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
United States-Based Companies						
Crysteco	0	0	0	0	0	
Epitaxy Inc.	10.7	10.7	10.6	12.5	14.8	
Unisil	0	0	0	0	0	
Other U.S. Companies	8.5	6.3	8.6	11.6	14.1	
Total	19.2	17.0	19.2	24.1	28.9	10.8
Japan-Based Companies						
Kawatec	0.3	1.0	2.6	3.2	0.0	
Komatsu Electronic Metals	53.8	70.7	59.3	81.9	109.8	
Mitsubishi Materials Silicon	90.2	93.4	87.6	81.5	133.0	
NSC Electron Corporation	0	0	0	0	0	
Sumitomo SiTix Silicon[1]	75.4	99.1	105.5	136.1	209.4	29.1
Shin-Etsu Handotai	191.6	213.9	218.1	252.6	292.3	
Showa Denko	0	0	0	0.2	1.1	
Toshiba Ceramics	48.9	57.5	48.8	57.9	71.7	
Total	460.2	535.6	521.9	613.4	817.3	
Europe-Based Companies						
MEMC Electronic Materials[2]	90.0	100.1	109.9	149.4	220.3	
Okmetic	0	0	0	0	0	
Topsil	0	0	0	0	0	
Wacker	93.3	78.5	122.5	177.1	230.1	
Other European Companies	0.0	0.0	0.0	0.0	0.0	
Total	183.3	178.6	232.4	326.5	450.4	25.2
ROW-Based Companies						
Episil	3.0	3.2	11.2	13.1	15.7	
Posco-Huls	0	0	0	0	0	
Siltron	0	0	0	0	0	
Other ROW Companies	0	0	0	0	0	
Total	3.0	3.2	11.2	13.1	15.7	51.2
Total Sales—World	665.7	734.4	784.7	977.1	1,312.3	18.5

[1]U.S. Semiconductor included from 1987 onward; Cincinnati Milacron included from 1989 onward
[2]Monsanto Electronic Materials included from 1989 ononic Materials included from 1989 onward; Kawatec included from 1994 onward
Source: Dataquest (June 1995)

Table 4-5
Each Company's Revenue from Shipments of Merchant Silicon Wafers* and Epitaxial Wafers to North America, 1990-1994 (End-User Revenue in Millions of U.S. Dollars)

Company	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
United States-Based Companies						
Crysteco	11.0	13.6	11.4	11.3	13.6	
Epitaxy Inc.	4.7	4.7	5.2	5.9	7.0	
Unisil	12.5	13.9	14.8	15.6	29.9	
Other U.S. Companies	21.2	10.5	11.8	13.9	16.5	
Total	49.4	42.7	43.2	46.7	67.0	7.9
Japan-Based Companies						
Kawatec	5.7	5.8	9.8	4.3	0	
Komatsu Electronic Metals	7.0	7.5	8.4	20.7	33.7	
Mitsubishi Materials Silicon	55.0	55.7	69.6	81.9	101.2	
NSC Electron Corporation	0	0	0	0	0	
Sumitomo SiTix Silicon[1]	66.9	69.5	96.3	127.4	182.8	
Shin-Etsu Handotai	138.5	161.9	193.0	224.8	280.0	
Showa Denko	0	0	0	0	0	
Toshiba Ceramics	0	0	0	0	0	
Total	273.1	300.4	377.1	459.1	597.7	21.6
Europe-Based Companies						
MEMC Electronic Materials[2]	199.0	201.6	202.6	215.8	264.7	
Okmetic	0	0	0	0	1.1	
Topsil	2.8	2.8	2.2	2.4	2.6	
Wacker	152.0	126.8	143.0	180.0	205.0	
Other European Companies	0	0	0	0	0	
Total	353.8	331.2	347.8	398.2	473.4	7.6
ROW-Based Companies						
Episil	0	0	0	0	0	
Posco-Huls	0	0	0	0	0	
Siltron	0.5	0.5	3.0	4.5	5.8	
Other ROW Companies	0	0	0	0	0.1	
Total	0.5	0.5	3.0	4.5	5.9	85.3
Total Sales—North America	676.8	674.8	777.1	908.5	1,144.0	14.0

*Includes prime, test, and monitor wafers
[1]U.S. Semiconductor included from 1987 onward; Cincinnati Milacron included from 1989 onward
[2]Monsanto Electronic Materials included from 1989 onward; DNS Electronic Materials included from 1989 onward; Kawatec included from 1994 onward
Source: Dataquest (June 1995)

Table 4-6
Each Company's Revenue from Shipments of Merchant Silicon Wafers* to North America, 1990-1994 (End-User Revenue in Millions of U.S. Dollars)

Company	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
United States-Based Companies						
Crysteco	11.0	13.6	11.4	11.3	13.6	
Epitaxy Inc.	0	0	0	0	0	
Unisil	12.5	13.9	14.8	15.6	29.9	
Other U.S. Companies	13.7	5.2	4.1	4.5	5.4	
Total	37.2	32.7	30.3	31.4	48.9	7.1
Japan-Based Companies						
Kawatec	5.4	4.8	7.4	1.3	0	
Komatsu Electronic Metals	5.6	4.7	5.2	18.5	29.1	
Mitsubishi Materials Silicon	47.8	44.6	49.8	58.5	56.6	
NSC Electron Corporation	0	0	0	0	0	
Sumitomo SiTix Silicon[1]	18.0	19.4	30.8	43.2	69.7	
Shin-Etsu Handotai	86.7	98.8	115.5	134.9	167.0	
Showa Denko	0	0	0	0	0	
Toshiba Ceramics	0	0	0	0	0	
Total	163.5	172.3	208.7	256.4	322.4	18.5
Europe-Based Companies						
MEMC Electronic Materials[2]	137.0	135.4	129.8	120.2	130.8	
Okmetic	0	0	0	0	1.1	
Topsil	2.8	2.8	2.2	2.4	2.6	
Wacker	90.0	88.0	67.0	74.0	82.0	
Other European Companies	0	0	0	0	0	
Total	229.8	226.2	199.0	196.6	216.5	-1.5
ROW-Based Companies						
Episil	0	0	0	0	0	
Posco-Huls	0	0	0	0	0	
Siltron	0.5	0.5	3.0	4.5	5.8	
Other ROW Companies	0	0	0	0	0.1	
Total	0.5	0.5	3.0	4.5	5.9	85.3
Total Sales—North America	431.0	431.7	441.0	488.9	593.7	8.3

*Includes prime, test, and monitor wafers
[1]U.S. Semiconductor included from 1987 onward; Cincinnati Milacron included from 1989 onward
[2]Monsanto Electronic Materials included from 1989 onward; DNS Electronic Materials included from 1989 onward; Kawatec included from 1994 onward
Source: Dataquest (June 1995)

Table 4-7
Each Company's Revenue from Shipments of Merchant Epitaxial Wafers to North America, 1990-1994 (End-User Revenue in Millions of U.S. Dollars)

Company	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
United States-Based Companies						
Crysteco	0	0	0	0	0	
Epitaxy Inc.	4.7	4.7	5.2	5.9	7.0	
Unisil	0	0	0	0	0	
Other U.S. Companies	7.5	5.3	7.7	9.4	11.1	
Total	12.2	10.0	12.9	15.3	18.1	10.4
Japan-Based Companies						
Kawatec	0.3	1.0	2.4	3.0	0	
Komatsu Electronic Metals	1.4	2.8	3.2	2.2	4.6	
Mitsubishi Materials Silicon	7.2	11.1	19.8	23.4	44.6	
NSC Electron Corporation	0	0	0	0	0	
Sumitomo SiTix Silicon[1]	48.9	50.1	65.5	84.2	113.1	
Shin-Etsu Handotai	51.8	63.1	77.5	89.9	113.0	
Showa Denko	0	0	0	0	0	
Toshiba Ceramics	0	0	0	0	0	
Total	109.6	128.1	168.4	202.7	275.3	25.9
Europe-Based Companies						
MEMC Electronic Materials[2]	62.0	66.2	72.8	95.6	133.9	
Okmetic	0	0	0	0	0	
Topsil	0	0	0	0	0	
Wacker	62.0	38.8	76.0	106.0	123.0	
Other European Companies	0	0	0	0	0	
Total	124.0	105.0	148.8	201.6	256.9	20.0
ROW-Based Companies						
Episil	0	0	0	0	0	
Posco-Huls	0	0	0	0	0	
Siltron	0	0	0	0	0	
Other ROW Companies	0	0	0	0	0	
Total	0	0	0	0	0	
Total Sales—North America	245.8	243.1	330.1	419.6	550.3	22.3

[1]U.S. Semiconductor included from 1987 onward; Cincinnati Milacron included from 1989 onward
[2]Monsanto Electronic Materials included from 1989 onward; onic Materials included from 1989 onward; Kawatec included from 1994 onward
Source: Dataquest (June 1995)

Table 4-8
Each Company's Revenue from Shipments of Merchant Silicon Wafers* and Epitaxial Wafers to Japan, 1990-1994 (End-User Revenue in Millions of U.S. Dollars)

Company	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
United States-Based Companies						
Crysteco	0.8	0.8	1.0	0.6	0.8	
Epitaxy Inc.	0	0	0	0	0	
Unisil	0	0.1	0.1	0.5	1.2	
Other U.S. Companies	0	0	0	1.8	2.0	
Total	0.8	0.9	1.1	2.9	4.0	49.5
Japan-Based Companies						
Kawatec	2.1	2.7	2.6	3.0	0.0	
Komatsu Electronic Metals	265.0	318.3	302.0	352.5	408.2	
Mitsubishi Materials Silicon	258.0	267.3	233.3	260.8	328.8	
NSC Electron Corporation	32.0	56.4	72.0	84.5	103.1	
Sumitomo SiTix Silicon[1]	250.5	269.6	226.1	260.1	316.5	
Shin-Etsu Handotai	492.5	534.5	499.8	562.1	658.1	
Showa Denko	10.2	11.9	13.9	16.4	20.7	
Toshiba Ceramics	127.4	145.8	138.0	206.0	271.0	
Total	1,437.7	1,606.5	1,487.7	1,745.4	2,106.4	10.0
Europe-Based Companies						
MEMC Electronic Materials[2]	54.4	66.2	62.8	87.7	124.7	
Okmetic	0	0	0	0	0	
Topsil	6.0	8.5	7.2	7.5	7.8	
Wacker	30.0	39.7	31.1	31.7	41.2	
Other European Companies	0	0	0	0	0	
Total	90.4	114.4	101.1	126.9	173.7	17.7
ROW-Based Companies						
Episil	0	0	8.8	10.1	12.0	
Posco-Huls	0	0	0	0	0	
Siltron	0	0	0	0	0	
Other ROW Companies	0	0	4.0	2.6	0.1	
Total	0	0	12.8	12.7	12.1	
Total Sales—Japan	1,528.9	1,721.8	1,602.7	1,887.9	2,296.2	10.7

*Includes prime, test, and monitor wafers
[1]U.S. Semiconductor included from 1987 onward; Cincinnati Milacron included from 1989 onward
[2]Monsanto Electronic Materials included from 1989 ononic Materials included from 1989 onward; Kawatec included from 1994 onward
Source: Dataquest (June 1995)

Table 4-9
Each Company's Revenue from Shipments of Merchant Silicon Wafers* to Japan, 1990-1994 (End-User Revenue in Millions of U.S. Dollars)

Company	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
United States-Based Companies						
Crysteco	0.8	0.8	1.0	0.6	0.8	
Epitaxy Inc.	0	0	0	0	0	
Unisil	0	0.1	0.1	0.5	1.2	
Other U.S. Companies	0	0	0	0	0	
Total	0.8	0.9	1.1	1.1	2.0	25.7
Japan-Based Companies						
Kawatec	2.1	2.7	2.4	2.8	0	
Komatsu Electronic Metals	212.6	250.4	245.9	272.9	303.0	
Mitsubishi Materials Silicon	176.0	185.6	166.1	203.5	241.2	
NSC Electron Corporation	32.0	56.4	72.0	84.5	103.1	
Sumitomo SiTix Silicon[1]	227.0	236.1	200.8	224.6	250.9	
Shin-Etsu Handotai	355.5	387.1	363.8	404.7	486.2	
Showa Denko	10.2	11.9	13.9	16.2	19.6	
Toshiba Ceramics	80.0	89.9	89.6	148.2	199.3	
Total	1,095.4	1,220.1	1,154.5	1,357.4	1,603.3	10.0
Europe-Based Companies						
MEMC Electronic Materials[2]	51.5	63.3	59.4	76.4	108.4	
Okmetic	0	0	0	0	0	
Topsil	6.0	8.5	7.2	7.5	7.8	
Wacker	25.8	30.4	23.1	23.5	29.1	
Other European Companies	0	0	0	0	0	
Total	83.3	102.2	89.7	107.4	145.3	14.9
ROW-Based Companies						
Episil	0	0	0	0	0	
Posco-Huls	0	0	0	0	0	
Siltron	0	0	0	0	0	
Other ROW Companies	0	0	4.0	2.6	0.1	
Total	0	0	4.0	2.6	0.1	
Total Sales—Japan	1,179.5	1,323.2	1,249.3	1,468.5	1,750.7	10.4

*Includes prime, test, and monitor wafers
[1]U.S. Semiconductor included from 1987 onward; Cincinnati Milacron included from 1989 onward
[2]Monsanto Electronic Materials included from 1989 ond; DNS Electronic Materials included from 1989 onward; Kawatec included from 1994 onward
Source: Dataquest (June 1995)

Table 4-10
Each Company's Revenue from Shipments of Merchant Epitaxial Wafers to Japan, 1990-1994 (End-User Revenue in Millions of U.S. Dollars)

Company	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
United States-Based Companies						
Crysteco	0	0	0	0	0	
Epitaxy Inc.	0	0	0	0	0	
Unisil	0	0	0	0	0	
Other U.S. Companies	0	0	0	1.8	2.0	
Total	0	0	0	1.8	2.0	
Japan-Based Companies						
Kawatec	0	0	0.2	0.2	0	
Komatsu Electronic Metals	52.4	67.9	56.1	79.6	105.2	
Mitsubishi Materials Silicon	82.0	81.7	67.2	57.3	87.6	
NSC Electron Corporation	0	0	0	0	0	
Sumitomo SiTix Silicon[1]	23.5	33.5	25.3	35.5	65.6	
Shin-Etsu Handotai	137.0	147.4	136.0	157.4	171.9	
Showa Denko	0	0	0	0.2	1.1	
Toshiba Ceramics	47.4	55.9	48.4	57.8	71.7	
Total	342.3	386.4	333.2	388.0	503.1	10.1
Europe-Based Companies						
MEMC Electronic Materials[2]	2.9	2.9	3.4	11.3	16.3	
Okmetic	0	0	0	0	0	
Topsil	0	0	0	0	0	
Wacker	4.2	9.3	8.0	8.2	12.1	
Other European Companies	0	0	0	0	0	
Total	7.1	12.2	11.4	19.5	28.4	41.4
ROW-Based Companies						
Episil	0	0	8.8	10.1	12.0	
Posco-Huls	0	0	0	0	0	
Siltron	0	0	0	0	0	
Other ROW Companies	0	0	0	0	0	
Total	0	0	8.8	10.1	12.0	
Total Sales—Japan	349.4	398.6	353.4	419.4	545.5	11.8

[1]U.S. Semiconductor included from 1987 onward; Cincinnati Milacron included from 1989 onward
[2]Monsanto Electronic Materials included from 1989 onward; DNS Electronic Materials included from 1989 onward; Kawatec included from 1994 onward
Source: Dataquest (June 1995)

Table 4-11
Each Company's Revenue from Shipments of Merchant Silicon Wafers* and Epitaxial Wafers to Europe, 1990-1994 (End-User Revenue in Millions of U.S. Dollars)

Company	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
United States-Based Companies						
Crysteco	2.3	2.4	3.3	1.9	3.3	
Epitaxy Inc.	0.9	0.9	0.7	0.9	1.0	
Unisil	0	0.1	0.2	2.3	3.6	
Other U.S. Companies	0.9	0.9	0.7	0.6	0.7	
Total	4.1	4.3	4.9	5.7	8.6	20.3
Japan-Based Companies						
Kawatec	0	0	0	0	0	
Komatsu Electronic Metals	7.0	6.8	7.4	2.7	3.4	
Mitsubishi Materials Silicon	2.6	1.5	1.6	1.7	2.0	
NSC Electron Corporation	0	0	0	0	0	
Sumitomo SiTix Silicon[1]	24.3	30.5	30.2	31.2	51.6	
Shin-Etsu Handotai	23.5	29.8	43.8	54.5	88.2	
Showa Denko	0	0	0	0	0	
Toshiba Ceramics	0	0	0	0	0	
Total	57.4	68.6	83.0	90.1	145.2	26.1
Europe-Based Companies						
MEMC Electronic Materials[2]	103.7	101.8	103.9	116.4	159.8	
Okmetic	4.3	4.0	5.4	11.1	12.9	
Topsil	5.2	6.3	5.7	6.0	6.5	
Wacker	105.7	105.7	131.3	150.0	205.0	
Other European Companies	1.4	2.0	2.0	2.2	2.6	
Total	220.3	219.8	248.3	285.7	386.8	15.1
ROW-Based Companies						
Episil	0	0	0	0	0.9	
Posco-Huls	0	0	0	0	0	
Siltron	0	0	0	0	0	
Other ROW Companies	0	0	0	0	0	
Total	0	0	0	0	0.9	
Total Sales—Europe	281.8	292.7	336.2	381.5	541.5	17.7

*Includes prime, test, and monitor wafers
[1]U.S. Semiconductor included from 1987 onward; Cincinnati Milacron included from 1989 onward
[2]Monsanto Electronic Materials included from 1989 onward; DNS Electronic Materials included from 1989 onward; Kawatec included from 1994 onward
Source: Dataquest (June 1995)

Table 4-12
Each Company's Revenue from Shipments of Merchant Silicon Wafers* to Europe, 1990-1994 (End-User Revenue in Millions of U.S. Dollars)

Company	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
United States-Based Companies						
Crysteco	2.3	2.4	3.3	1.9	3.3	
Epitaxy Inc.	0	0	0	0	0	
Unisil	0	0.1	0.2	2.3	3.6	
Other U.S. Companies	0.2	0.2	0.2	0.2	0.2	
Total	2.5	2.7	3.7	4.4	7.1	29.8
Japan-Based Companies						
Kawatec	0	0	0	0	0	
Komatsu Electronic Metals	7.0	6.8	7.4	2.7	3.4	
Mitsubishi Materials Silicon	1.8	1.1	1.2	1.3	1.5	
NSC Electron Corporation	0	0	0	0	0	
Sumitomo SiTix Silicon[1]	22.0	20.4	21.7	23.1	33.4	
Shin-Etsu Handotai	21.0	26.7	39.5	49.5	81.5	
Showa Denko	0	0	0	0	0	
Toshiba Ceramics	0	0	0	0	0	
Total	51.8	55.0	69.8	76.6	119.8	23.3
Europe-Based Companies						
MEMC Electronic Materials[2]	79.4	75.3	76.4	81.5	100.7	
Okmetic	4.3	4.0	5.4	11.1	12.9	
Topsil	5.2	6.3	5.7	6.0	6.5	
Wacker	80.0	78.6	97.2	96.0	123.0	
Other European Companies	1.4	2.0	2.0	2.2	2.6	
Total	170.3	166.2	186.7	196.8	245.7	9.6
ROW-Based Companies						
Episil	0	0	0	0	0	
Posco-Huls	0	0	0	0	0	
Siltron	0	0	0	0	0	
Other ROW Companies	0	0	0	0	0	
Total	0	0	0	0	0	
Total Sales—Europe	224.6	223.9	260.2	277.8	372.6	13.5

*Includes prime, test, and monitor wafers
[1]U.S. Semiconductor included from 1987 onward; Cincinnati Milacron included from 1989 onward
[2]Monsanto Electronic Materials included from 1989 onward; DNS Electronic Materials included from 1989 onward; Kawatec included from 1994 onward
Source: Dataquest (June 1995)

Table 4-13
Each Company's Revenue from Shipments of Merchant Epitaxial Wafers to Europe, 1990-1994 (End-User Revenue in Millions of U.S. Dollars)

Company	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
United States-Based Companies						
Crysteco	0	0	0	0	0	
Epitaxy Inc.	0.9	0.9	0.7	0.9	1.0	
Unisil	0	0	0	0	0	
Other U.S. Companies	0.7	0.7	0.5	0.4	0.5	
Total	1.6	1.6	1.2	1.3	1.5	-1.6
Japan-Based Companies						
Kawatec	0	0	0	0	0	
Komatsu Electronic Metals	0	0	0	0	0	
Mitsubishi Materials Silicon	0.8	0.4	0.4	0.4	0.5	
NSC Electron Corporation	0	0	0	0	0	
Sumitomo SiTix Silicon[1]	2.3	10.1	8.5	8.1	18.2	
Shin-Etsu Handotai	2.5	3.1	4.3	5.0	6.7	
Showa Denko	0	0	0	0	0	
Toshiba Ceramics	0	0	0	0	0	
Total	5.6	13.6	13.2	13.5	25.4	45.9
Europe-Based Companies						
MEMC Electronic Materials[2]	24.3	26.5	27.5	34.9	59.1	
Okmetic	0	0	0	0	0	
Topsil	0	0	0	0	0	
Wacker	25.7	27.1	34.1	54.0	82.0	
Other European Companies	0	0	0	0	0	
Total	50.0	53.6	61.6	88.9	141.1	29.6
ROW-Based Companies						
Episil	0	0	0	0	0.9	
Posco-Huls	0	0	0	0	0	
Siltron	0	0	0	0	0	
Other ROW Companies	0	0	0	0	0	
Total	0	0	0	0	0.9	
Total Sales—Europe	57.2	68.8	76.0	103.7	168.9	31.1

[1]U.S. Semiconductor included from 1987 onward; Cincinnati Milacron included from 1989 onward
[2]Monsanto Electronic Materials included from 1989 onward; DNS Electronic Materials included from 1989 onward; Kawatec included from 1994 onward
Source: Dataquest (June 1995)

Table 4-14
Each Company's Revenue from Shipments of Merchant Silicon Wafers* and Epitaxial Wafers to Asia/Pacific-ROW, 1990-1994
(End-User Revenue in Millions of U.S. Dollars)

Company	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
United States-Based Companies						
Crysteco	0	0	0.6	1.0	0.2	
Epitaxy Inc.	5.1	5.1	4.7	5.7	6.8	
Unisil	0.0	2.5	2.5	3.9	5.3	
Other U.S. Companies	0.5	0.5	0.6	0.2	0.8	
Total	5.6	8.1	8.4	10.8	13.1	23.7
Japan-Based Companies						
Kawatec	3.2	2.8	1.5	1.4	0.0	
Komatsu Electronic Metals	0	0	0	1.4	7.6	
Mitsubishi Materials Silicon	1.8	1.9	2.0	19.2	43.2	
NSC Electron Corporation	0	0	0	0	2.7	
Sumitomo SiTix Silicon[1]	6.4	12.5	18.3	24.9	31.5	
Shin-Etsu Handotai	37.0	42.3	43.8	54.3	148.0	
Showa Denko	0	0	0	0	0	
Toshiba Ceramics	2.3	2.4	2.7	3.1	4.0	
Total	50.7	61.9	68.3	104.3	237.0	47.0
Europe-Based Companies						
MEMC Electronic Materials[2]	53.8	77.0	114.4	132.6	111.6	
Okmetic	0.7	0.5	0.5	5.6	5.0	
Topsil	1.5	1.9	2.2	2.6	3.2	
Wacker	25.9	23.7	31.9	39.5	49.2	
Other European Companies	0	0	0	0	0	
Total	81.9	103.1	149.0	180.3	169.0	19.9
ROW-Based Companies						
Episil	3.0	3.2	2.4	3.0	2.8	
Posco-Huls	0	0	0	17.3	96.8	
Siltron	25.7	34.9	45.1	56.5	84.0	
Other ROW Companies	10.0	12.5	8.2	4.2	7.5	
Total	38.7	50.6	55.7	81.0	191.1	49.1
Total Sales—Asia/Pacific-ROW	176.9	223.7	281.4	376.4	610.2	36.3

*Includes prime, test, and monitor wafers

[1] U.S. Semiconductor included from 1987 onward; Cincinnati Milacron included from 1989 onward

[2] Monsanto Electronic Materials included from 1989 onward; DNS Electronic Materials included from 1989 onward; Kawatec included from 1994 onward

Source: Dataquest (June 1995)

Table 4-15
Each Company's Revenue from Shipments of Merchant Silicon Wafers* to Asia/Pacific-ROW, 1990-1994 (End-User Revenue in Millions of U.S. Dollars)

Company	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
United States-Based Companies						
Crysteco	0	0	0.6	1.0	0.2	
Epitaxy Inc.	0	0	0	0	0	
Unisil	0	2.5	2.5	3.9	5.3	
Other U.S. Companies	0.2	0.2	0.2	0.2	0.3	
Total	0.2	2.7	3.3	5.1	5.8	132.1
Japan-Based Companies						
Kawatec	3.2	2.8	1.5	1.4	0	
Komatsu Electronic Metals	0	0	0	1.3	7.6	
Mitsubishi Materials Silicon	1.6	1.7	1.8	18.8	42.9	
NSC Electron Corporation	0	0	0	0	2.7	
Sumitomo SiTix Silicon[1]	5.7	7.1	12.1	16.6	19.0	
Shin-Etsu Handotai	36.7	42.0	43.5	54.0	147.3	
Showa Denko	0	0	0	0	0	
Toshiba Ceramics	0.8	0.8	2.3	3.0	4.0	
Total	48.0	54.4	61.2	95.1	223.5	46.9
Europe-Based Companies						
MEMC Electronic Materials[2]	53.0	72.5	108.2	125.0	100.6	
Okmetic	0.7	0.5	0.5	5.6	5.0	
Topsil	1.5	1.9	2.2	2.6	3.2	
Wacker	24.5	20.4	27.5	30.6	36.2	
Other European Companies	0	0	0	0	0	
Total	79.7	95.3	138.4	163.8	145.0	16.1
ROW-Based Companies						
Episil	0	0	0	0	0	
Posco-Huls	0	0	0	17.3	96.8	
Siltron	25.7	34.9	45.1	56.5	84.0	
Other ROW Companies	10.0	12.5	8.2	4.2	7.5	
Total	35.7	47.4	53.3	78.0	188.3	51.5
Total Sales—Asia/Pacific-ROW	163.6	199.8	256.2	342.0	562.6	36.2

*Includes prime, test, and monitor wafers
[1]U.S. Semiconductor included from 1987 onward; Cincinnati Milacron included from 1989 onward
[2]Monsanto Electronic Materials included from 1989 onward; DNS Electronic Materials included from 1989 onward; Kawatec included from 1994 onward
Source: Dataquest (June 1995)

Table 4-16
Each Company's Revenue from Shipments of Merchant Epitaxial Wafers to Asia/Pacific-ROW, 1990-1994 (End-User Revenue in Millions of U.S. Dollars)

Company	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
United States-Based Companies						
Crysteco	0	0	0	0	0	
Epitaxy Inc.	5.1	5.1	4.7	5.7	6.8	
Unisil	0	0	0	0	0	
Other U.S. Companies	0.3	0.3	0.4	0	0.5	
Total	5.4	5.4	5.1	5.7	7.3	7.8
Japan-Based Companies						
Kawatec	0	0	0	0	0	
Komatsu Electronic Metals	0	0	0	0.1	0	
Mitsubishi Materials Silicon	0.2	0.2	0.2	0.4	0.3	
NSC Electron Corporation	0	0	0	0	0	
Sumitomo SiTix Silicon[1]	0.7	5.4	6.2	8.3	12.5	
Shin-Etsu Handotai	0.3	0.3	0.3	0.3	0.7	
Showa Denko	0	0	0	0	0	
Toshiba Ceramics	1.5	1.6	0.4	0.1	0	
Total	2.7	7.5	7.1	9.2	13.5	49.5
Europe-Based Companies						
MEMC Electronic Materials[2]	0.8	4.5	6.2	7.6	11.0	
Okmetic	0	0	0	0	0	
Topsil	0	0	0	0	0	
Wacker	1.4	3.3	4.4	8.9	13.0	
Other European Companies	0	0	0	0	0	
Total	2.2	7.8	10.6	16.5	24.0	81.7
ROW-Based Companies						
Episil	3.0	3.2	2.4	3.0	2.8	
Posco-Huls	0	0	0	0	0	
Siltron	0	0	0	0	0	
Other ROW Companies	0	0	0	0	0	
Total	3.0	3.2	2.4	3.0	2.8	-1.7
Total Sales—Asia/Pacific-ROW	13.3	23.9	25.2	34.4	47.6	37.5

[1] U.S. Semiconductor included from 1987 onward; Cincinnati Milacron included from 1989 onward
[2] Monsanto Electronic Materials included from 1989 onward DNS Electronic Materials included from 1989 onward; Kawatec included from 1994 onward
Source: Dataquest (June 1995)

Section 5. Wafer Pricing

Dataquest conducts a survey of the average polished and epitaxial wafer prices during the first calendar quarter each year. The survey covers pricing trends in the United States, Europe, Japan, Korea, and Taiwan and is a direct survey of wafer suppliers and brokers, both formal and informal. The raw data is averaged by region and provides part of the correlation among silicon wafer revenue, size distribution, and silicon area consumption.

Tables 5-1 and 5-2 represent the average prices used for regional prime, test, and epitaxial wafers for five different wafer sizes where available. These prices *should not be used as a benchmark* for price comparisons among suppliers.

Wafer pricing is a complex process involving many specifications and variables. In addition, our survey methodology is strict enough only to gauge approximate values and trends for use as a research tool and guideline. In past publications of the market share estimates, Dataquest has published the results of the current year's survey (in this case first quarter, 1995). To prevent their use as a benchmark for price comparisons, we have decided to delay the publication of these results until next year's database update.

Table 5-1
Regional Average Selling Price of Polished and Epitaxial Wafers, at Start of Year 1990-1994 Price per Wafer (U.S. Dollars and Japanese Yen)

Wafer Diameter	Area (square inches)	1990	1991	1992	1993	1994
North America: polished CZ ($)						
3-inch	7.07	7.25	7.10	7.04	7.04	7.04
100mm	12.17	9.98	9.96	10.47	10.91	10.70
125mm	19.02	18.75	18.80	19.05	19.05	18.80
150mm	27.39	31.50	32.44	31.75	32.44	32.00
200mm	48.70	121.05	109.80	104.71	101.93	118.00
North America: epi ($)						
3-inch	7.07	24.39	24.39	24.39	NA	NA
100mm	12.17	32.30	32.30	32.30	27.90	26.50
125mm	19.02	51.50	51.50	51.50	48.85	47.75
150mm	27.39	83.25	83.25	83.25	81.54	81.00
200mm	48.70	204.25	195.75	181.40	192.50	205.00
Japan: polished CZ (yen)						
3-inch	7.07	1,525	1,525	1,525	1,310	1,310
100mm	12.17	1,805	1,870	1,865	1,510	1,400
125mm	19.02	3,410	3,320	3,300	3,100	2,740
150mm	27.39	6,100	6,100	5,900	5,400	4,700
200mm	48.70	27,450	22,470	19,750	19,600	15,200
Japan: epi (yen)						
3-inch	7.07	5,127	5,127	5,127	3,700	3,700
100mm	12.17	5,700	5,700	5,600	4,300	4,000
125mm	19.02	10,000	10,000	9,875	8,700	8,500
150mm	27.39	18,754	18,754	16,750	16,500	16,500
200mm	48.70	NA	NA	NA	38,750	28,500
Europe: polished CZ ($)						
3-inch	7.07	8.05	8.05	8.05	8.05	8.05
100mm	12.17	11.75	11.80	11.40	11.66	11.50
125mm	19.02	19.03	21.35	21.30	21.07	20.00
150mm	27.39	32.45	33.09	33.15	33.40	34.30
200mm	48.70	123.39	115.40	115.75	104.71	122.00
Europe: epi ($)						
3-inch	7.07	25.01	23.70	24.01	24.10	24.10
100mm	12.17	35.07	34.69	33.40	33.40	33.00
125mm	19.02	57.02	57.09	55.41	55.41	53.50
150mm	27.39	88.31	86.75	87.40	84.50	83.00
200mm	48.70	NA	NA	NA	NA	213.00

(Continued)

Table 5-1 (Continued)
Regional Average Selling Price of Polished and Epitaxial Wafers, at Start of Year 1990-1994 Price per Wafer (U.S. Dollars and Japanese Yen)

Wafer Diameter	Area (square inches)	1990	1991	1992	1993	1994
Asia/Pacific: polished CZ ($)						
3-inch	7.07	7.25	7.25	7.25	7.25	7.25
100mm	12.17	9.50	10.66	10.47	10.47	10.50
125mm	19.02	17.50	18.63	19.61	19.34	19.22
150mm	27.39	29.12	33.75	34.95	34.54	34.90
200mm	48.70	NA	NA	NA	101.00	115.00
Asia/Pacific: epi ($)						
3-inch	7.07	25.10	25.10	25.10	NA	NA
100mm	12.17	34.71	35.05	35.00	35.50	34.50
125mm	19.02	53.87	53.87	51.90	52.00	50.75
150mm	27.39	86.23	85.70	83.20	82.00	81.00
200mm	48.70	NA	NA	NA	NA	NA

NA = Not applicable or not available
Source: Dataquest (June 1995)

Table 5-2
Regional Average Selling Price of Polished and Epitaxial Wafers, at Start of Year 1990-1994 Price per Square Inch (U.S. Dollars and Japanese Yen)

Wafer Diameter	Area (square inches)	1990	1991	1992	1993	1994
North America: polished CZ ($)						
3-inch	7.07	1.03	1.00	1.00	1.00	1.00
100mm	12.17	0.82	0.82	0.86	0.90	0.88
125mm	19.02	0.99	0.99	1.00	1.00	0.99
150mm	27.39	1.15	1.18	1.16	1.18	1.17
200mm	48.70	2.49	2.25	2.15	2.09	2.42
North America: epi ($)						
3-inch	7.07	3.45	3.45	3.45	NA	NA
100mm	12.17	2.65	2.65	2.65	2.29	2.18
125mm	19.02	2.71	2.71	2.71	2.57	2.51
150mm	27.39	3.04	3.04	3.04	2.98	2.96
200mm	48.70	4.19	4.02	3.72	3.95	4.21

(Continued)

Table 5-2 (Continued)
Regional Average Selling Price of Polished and Epitaxial Wafers, at Start of Year 1990-1994 Price per Square Inch (U.S. Dollars and Japanese Yen)

Wafer Diameter	Area (square inches)	1990	1991	1992	1993	1994
Japan: polished CZ (yen)						
3-inch	7.07	216	216	216	185	185
100mm	12.17	148	154	153	124	115
125mm	19.02	179	175	174	163	144
150mm	27.39	223	223	215	197	172
200mm	48.70	564	461	406	402	312
Japan: epi (yen)						
3-inch	7.07	725	725	725	523	523
100mm	12.17	468	468	460	353	329
125mm	19.02	526	526	519	457	447
150mm	27.39	685	685	612	602	602
200mm	48.70	NA	NA	NA	796	585
Europe: polished CZ ($)						
3-inch	7.07	1.14	1.14	1.14	1.14	1.14
100mm	12.17	0.97	0.97	0.94	0.96	0.94
125mm	19.02	1.00	1.12	1.12	1.11	1.05
150mm	27.39	1.18	1.21	1.21	1.22	1.25
200mm	48.70	2.53	2.37	2.38	2.15	2.51
Europe: epi ($)						
3-inch	7.07	3.54	3.35	3.40	3.41	3.41
100mm	12.17	2.88	2.85	2.74	2.74	2.71
125mm	19.02	3.00	3.00	2.91	2.91	2.81
150mm	27.39	3.22	3.17	3.19	3.09	3.03
200mm	48.70	NA	NA	NA	NA	4.37
Asia/Pacific: polished CZ ($)						
3-inch	7.07	1.03	1.03	1.03	1.03	1.03
100mm	12.17	0.78	0.88	0.86	0.86	0.86
125mm	19.02	0.92	0.98	1.03	1.02	1.01
150mm	27.39	1.06	1.23	1.28	1.26	1.27
200mm	48.70	NA	NA	NA	2.07	2.36
Asia/Pacific: epi ($)						
3-inch	7.07	3.55	3.55	3.55	NA	NA
100mm	12.17	2.85	2.88	2.88	2.92	2.83
125mm	19.02	2.83	2.83	2.73	2.73	2.67
150mm	27.39	3.15	3.13	3.04	2.99	2.96
200mm	48.70	NA	NA	NA	NA	NA

NA = Not applicable or not available
Source: Dataquest (June 1995)

Table 6-1
Silicon Wafer Plant Expansions/New Lines Since 1990

Company	Location	Status	Size (inches)	Initial Capacity (K Wafers/mo.)	Start Date	Capital Spending ($ Millions)	Capital Spending (Million Yen)
Shin-Etsu Handotai	Shirakawa	R&D			3/90	14.3	2,000
	Isobe	Epi Expansion				14.3	2,000
	Nagano	New Volume Production Line	6		2/91	25.7	3,500
	Naoetsu	New Volume Production Line	6		3/91	33.1	4,500
	Mimasu	Polishing Line			4/91	40.4	5,500
	Shirakawa	8-Inch Volume Production	6	30	4/92	118.6	15,000
	Camus, OR	8-Inch Volume Production	6	10	2/91	7.4	1,000
	England	6-Inch Volume Production	6	200	Q1/91	33.1	4,500
	Vancouver, WA	Epi Expansion			1994		
	Malaysia	8-Inch Volume Production	8	100/200	1994/5		20,000
	Vancouver, WA	8-Inch Expansion	8	50/90	1994/5		
	Japan	8-Inch Expansion	8	40/100	1994/5		
Sumitomo SiTix	Imari	No. 3 Volume Production Line	6, 8	130	1991	125.0	17,000
	Imari	Expansion of No. 3 Line	6, 8	170	1994/5		8,400
	Mainville, OH	Expansion			Q1/92	23.7	3,000
	Mainville, OH	No. 2 Plant (Substrate Production)			3/94		3,600
	Fremont, CA	Epi Expansion			1993		1,200
	Albuquerque, NM	8-Inch Epitaxial Wafer Line	8	20	1/95	32.0	
	Imari	Expansion of No. 3 Line	8	60	1996		
Mitsubishi Materials Silicon	Noda	Pilot Line	8	5	9/90	27.8	4,000
	Yonezawa	Volume Production	6	250	Q1/91	29.4	4,000
	Noda	R&D for 4M			4/90	13.9	2,000
	Central Research	R&D for 16M	8		1990	13.9	2,000
	Ikuno	8-Inch Volume Production	8	20	Q1/91	55.1	7,500
	Chitose	Epi Production Line			7/93		10,000
	Ikuno	Expansion	8	20	1994		

(Continued)

Table 6-1 (Continued)
Silicon Wafer Plant Expansions/New Lines Since 1990

Company	Location	Status	Size (inches)	Initial Capacity (K Wafers/mo.)	Start Date	Capital Spending ($ Millions)	Capital Spending (Million Yen)
Mitsubishi Materials Silicon (Continued)	Ikuno	Expansion	8	10/35	1995/6		
	Salem, Oregon	Prime and Epi	8	60/100	1996/7		
	To Be Announced	Prime	8	20	1998		
Komatsu Electronic Metals	Nagasaki	8-Inch Expansion	8	50	1995		4,000
	Miyazaki	8-Inch Expansion	8	10	1995		2,000
	Hiratsuka	Technical Center			Q3/91	14.7	2,000
	Portland, OR	Delayed					
	Taiwan	JV with Formosa Plastics (8 Inch Line)	8	100/200	1997/TBA	250.0	
Toshiba Ceramics	Yamagata	Expand at Okuni Plant	6	300			4,000
	Central Research	Pilot Line	8		9/90	3.5	500
	Niigata	Volume Production Line	8	100	7/93		22,210
	Tokuyama	Epi Expansion	5	90	1994		5,000
	Niigata	Expansion - pulling/polishing	8	10	1994		
	Oguni	8-Inch Expansion			1995		
Showa Denko	Chichibu	Expansion	6, 8	30	7/91	22.1	3,000
	Chichibu	Expansion	6		1997		
NSC Electron	Hikari	Expansion	8	10	4/93		10,000
	Hikari	Expansion	8	10	1996		
MEMC	St. Peters, MO	Expansion	8	30	11/91	31.9	4,340
	St. Peters, MO	Expansion	8	30	1995		
	Utsonomiya	Volume Production Line	8	30	1995		10,000

(Continued)

Table 6-1 (Continued)
Silicon Wafer Plant Expansions/New Lines Since 1990

Company	Location	Status	Size (inches)	Initial Capacity (K Wafers/mo.)	Start Date	Capital Spending ($ Millions)	Capital Spending (Million Yen)
Posco-Huls	Korea	Volume Production Line	6, 8		3/92	121.8	15,400
	Korea	Expansion	8	30	1994		
	Korea	Expansion	8	90	1995		
	Korea	Expansion	8	40	1996		
Wacker-Chemitronic	Wasserburg, Germany	Expansion of Epi	6		6/90	5.0	700
	Portland, OR	Upgrade Facility	6, 8		1993	45.0	
	U.S. and Germany	Expansion of Production	8		1994		
	Portland, OR	Line 2	8	75/125	1996/8	230.0	
	Wasserburg, Germany	8-Inch Expansion	8	50	1995		
MEMC-China Steel JV	Hsinchu Park, Taiwan	Volume Production	6, 8	125/215	1996/7	191.0	
MEMC Southwest (MEMC-Texas Instruments JV)	Sherman, TX	New 8-Inch Line and Upgrades	8	100/200	1997/8	300	

Source: Dataquest (June 1995)

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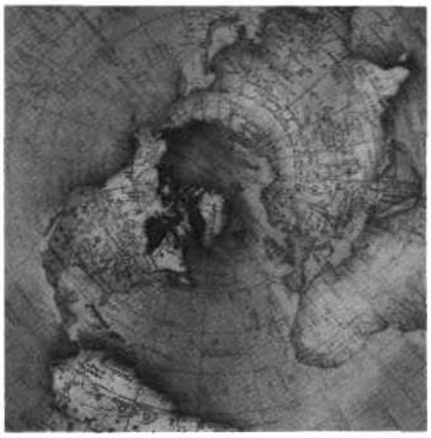

Dataquest

Midyear 1995 Forecast: Capital Spending, Wafer Fab Equipment, and Silicon

Market Trends

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
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Table of Contents

Table of Contents (Continued)

List of Figures

List of Tables

Chapter 1
Executive Summary 1995: Déjà vu, It's 1994 All Over Again

We knew a few months ago that the 1995 market would surprise us with its strength. A monthly leading indicator we have been developing went crazy in April and has not rested since. Our May capital spending survey confirmed our indicator—that 1995 is basically 1994 all over again. Two major factors have contributed to this, both unanticipated six months ago.

First, Intel's new aggressiveness in pricing for the Pentium has accelerated the transition toward Pentium PCs and the chips that support them. We have seen phenomenal semiconductor book-to-bill numbers in the first half of this year. Taking into consideration a revision of our PC unit forecast to a 16 percent compound annual growth rate (CAGR), Dataquest made a change in its longer-term view of the semiconductor industry, raising the basic CAGR to over 16 percent (we had been in the 13 to 14 percent range).

Second, the continued lack of economic yields for the 1Mx16 version of the 16Mb DRAM has kept the industry "stuck" at producing a higher number of 4Mb units, which have lower bit-per-square-inch densities, and driven the industry to add square inch capacity (that is, capital equipment) at higher rates than anticipated. From what we can see now, there will be plenty of equipment that could be brought to bear on 16Mb DRAM capacity by year-end 1996, and on line to answer demand through 1997. A marked downturn in the DRAM investment cycle will be triggered by the 1Mx16 configuration of the 16Mb DRAM achieving yield in the 60 to 65 percent area, expected to occur sometime in 1996.

Desktop connectivity products, telecommunications, and the PC market will lead to stable growth in microcomponents and logic devices, giving strategic strength to the North American region. Japan will be concentrating on ramping memories to try and hold its market share against the Korean and now the Taiwanese. A struggling economy will keep capital investment muted once the DRAM ramp is satisfied. Globalization strategies will benefit investment in both Europe and Asia/Pacific, the two fastest-growing regions for the next six years.

Dataquest has been bullish on the prospects for Europe, and 1995 is no different. Europe will actually rival Asia/Pacific for the fastest-growing region in 1995. European companies are a large part of this expansion, aided by strong domestic economies. Major projects by the multinational manufacturers are also contributing. In the long term, we still see Europe as the second fastest-growing region for spending through the decade.

The Asia/Pacific-ROW region will grow at an astronomical pace in 1995, as Korean DRAM expansion accelerates (even more), foundry expansion in Taiwan, Singapore, and others continues to grow, and new DRAM players enter the scene in Taiwan (PowerChip, Vanguard, and Nan Ya). As these new projects being started in 1995 will continue to consume capital funds in 1996, we are looking for continued modest growth in 1996. Asia/Pacific-ROW will continue to be the fastest-growing region through this decade. The year 1995 will be a watershed year for capital spending, as the Asia/Pacific region becomes the largest capital spending region in the world, surpassing both Japan and North America.

Dataquest believes that the relatively large capacity expansion phase of 1993 to 1995 (three-year growth of 200 percent) has now exceeded the three-year growth recorded in the 1987-to-1989 expansion. It should be noted, however, that the two periods are different in one key respect: The current period is also experiencing an accelerated long-term growth for the underlying semiconductor industry, driven by a productivity-related PC boom. This PC boom is expected to continue, so we are not overly alarmed about the magnitude of this cycle. Momentum of investments will make 1996 a healthy growth year in capital spending.

However, we also believe that in 1996 spending will decelerate, causing a flat spending pattern through 1997 and 1998. Although we continue to believe the cyclical nature of investment in semiconductor capacity will diminish, it will now require that the PC boom continue to drive the underlying semiconductor growth large enough to dampen the memory component of the cycle. After a two-year flat period, investments should pick up again in 1999.

The year 1995 will rival 1994 as the peak growth year in the industry, with wafer fab equipment growing 52 percent, and we are forecasting the spending momentum will carry over, resulting in a 22 percent growth in the front-end equipment market for 1996 to $19.9 billion. Segment growth in 1994 and 1995 is being led by DRAM or capital spending-sensitive equipment, with steppers, high-current and high-voltage implant, wafer inspection, and polysilicon etch exhibiting significantly stronger growth than market growth. We expect no major segment declines in 1995, as capacity additions are broad-based and worldwide.

After four strong expansion years from 1993 through 1996, equipment purchases in 1997 should decline modestly, followed by a relatively flat growth in 1998. Investment in DRAM capacity will be curtailed as producers elect to convert their 4Mb DRAM capacity to 16Mb, which adds bit capacity through the instant increase in bits per square inch. Also, many Japanese DRAM facilities now running 150mm wafers will convert to 200mm wafers, further delaying the need for new equipment. DRAM-sensitive equipment technologies or capital-intensive segments such as steppers, implantation, diffusion, and polysilicon etch will be affected more than logic-sensitive technologies such as sputtering, epitaxial reactors, RTP, nontube CVD, or metal etch. The next expansion should kick in by 1999, driven by 0.35- to 0.4-micron capacity expansion. The wafer fab equipment market is forecast to be $29.7 billion in the year 2000.

We have factored in an infrastructure investment in equipment for late 1997 through 1999, which will affect the forecast size of the markets positively. This additional investment will be for initial equipment to fill a number of 300mm fabs to run silicon by 1998 and 1999. However, our outlook for a significant 300mm equipment market will wait until after 2000.

Yield enhancement is the trend of the time. Any system technology that can be relatively low-priced and has a direct impact on yield will gain immediate acceptance in volume. Areas particularly important that are emerging today are in cleaning technology, photostabilizers, and process control metrology.

The silicon wafer market, driven by a stronger long-term picture for semiconductors in general, will grow faster over the next six years than the recent past. As the industry transforms into a 200mm baseline, the outlook for silicon wafer manufacturers becomes brighter. Silicon manufacturers have answered the call for 200mm capacity, and the semiconductor market has again responded with the cry "More, more!" We believe silicon manufacturers' ramp plans in 200mm have been strategically and smartly measured since the over-capacity situations of 1985, and after, are still remembered. While there is going to be activity with 300mm wafers, this is expected to be R&D-focused and low volumes until after the turn of the decade.

Dataquest Perspective

Our forecast for capital spending and wafer fab equipment sales during the next six years assumes that the explosive growth in 1995 will carry over into 1996. These are being driven by the PC market, with telecommunications and networking spurring demand for semiconductor chips across a broad spectrum—along with continued tight capacity convincing companies to expand. Our outlook for the future includes a modest decline in equipment spending in 1997, and a relatively flat 1998, before a resumption of double-digit growth in 1999.

The semiconductor industry has a global manufacturing business. Production of semiconductors is constantly shifting among regions, as new capital money is flowing toward areas with relative lower capital cost and higher-growth areas of consumption. Where the PC goes, so go semiconductors. This is true from the perspective of the business forecast, as well as the production line. Europe and Asia/Pacific, with very large capital spending upticks over the last several years and continuing in 1995, will continue to gain share in world production over the next several years.

The shifts and currents in semiconductor production trends mean that equipment and material suppliers will absolutely need a global presence in every sense of the word to remain competitive in the market. Product supply and support can no longer concentrate on local trends, as all major semiconductor companies have made it clear that they are investing on a worldwide basis. We see evidence of these trends as Lam Research and Watkins-Johnson set up direct offices in Japan, as Tokyo Electron Ltd. (TEL) acquires the Varian half of Varian/TEL to go direct into Europe and North America, and as ASM Lithography accelerates penetration into Asia/Pacific. Silicon plants are now being strategically placed, such as SEH's Malaysian plant, Komatsu's joint venture with Formosa Plastics in Taiwan, and MEMC's joint ventures in both Korea (Posco-Huls) and Taiwan (Taisil).

Furthermore, the concept of contract manufacturing in semiconductors is clearly here to stay. Equipment and material suppliers could find themselves selling their technical products to an international team from several companies, including the manufacturer and the designer. However, the emergence of the dedicated foundry company, taking ownership of the process and manufacturing flow, will tend to centralize this activity.

Although we continue to believe the cyclical nature of investment in semiconductor capacity will diminish, it will take a few more boom-and-bust cycles before the underlying semiconductor growth is large enough to dampen the memory component of the cycle, provided the PC boom is sustained as forecast.

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Chapter 2
Semiconductor Capital Spending Forecast

This chapter presents data on worldwide semiconductor capital spending by region. Capital spending in a region includes spending by all semiconductor producers with plants in that region. Components of capital spending are property, plant, and equipment expenditure for front- and back-end semiconductor operations.

Chapter Highlights

This chapter will discuss the following highlights:

- After a strong 53.4 percent growth in 1994, Dataquest has upgraded the 1995 forecast for global semiconductor capital spending to 60 percent growth at $34.8 billion. Anticipated continued tight capacity, and a strong semiconductor market in 1995, means continued growth continuing into 1996, currently forecast at about 15 percent.
- North America is showing consistent strength with a 44.7 percent growth in 1995. Worldwide demand for desktop connectivity products and telecommunications equipment continue to fuel the investment strategies in U.S.-manufactured semiconductor products, heavily weighted toward logic and ASIC capacity. North American capital spending is expected to moderate in 1996 and 1997 as these investments are absorbed and the U.S. PC market exhibits more normal historic growth patterns, although worldwide PC unit sales will continue at a 16 percent CAGR.
- Japanese companies are continuing to invest in semiconductor capacity to preserve their market share position in memories, although the recent strength in the yen is keeping a lid on spending enthusiasm. Japan as a region kept pace with the world in investment in 1994 but will lag the market in 1995 as Japanese companies invest more outside Japan. Healthy but subdued growth of 34.2 percent is anticipated in 1995, but only 15 percent on a yen basis. Lagging investment patterns in Japan is expected to continue throughout the decade.
- Dataquest has been bullish on the prospects for Europe, and 1995 is no different. Europe will actually rival Asia/Pacific for the fastest-growing region, with capital spending growing a remarkable 94 percent. European companies are a large part of this expansion, aided by strong domestic economies; major projects by the multinational manufacturers are also contributing. In the long term, we still see Europe as the second fastest-growing region for spending through the decade.
- Following a very strong capital investment growth year of 77 percent in 1994, the Asia/Pacific-ROW region will grow at an astronomical 94 percent in 1995, as Korean DRAM expansion accelerates (even more), foundry expansion in Taiwan, Singapore, and others continue to grow, and new DRAM players enter the scene in Taiwan (PowerChip, Vanguard, and Nan Ya). As these new projects being started in 1995 will continue to consume capital funds in 1996, we are looking for about 23 percent growth in 1996. Asia/Pacific-ROW will continue to be the fastest-growing region through this decade.

- 1995 will be a watershed year for capital spending, as the Asia/Pacific region becomes the largest capital spending region in the world, surpassing both Japan and North America.

Capital Spending Tables

A projected list of the top 20 semiconductor capital spending companies in 1994 is presented in Table 2-1, with the same list for projected 1995 spending shown in Table 2-2. Capital spending details by region are provided in the next two tables. Table 2-3 shows historical semiconductor capital spending by region for the years 1987 through 1994. Table 2-4 shows the capital spending forecast by region for the years 1994 through 2000. Yearly exchange rate variations can have a significant effect on the interpretation of the 1987 through 1994 data. For more information about the exchange rates used and their effects, refer to Appendix B.

Table 2-1
Semiconductor Capital Spending—Top 20 Spenders, 1994 versus 1993 (Millions of U.S. Dollars)

1994 Rank	1993 Rank	Company	1994	1993	Percent Change
1	1	Intel	2,419.0	1,700.0	42.3
2	2	Motorola	1,640.0	1,100.0	49.1
3	6	NEC	1,117.3	696.9	60.3
4	7	Samsung	1,000.0	630.0	58.7
5	5	Fujitsu	988.6	700.1	41.2
6	3	Hitachi	969.9	775.6	25.1
7	4	Toshiba	933.1	719.4	29.7
8	8	Texas Instruments	825.0	545.0	51.4
9	12	LG Semicon	800.0	400.0	100.0
10	9	SGS-Thomson	780.0	480.0	62.5
11	13	Hyundai	700.0	400.0	75.0
12	10	Mitsubishi	690.0	449.6	53.5
13	15	Advanced Micro Devices	625.0	357.0	75.1
14	11	IBM Microelectronics	525.0	412.0	27.4
15	21	Matsushita	513.2	168.6	204.4
16	17	Siemens AG	410.0	299.0	37.1
17	14	Sony	392.9	359.7	9.2
18	20	Micron Technology	387.0	184.6	109.6
19	23	Philips	385.0	134.0	187.3
20	16	Sanyo	356.1	347.0	2.6
		Total Top 20 Companies	16,457.1	10,858.6	51.6
		Total Worldwide Capital Spending	21,775.9	14,194.3	53.4
		Top 20 Companies' Percentage of Total	75.6	76.5	

Source: Dataquest (July 1995)

Table 2-2
Semiconductor Capital Spending—Top 20 Spenders, 1995 versus 1994
(Millions of U.S. Dollars)

1995 Rank	1994 Rank	Company	1995	1994	Percent Change
1	1	Intel	3,538.0	2,419.0	46.3
2	2	Motorola	2,250.0	1,640.0	37.2
3	9	LG Semicon	2,125.0	800.0	165.6
4	4	Samsung	1,975.0	1,000	97.5
5	3	NEC	1,643.6	1,117.3	47.1
6	11	Hyundai	1,500.0	700.0	114.3
7	5	Fujitsu	1,419.5	988.6	43.6
8	6	Hitachi	1,357.8	969.9	40.0
9	7	Toshiba	1,229.1	933.1	31.7
10	16	Siemens AG	1,060.0	410.0	158.5
11	14	IBM Microelectronics	1,000.0	525.0	90.5
12	8	Texas Instruments	975.0	825.0	18.2
13	12	Mitsubishi	949.0	690.0	37.5
14	15	Matsushita	909.0	513.2	77.1
15	10	SGS-Thomson	850.0	780.0	9.0
16	18	Micron Technology	800.0	387.0	106.7
17	19	Philips	750.0	385.0	94.8
18	13	Advanced Micro Devices	696.0	625.0	11.4
19	20	Sanyo	642.2	356.1	80.4
20	23	TSMC	528.0	307.0	72.0
		Total Top 20 Companies	26,197.2	16,371.2	60.0
		Total Worldwide Capital Spending	34,844.7	21,775.9	60.0
		Top 20 Companies' Percentage of Total	75.2	75.2	

Note: 1995 numbers are projections.
Source: Dataquest (July 1995)

The historical numbers presented in Table 2-3 have been restated slightly to coincide with our roll-up of the company-by-company database of capital spending. About two years ago, Dataquest began a process to improve the capital spending data collection and methodology. Now that this process is complete, we wish to make our published figures agree with our database. In almost all cases, the changes are very minor.

And the Spending Binge Continues . . .

After a three-year rest, 1993 started a growth cycle in a big way. After a 22.4 percent growth in semiconductor capital spending in 1993, an acceleration growth year of 53.4 percent followed in 1994. Dataquest has upgraded our forecast for 1995 to peak at 60 percent growth worldwide, based on our most recent capital spending survey.

Table 2-3
Worldwide Capital Spending by Region, 1987 to 1994 (Millions of U.S. Dollars)

	1987	1988	1989	1990	1991	1992	1993	1994
North America	2,622	3,349	3,794	4,217	3,895	4,135	4,943	7,178
Percent Growth	25.9	27.7	13.3	11.1	-7.6	6.2	19.5	45.2
Japan	2,458	4,495	5,360	5,596	5,702	3,958	4,315	6,460
Percent Growth	33.2	82.9	19.2	4.4	1.9	-30.6	9.0	49.7
Japan (Billions of Yen)	356	584	740	806	768	500	480	658
Percent Growth	15.4	64.0	26.7	8.9	-4.7	-34.9	-4.0	37.0
Europe	885	960	1,186	1,560	1,248	1,188	1,730	2,479
Percent Growth	15.7	8.5	23.5	31.5	-20.0	-4.8	45.6	43.3
Asia/Pacific-ROW	540	1,033	1,865	1,542	2,300	2,318	3,206	5,659
Percent Growth	23.6	91.3	80.5	-17.3	49.2	0.8	38.3	76.5
Worldwide	6,505	9,837	12,205	12,915	13,145	11,599	14,194	21,776
Percent Growth	26.8	51.2	24.1	5.8	1.8	-11.8	22.4	53.4

Note: The data in this table includes merchant and captive semiconductor companies.
Source: Dataquest (July 1995)

Table 2-4
Worldwide Capital Spending by Region, 1994 through 2000 (Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
North America	7,178	10,386	11,460	11,677	12,275	14,335	17,633	16.2
Percent Growth	45.2	44.7	10.3	1.9	5.1	16.8	23.0	
Japan	6,460	8,669	9,387	8,905	9,164	10,251	12,906	12.2
Percent Growth	49.7	34.2	8.3	-5.1	2.9	11.9	25.9	
Japan (Billions of Yen)	658	758	821	779	801	897	1,129	9.4
Percent Growth	37.0	15.3	8.3	-5.1	2.9	11.9	25.9	
Europe	2,479	4,811	5,609	5,937	6,252	7,075	8,188	22.0
Percent Growth	43.3	94.1	16.6	5.8	5.3	13.2	15.7	
Asia/Pacific-ROW	5,659	10,979	13,481	13,274	14,395	16,079	22,441	25.8
Percent Growth	76.5	94.0	22.8	-1.5	8.4	11.7	39.6	
Worldwide	21,776	34,845	39,937	39,793	42,086	47,740	61,168	18.8
Percent Growth	53.4	60.0	14.6	-0.4	5.8	13.4	28.1	

Note: The data in this table includes merchant and captive semiconductor companies.
Source: Dataquest (July 1995)

The continued growth in personal computer unit sales, with increased growth in telecommunications and networking products, has created tremendous demand for a variety of semiconductor components. The wafer fab capacity crunch has continued into all regions, and most semiconductor products, most notably DRAMs and advanced ASICs. The capacity shortage has given rise to a sharp acceleration in capital spending in all areas, with the strongest-growth occurring in DRAM expansion in Asia/Pacific and now Europe.

The big three Korean companies will increase spending by an unbelievable 124 percent to a combined $5.6 billion in 1995, and a mostly new crowd of Taiwanese companies are now entering the DRAM manufacturing business, spending over $1 billion collectively in 1995. Japanese suppliers of memory are increasing investment as well, collectively increased nearly 45 percent to $10.6 billion, an equivalent dollar increase as Korean companies' investment. Intel and Motorola still head the list for 1994, as the microprocessor and microcontroller demand continues to be strong. Equipping new and acquired facilities (in the case of Motorola) will continue to drive these companies in 1995. The three Korean companies, with the aforementioned increase in DRAM capacity spending, now occupy the No. 3, No. 4, and No. 6 spots in the billion dollar spending club, which currently consists of 11 companies, with four near or over $2 billion. NEC, Fujitsu, Hitachi, Toshiba, and Siemens all make this top 10 as the memory capacity keeps rolling in. In fact, the top spenders from No. 3 through No. 14 are all heavily concentrated in DRAM spending. With the general health of the industry, smaller semiconductor companies in all regions are participating in the capital spending boom in 1995, keeping the concentration of capital spending by the top 20 flat at 75 percent.

TSMC debuts on the top 20 list for 1995, as foundry capacity expansion has now evolved into a major trend. In fact, foundry spending in Asia/Pacific will nearly double in 1995 to an estimated $1.6 billion. This industry has transformed into a dedicated niche business and is no longer a specialized way to use excess capacity.

When Will the Spending Boom End?

Our longer-term forecast projects that significant growth in capital spending will spill into 1996 from the sheer momentum with a moderated growth of 14.6 percent, concentrated toward filling new fabs with equipment as 29 (yes, 29) new 200mm fabs are planning to come on line in 1996, as well as five 150mm fabs for a total of 34. This compares with a total of 28 for 1995 (19 of which are 200mm). Dataquest believes that in mid-1996, a decelerating capital spending picture will begin to emerge, as the capacity additions of 1994 and 1995 are ramped. From what we can see now, there is plenty of equipment that could be brought to bear on 16Mb DRAM capacity by midyear 1996 and on line to answer demand through 1997.

Overall semiconductor product demand is expected to remain strong through 2000 with a CAGR of 16.3 percent (see Chapter 5), so we expect that microcomponent capacity will start to ramp up again in 1998, with the next major investment cycle picking up in 1999. Our model does not currently include significantly more 16Mb DRAM capacity expansion (over what is already being put in place in 1995 and 1996) until 1999. In the two "pause" years of 1997 and 1998, we believe DRAM manufacturers will concentrate on converting capacity away from 4Mb toward 16Mb, which increases bits per square inch processed, and then concentrate on shrinks to squeeze value out per square inch before a capital cycle starts again. In addition, in Japan, we expect that many 4Mb/16Mb fabs currently running 150mm wafers will convert to 200mm wafers, further gaining efficiency and productivity from the sunk capital investment.

Through 2000, we project a five-year worldwide capital spending CAGR of 18.8 percent, slightly ahead of the semiconductor consumption growth. We believe that capital spending may be influenced in 1997 and 1998 positively with the facility construction and purchase of equipment toward the world's first 300mm wafer fab. We have built this infrastructure investment in our model.

About a year ago, we introduced a model that quantifies the over/underinvestment picture for wafer fab equipment and semiconductor capacity. While the last several years of activity have created and sustained a net underinvestment, and not fully corrected in 1994, this picture is now corrected to create about a 32 percent overinvestment by the end of the year (see Chapter 3 and Figures 3-1 and 3-2).

The North American Market Continues to Exhibit Strategic Strength

Capital spending in North America will grow a consistent 44.7 percent in 1995, with most of the investment growth in 1995 coming from U.S. companies connected with ASIC and logic products. We expect capital spending to decelerate gradually through 1997 with a resumed acceleration in 1998, resulting in a CAGR of 16.2 percent for 1994 through 2000. This somewhat lower than the market expansion is because of an emerging trend to shift production into the foundry market, which is concentrated in Asia (see Chapter 6).

The relatively strong growth in capital spending has been driven by the ongoing growth in PCs, telecommunications, and networking. These products have seen increasing use as tools to increase the productivity of the workplace. These electronic products, with their increased semiconductor content, have created enormous demand for microprocessors, microcontrollers, SRAM, programmable logic and memory, standard logic, and peripheral controllers. The U.S. companies dominate many of these market segments. These segments combined are expected to maintain fairly stable growth rates over the next few years, with PC growth slowing (yet still maintaining a 16 percent CAGR) and networking and telecommunications expanding. The near-term market for PCs has reaccelerated from Intel's new aggressive Pentium pricing strategy, which has hastened the conversion to the Pentium.

New products and services, such as personal communicators, interactive television, and video-on-demand, provide the potential for enormous growth in semiconductor sales, especially for highly integrated complex logic and signal processing chips that will be the core engines of future systems.

While the strategic strength of the core logic products enables a healthy and flourishing semiconductor production environment, it is also one that is less volatile in capital spending. In these boom years of 1994 and 1995, the North American region grew at somewhat lower than the market rates. This trait will also enable the North American market to grow in capital spending faster than market rates in the slower years such as 1997. We believe companies will strategically invest in capacity to preserve competitive advantage, and any cutbacks are likely to occur in the smaller companies rather than the first-tier manufacturers.

Capital investments in North America for 1994 mainly focused on equipping new fabs coming on line by both major and small companies. The major projects include Intel's Fab 11.2 in New Mexico and expected orders for Fab 12 in Arizona, AMD's Fab 25 in Austin, Texas, Motorola's MOS-13 in Texas and its continued ramp of MOS-12 in Arizona, Cypress' Fab 4 in Minnesota, SGS-Thomson's new Arizona facility, IBM's expansion in Burlington (yes, IBM is back!) , and the ongoing purchases for Texas Instruments' DMOS-5 fab in Dallas. Smaller companies are also spurring the growth this year, with Integrated Device Technology, VLSI Technology, Zilog, Atmel, International Rectifier, AMI, and National Semiconductor all bringing on new capacity. Samsung, which has stated an intention to invest $1 billion to build a fab in the United States, has yet to pick a site. We understand that it has narrowed the selection to two sites: Oregon or Texas. We would expect an announcement within the next few months, and we have factored this into our 1998 forecast.

Japan: DRAM Capacity Additions Drive Spending, but a Strong Yen Subdues

Japan's 34.2 percent increase in capital spending in 1995 is only 15.3 percent on a yen basis, as Japanese companies look to invest outside Japan to optimize buying power. We are forecasting a subdued 8 percent growth in capital spending for 1996, factoring in a slight decline in 1997 as the mission will have been accomplished in DRAMs in the near term.

Some of the Japanese electronics giants are experiencing good profit growth, driven by semiconductor operations. The demand for world memory capacity presented an opportunity to grow profits from semiconductors. Investments by Japanese companies will grow by nearly 44 percent in 1995, with an increased amount going overseas. However, as long as the Japanese economy is under pressure, Japanese companies will feel a "patriotic" dedication to invest in Japan, and we see no company spending more than 30 percent of committed investment outside Japan. With the strength of the yen, multinationals are reducing their investment proportion inside Japan as well.

Although new facilities by Japanese companies will come on line outside Japan throughout the rest of this decade, DRAM investments inside Japan are really the only driving force today. Beyond 1995, investment increases in Japan will need to come from growing the domestic economy. Dataquest believes an economic recovery in Japan started in 1994, but with slow acceleration, and could stall if the yen does not stabilize. The degree at which companies will invest will be affected by the strength of this recovery. As we see no real fundamental change coming in Japan until very late in the decade, we are forecasting a below-average CAGR of 9.4 percent in Japan for the years 1994 through 2000.

One bright spot could be that a PC boom could emerge in Japan over the next year or two, spawned by the networking infrastructure that is currently being built. This would breathe new life into the Japanese semiconductor market, and our forecast would be brightened a bit. However, we believe that even a PC boom would still lead to a growth forecast that is several percentage points below the world average. The fundamentals of a Japanese production capacity is still too heavily concentrated in DRAMs, with no clear future direction emerged as yet, keeping us from being more optimistic for capital activities in Japan.

Europe Sustains Presence as a Growth Market

After a higher-than-expected growth bubble of 45.6 percent in 1993, European spending moderated to a slower-than-market growth rate in 1994 as multinationals (such as Intel) substantially completed the majority of their expansions in 1993. The growth of 43.3 percent in 1994 is nonetheless extremely healthy, primarily being fueled by the Europeans themselves, with the ever-present SGS-Thomson, Philips expanding in Nijmegen, and Ericsson equipping its expansion.

Europe continues to attract the capital in 1995, with a true explosion of spending, forecast to grow a whopping 94 percent. Multinationals have reentered, with Motorola upgrading the Scotland fab bought from Digital, the new IBM/Philips venture in Germany, Analog Devices expanding in Ireland, Texas Instruments expanding again in Italy, and the IBM/Siemens fab in France continuing to ramp 16Mb DRAMs. In addition, Siemens' new fab in Dresden, Germany, is a key expansion, pulling Siemens into the top 10 in capital spending worldwide. NEC and other Japanese companies' continued commitment to Europe has given the latest boost in investment momentum, and we are looking for continued growth in 1996 of 16.6 percent.

Europe is being viewed as a strategic location for production to take better advantage of European and 16Mb DRAM growth in the future, driven by the PC production boom (see Chapter 6) without the import tariffs. Samsung has announced a fab to come on line in Europe during 1998, but as of the writing undecided about the exact location.

With increased multinational presence starting again in 1995 as the economies pick up, and with recent trends of PC production and foundry providers (Newport WaferFab and Tower Semiconductor), we now expect Europe to be an above-average investment region in the long term, with a six-year CAGR of 22 percent, the second fastest region in the world.

Asia/Pacific Madly Investing in Two Distinct Ways

The often erratic but sustained semiconductor capital spending growth in the Asia/Pacific region continued at the explosive rate of 76.5 percent in 1994. And if one thought this market could not accelerate from that level, think again—for 1995 becomes the year that the Asia/Pacific region is the largest expansion region in the world, surpassing both Japan and North America in terms of dollars spent. Our forecast is for 94 percent growth in 1995, and a moderated growth of about 23 percent in 1996 as several new fab projects continue to be built and equipped, and the number of new projects growing. Longer term, we expect Asia/Pacific to exhibit the most aggressive growth in capital spending of any region. Dataquest forecasts a 1994-through-2000 CAGR of 25.8 percent.

Spending in 1995 is coming primarily from two areas, DRAMs and foundry capacity. The Korean conglomerates are continuing their relentless DRAM capacity expansion plans in 1995. Hyundai is installing equipment for its new E-3 project, the third phase of a 200mm wafer, 16Mb DRAM fab started in 1992. LG Semicon (formerly Goldstar) is expanding its equivalent C2 line, as the agreement with Hitachi for the 16Mb DRAM ramps. LG Semicon is also bringing on line the G-FAB for non-DRAM memory products. Samsung is continuing to spend, ramping Line 6, also a 200mm, 16Mb DRAM facility.

The real story in 1995 are the new Taiwan players. Vanguard International will be bringing on its new DRAM fab later this year, and PowerChip and Nan Ya have broken ground on DRAM fabs coming on line in 1996. All of these are targeted at 16Mb DRAM running 200mm wafers. Current players such as TI/Acer and MOSel-Vitelic are also increasing their spending with new projects.

Taiwan chip companies TSMC, Macronix, Winbond, and UMC, along with Chartered Semiconductor in Singapore, have added major projects in expansion of foundry capacity; and a new foundry player has emerged in Thailand—SubMicron Technology (STI). STI has $1.6 billion funding for two separate fab lines, the first to come on line in 1996. Separate funding to establish a technology park similar to Hsin-chu in Taiwan exists, with the location to be in or near Bangkok. The combined spending of these companies for foundry (which excludes spending associated with their own products in the case of UMC, Macronix, and Winbond) increased from about $900 million in 1994 to about $1.6 billion in 1995, continuing at probably higher levels into 1996. The driving force is the changing face of contract manufacturing in semiconductors. Gone are the days when excess fab capacity could support the foundry business of fabless companies (as well as integrated device manufacturers (IDMs), which are companies with fabs).

Dataquest estimates that only about 40 percent of the contracted manufacturing of semiconductors originates from fabless companies. The remainder is from IDMs that wish to place manufacturing lower value-added products away from their own facilities to maximize resources and cost. The last few years have seen the flourishing of the dedicated foundry, most of this type of capacity in Asia/Pacific. However, it is still believed that the largest concentration of foundry capacity in the world resides in Japan, with companies like Rohm, Seiko-Epson, Sharp, and other large integrated companies.

However, the appetite for leading-edge foundries has caused another transformation to occur. With the cost of capital increasing and at a higher level for leading-edge equipment, foundry companies such as Chartered have established longer-term contracts with design companies, often with capital infusions toward production equipment. On the buyer's side, companies are now receiving guaranteed capacity for their products. It should be noted that TSMC, the largest foundry company in the world, does not prescribe to the concept of capital infusion. This is a similar business model to Solectron's in the electronic equipment marketplace.

The foundry industry is now a *strategic* industry rather than simply a tactical one. With this transformation nearly complete, we are starting to see the dedicated investment to build new foundry capacity.

In addition to the established semiconductor-producing countries, huge long-term opportunities exist in developing countries like China and the Commonwealth of Independent States (formerly the Soviet Union). Ultimate demand for semiconductor products in those countries could approach demand in superconsumer countries like the United States and Japan. China, in particular, generates a GDP comparable to that of Japan if evaluated on a purchasing power parity basis. U.S., European, and

Japanese telecommunications companies are working with the Chinese government to install telephone exchange equipment and digital lines.

Several hurdles must be overcome before either China or Russia becomes a viable market for advanced front-end semiconductor manufacturing. Technology export restrictions must be eased to allow the construction of relatively advanced fabrication facilities. Foreign suppliers must establish local sales and service centers and need to define their market access. Financing capability must be established by the host countries. Solidification of international trade relationships through participation in the General Agreement of Tariffs and Trade (GATT) must also be established. China's internal political structure poses a potential barrier to achieving continued most favored nation status with the United States. It will likely take a few years to sort out these issues. Dataquest assumes that semiconductor investment in China could begin to expand in the 1997 time frame (today, NEC is leading the investment charge), accelerating into the later half of the decade.

Who's Investing Where?

In our capital spending survey recently completed, Dataquest gathered a picture of how money is being spent. Table 2-5 summarizes how companies based in different regions are spending their money abroad for 1994, and Table 2-6 summarizes the same for 1995. About 78 percent of money spent goes into the domestic economy worldwide, and that ratio holds steady for 1994 and 1995.

Asia/Pacific companies have historically placed all of their investments domestically, but 1994 saw diversification for the first time, and this should continue in 1995. Asia/Pacific companies spent about 96 percent of their money domestically in 1994, and this percentage is expected to drop slightly to 92 percent in 1995. Europeans have been the most aggressive capital exporters historically, placing only 63 percent of their investment inside of Europe. This figure has grown to 68 percent in 1995 as the domestic economies have seen the emergence of some companies that invest mainly in Europe.

Table 2-5
Regional Investment Patterns of Semiconductor Manufacturers in 1994
(Millions of U.S. Dollars)

	World	North America	Japan	Europe	Asia/ Pacific-ROW	Percent of World Spending (%)
North American Companies	8,628.3	6,223.7	566.3	957.4	880.9	39.6
Japanese Companies	7,326.9	541.9	5,892.9	308.7	583.5	33.6
European Companies	1,866.0	277.6	0.4	1,182.7	405.3	8.6
Asia/Pacific-ROW Companies	3,954.7	135.0	0	30.0	3,789.7	18.2
All Companies	21,775.9	7,178.1	6,459.6	2,478.8	5,659.4	100.0
Percent Growth from 1993 (%)	53.4	45.2	49.7	43.3	76.5	-

Source: Dataquest (July 1995)

Table 2-6
Regional Investment Patterns of Semiconductor Manufacturers in 1995
(Millions of U.S. Dollars)

	World	North America	Japan	Europe	Asia/ Pacific-ROW	Percent of World Spending (%)
North American Companies	12,294.6	8,859.1	491.0	1,567.0	1,377.5	35.3
Japanese Companies	10,579.5	918.5	8,177.4	717.7	765.8	30.4
European Companies	3,112.0	339.4	0.6	2,111.6	660.4	8.9
Asia/Pacific-ROW Companies	8,858.6	268.5	0.0	414.8	8,175.3	25.4
All Companies	34,844.7	10,385.6	8,669.1	4,811.0	10,979.0	100.0
Percent Growth from 1994 (%)	60.0	44.7	34.2	94.1	94.0	-

Source: Dataquest (July 1995)

Japanese companies' domestic investment in 1994 is very close to the worldwide average with about 80 percent, dropping to 77 percent in 1995. North American companies are also high domestic spenders, with about 72 percent staying at home for both years.

The North American and Japanese regions are net investors, while European and Asia/Pacific regions are net beneficiaries of that investment, paralleling the net exporters of semiconductors.

While all regions are spending in Asia/Pacific, and all multinational regions investing in Europe, only North American companies have the strategic vision to invest in Japan. Japanese companies are also investing on a worldwide basis. We believe it is one of the key elements necessary in a strategic plan for a semiconductor company to be competitive on a global basis.

Dataquest Perspective

Capital spending exploded in 1994 and is accelerating in 1995. The major reason for the acceleration is the surprisingly persistent growth in unit PC shipments, with the aggressiveness of Intel's Pentium pricing strategy. Major DRAM expansion accelerated in the second half of 1993 and will continue through the first half of 1996. From what we can see now, there is plenty of equipment that could be brought to bear on 16Mb DRAM capacity by year-end 1996 and on line to answer demand through 1997. A marked downturn in the DRAM investment cycle will be triggered by the 1Mx16 configuration of the 16Mb DRAM, achieving yield in the 60 to 65 percent area, expected to occur sometime in 1996.

Desktop connectivity products, telecommunications, and the PC market will lead to stable growth in microcomponents and logic devices giving strategic strength to the North American region. Japan will be concentrating on a ramping memories to try and hold its market share against the Korean companies, and now the Taiwanese. A struggling economy will keep capital investment muted once the DRAM ramp is satisfied. Globalization strategies will benefit both European and Asia/Pacific investment, the latter being the fastest-growing region during the next five years.

Dataquest believes that the relatively large capacity expansion phase of 1993 to 1995 (three-year growth of 200 percent) has now exceeded the three-year growth recorded in the 1987-to-1989 expansion. It should be noted, however, that the two periods are different in one key respect: The current period is also experiencing an accelerated long-term growth for the underlying semiconductor industry, driven by a productivity-related PC boom. This PC boom is expected to continue, so we are not overly alarmed about the magnitude of this cycle. Momentum of investments will make 1996 a healthy growth year in capital spending.

However, we also believe that in 1996 spending will decelerate, causing a flat spending pattern through 1997 and 1998. Although we continue to believe the cyclical nature of investment in semiconductor capacity will diminish, it will now require that the PC boom continue to drive the underlying semiconductor growth large enough to dampen the memory component of the cycle. After a two-year flat period, investments should pick up again in 1999.

Chapter 3
Wafer Fab Equipment Spending Forecast

This chapter presents data on worldwide spending by region for wafer fabrication equipment. Wafer fab equipment spending in a region includes spending by all semiconductor producers with plants in that region. Included are all classifications of equipment for front-end semiconductor operations.

Chapter Highlights

Highlights of this chapter are as follows:

- Wafer fab equipment spending in 1995 will continue at a neck-breaking 52 percent growth worldwide, after a 56 percent growth year in 1994.
- This growth will be driven by Asia/Pacific region (79 percent growth) and a PC production boom in Europe (69 percent wafer fab equipment growth). Continued investment in North America and a DRAM-sensitive Japan (40 and 37 percent growth, respectively) round out the third year of the boom.
- Momentum from 1995 and 29 new 200mm fabs coming on line in 1996 will keep growth intact. Dataquest is now forecasting nearly 22 percent growth in wafer fab equipment in 1996.
- Segment growth in 1994 and continued growth in 1995 are being led by DRAM and capital-spending-sensitive equipment, with steppers, high-current and high-voltage implant, wafer inspection, and polysilicon etch exhibiting significantly stronger growth than market growth. We expect no major segment declines in 1995, as capacity additions are broad-based and worldwide.
- Our model that measures the net cumulative under- or overinvestment indicates that by the end of 1995, the semiconductor manufacturing world will be overinvested in wafer fab equipment to the tune of $5.2 billion, or 31.7 percent of the market. This is above the peaks exhibited in 1984 and 1989, so excess capacity should emerge in 1996, probably in the DRAM market where capacity has been added recently.
- After four strong expansion years in 1993 through 1996, equipment purchases in 1997 should decline modestly, followed by a relatively flat growth in 1998. The next expansion should kick in by 1999, driven by a 0.35- to 0.4-micron capacity expansion. The worldwide wafer fab equipment market is forecast to grow at an 18.4 percent CAGR between 1994 and 2000.
- We have factored in an infrastructure investment in equipment for 1997 through 1999, which will affect the forecast size of the markets positively. This additional investment will be for initial equipment to fill a few 300mm fabs to run silicon by 1998 and 1999. The bulk of this "300mm equipment bubble" will occur in 1998. However, our outlook for a significant 300mm equipment market will wait until 2000 and 2001.

This chapter presents historical and forecast data on the worldwide wafer fabrication equipment market, by region and by key equipment segment.

In this midyear forecast outlook on wafer fab equipment, we have chosen to focus our forecast of equipment categories on specific segments and issues, namely:

- The annual investment theme for 1995 to 2000
- Steppers and automatic photoresist processing equipment (track) in lithography
- Dry etch and chemical mechanical polishing (CMP) in etch and clean
- Silicon epitaxy, CVD, and PVD in deposition
- Diffusion and RTP
- Ion implantation (medium current, high current, and high voltage)
- Segments of emerging importance

These segments of the equipment market represent not only the majority of all wafer fab equipment expenditure in the world today, but also embody the key technological capability for advanced device production. Highlights of some of the factors affecting individual equipment segment forecasts also are presented.

Equipment spending in a region refers to spending by all companies—both domestic and foreign—within the region. In addition, we note that annual exchange rate variations can have a significant effect on 1988 through 1994 data appearing in the tables in this chapter. Appendix B details the exchange rates used in this document.

Tables in this chapter provide details on the following:

- Table 3-1—Historical market data by geographic region for the years 1988 through 1994
- Table 3-2—Forecast market data by geographic region for the years 1994 through 2000
- Table 3-3—Historical data for key equipment segments for the years 1988 through 1994
- Table 3-4—Forecast data for key equipment segments for the years 1994 through 2000

Annual Investment Themes for 1994 to 1998

Behind our equipment and segment forecasts are assumptions about how semiconductor producers will perform and invest. These are summarized in Table 3-5 for the years 1995 through 2000. The following areas are considered: the availability of profits for reinvestment, memory versus logic growth, technology shifts, and brick and mortar versus equipment purchases.

When Will Capacity Expand to Meet Demand? An Update to the Over- or Underinvestment Model

In our forecasts last year, we introduced a model that provided a measure of the net cumulative over- or underinvestment in wafer fab equipment to support capacity needs in the industry. Since equipment purchases

Table 3-1
Worldwide Wafer Fab Equipment Market by Region, 1988-1994
(Millions of U.S. Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1988-1994
North America	1,534	1,657	1,589	1,524	1,570	2,129	3,141	12.7
Percent Change	38.9	8.0	-4.1	-4.1	3.0	35.6	47.5	-
Japan	2,270	2,813	2,992	3,007	2,096	2,460	3,668	8.3
Percent Change	77.8	23.9	6.4	0.5	-30.3	17.4	49.1	-
Europe	662	721	764	641	634	978	1,385	13.1
Percent Change	25.9	8.9	6.0	-16.1	-1.1	54.3	41.6	-
Asia/Pacific	519	820	522	843	789	1,309	2,562	30.5
Percent Change	126.6	58.0	-36.3	61.5	-6.4	65.9	95.7	-
Total Wafer Fab Equipment	4,984	6,011	5,867	6,014	5,089	6,876	10,755	13.7
Percent Change	58.9	20.6	-2.4	2.5	-15.4	35.1	56.4	-

Note: Some columns may not add because of rounding.
Source: Dataquest (July 1995)

Table 3-2
Worldwide Wafer Fab Equipment Market by Region, 1994-2000
(Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
North America	3,141	4,409	5,040	4,966	5,160	6,065	7,801	16.4
Percent Change	47.5	40.4	14.3	-1.5	3.9	17.5	28.6	-
Japan	3,668	5,008	5,459	4,931	4,953	5,643	7,146	11.8
Percent Change	49.1	36.5	9.0	-9.7	0.4	13.9	26.6	-
Europe	1,385	2,341	2,740	2,696	2,842	3,317	4,002	19.3
Percent Change	41.6	69.0	17.0	-1.6	5.4	16.7	20.7	-
Asia/Pacific	2,562	4,582	6,615	6,296	6,369	7,470	10,751	27.0
Percent Change	95.7	78.8	44.4	-4.8	1.2	17.3	43.9	-
Total Wafer Fab Equipment	10,755	16,340	19,854	18,888	19,323	22,495	29,701	18.4
Percent Change	56.4	51.9	21.5	-4.9	2.3	16.4	32.0	-

Note: Some columns may not add because of rounding.
Source: Dataquest (July 1995)

Table 3-3
Wafer Fab Equipment Revenue by Equipment Segment, 1988-1994
(Millions of U.S. Dollars)

Equipment Segment	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1988-1994
Worldwide Fab Equipment ($M)	4,984	6,011	5,867	6,014	5,089	6,876	10,755	13.7
Percent Change	58.9	20.6	-2.4	2.5	-15.4	35.1	56.4	-
Steppers	921	1,181	1,052	979	646	1,014	1,838	12.2
Track	253	322	317	364	353	507	711	18.8
Other Lithography[1]	307	261	242	205	147	162	190	-7.7
Total Lithography/Track	1,481	1,764	1,612	1,549	1,147	1,683	2,739	10.8
Automated Wet Stations	144	243	268	291	286	285	519	23.8
Other Clean Process[2]	133	134	132	143	103	198	233	9.8
Dry Etch	533	670	690	717	682	1,096	1,555	19.5
Dry Strip	100	121	118	119	123	138	202	12.4
Chemical Mechanical Polishing	NS	NS	NS	11	20	44	65	NA
Total Etch and Clean	911	1,168	1,208	1,281	1,212	1,761	2,573	18.9
Tube CVD	186	220	259	268	213	283	446	15.7
Non-Tube Reactor CVD	275	388	457	474	437	585	903	21.9
Sputtering	260	320	359	425	446	584	1,025	25.7
Silicon Epitaxy	86	75	68	89	84	83	100	2.7
Other Deposition[3]	165	170	153	147	119	115	101	-7.8
Total Deposition	972	1,173	1,296	1,403	1,300	1,650	2,575	17.6
Diffusion	296	332	325	326	246	342	492	8.9
RTP	22	25	33	46	36	45	80	23.6
Total Diffusion/RTP	318	357	358	372	283	388	572	10.3
Medium Current Implant	118	131	114	108	83	108	234	12.1
High Current Implant	241	301	250	228	164	233	391	8.4
High Voltage Implant	18	25	7	18	16	18	29	8.1
Total Ion Implantation	377	457	370	353	263	359	654	9.6
Total Process Control[4]	608	676	605	643	544	634	1,017	8.9
Factory Automation	130	195	216	227	194	250	412	21.2
Other Equipment	187	222	202	185	146	151	213	2.2
Total FA/Other Equipment	317	417	418	412	340	401	625	12.0
Total Wafer Fab Equipment	4,984	6,011	5,867	6,014	5,089	6,876	10,755	13.7

NS = Not surveyed
NA = Not applicable
[1] Includes contact/proximity, projection aligners, direct-write, maskmaking, and x-ray lithography
[2] Includes spray processors, post-CMP clean, vapor phase clean, and other clean processes as defined in our Market Statistics book
[3] Includes Evaporation, MOCVD, and MBE
[4] Includes optical CD, CD SEM, wafer inspection, and other process control equipment
Note: Some columns do not add to totals shown because of rounding.
Source: Dataquest (July 1995)

Table 3-4
Wafer Fab Equipment Revenue Forecast by Equipment Segment, 1994-2000
(Millions of U.S. Dollars)

Equipment Segment	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
Worldwide Fab Equipment ($M)	10,755	16,340	19,854	18,888	19,325	22,495	29,701	18.4
Percent Change	56.4	51.9	21.5	-4.9	2.3	16.4	32.0	-
Steppers	1,838	2,990	3,306	2,833	2,638	3,217	4,752	17.2
Track	711	1,029	1,360	1,366	1,411	1,665	2,109	19.9
Other Lithography[1]	190	260	316	310	321	353	416	14.0
Total Lithography/Track	2,739	4,279	4,981	4,509	4,369	5,235	7,277	17.7
Automated Wet Stations	519	778	999	999	1,034	1,102	1,393	17.9
Other Clean Process[2]	233	341	428	438	454	484	597	17.0
Dry Etch	1,555	2,271	2,750	2,663	2,822	3,399	4,529	19.5
Dry Strip	202	297	347	340	367	416	529	17.4
Chemical Mechanical Polishing	65	95	141	142	164	225	342	31.9
Total Etch and Clean	2,573	3,783	4,666	4,582	4,841	5,626	7,390	19.2
Tube CVD	446	662	838	812	812	922	1,191	17.8
Non-Tube Reactor CVD	903	1,389	1,702	1,662	1,706	1,980	2,569	19.0
Sputtering	1,025	1,536	1,827	1,794	1,875	2,227	2,851	18.6
Silicon Epitaxy	100	134	169	185	213	241	273	18.2
Other Deposition[3]	101	118	131	113	110	115	131	4.4
Total Deposition	2,575	3,838	4,666	4,567	4,715	5,484	7,015	18.2
Diffusion	492	735	921	861	864	990	1,292	17.5
RTP	80	123	165	183	234	256	312	25.5
Total Diffusion/RTP	572	858	1,086	1,045	1,098	1,246	1,604	18.8
Medium-Current Implant	234	324	375	317	300	355	487	13.0
High-Current Implant	391	631	784	680	628	742	1,054	18.0
High-Voltage Implant	29	87	113	93	104	140	202	38.0
Total Ion Implantation	654	1,041	1,273	1,090	1,032	1,237	1,744	17.7
Total Process Control[4]	1,017	1,551	1,954	1,942	2,027	2,250	2,819	18.5
Factory Automation	412	650	824	812	860	990	1,337	21.7
Other Equipment	213	340	405	342	383	427	517	15.9
Total FA/Other Equipment	625	990	1,229	1,154	1,243	1,417	1,853	19.9
Total Wafer Fab Equipment	10,755	16,340	19,854	18,888	19,325	22,495	29,701	18.4

[1] Includes contact/proximity, projection aligners, direct-write, maskmaking, and x-ray lithography
[2] Includes spray processors, post-CMP clean, vapor phase clean, and other clean processes as defined in our Market Statistics book
[3] Includes Evaporation, MOCVD, and MBE
[4] Includes optical CD, CD SEM, wafer inspection, and other process control equipment
Note: Some columns do not add to totals shown because of rounding.
Source: Dataquest (July 1995)

Table 3-5
Annual Driving Forces and Investment Themes for Wafer Fab Equipment, 1995 to 2000

	1995	1996	1997	1998	1999	2000
Logic Semiconductor Unit Growth*	Solid	Solid	Moderate	Moderate	Moderate	Solid
Investment in Logic Capacity*	Solid	Solid	Moderate	Moderate	Moderate	Solid
Memory Semiconductor Unit Growth*	Solid	Weak	Moderate	Moderate	Solid	Strong
Investment in Memory Capacity*	Strong	Moderate	Weak	Weak	Moderate	Strong
Front-End Equipment versus Facilities Loading of Capital	Facilities	Equipment	Facilities	Balanced	Balanced	Equipment
Primary Technologies Invested	0.35-0.6 micron	0.35-0.5 micron	0.35-0.5 micron	0.3-0.5 micron	0.25-0.4 micron	0.25-0.4 micron

*Scale: Strong > Solid > Moderate > Weak > Dead
Source: Dataquest (July 1995)

precede actual capacity on line by a number of months or quarters, this model could be viewed as a "leading indicator" to capacity shortages and excesses. The results of this model are close to a 1- to 2-year indicator of turning points in the equipment industry. The methodology of the net cumulative investment (NCI) model is linked to our forecast model.

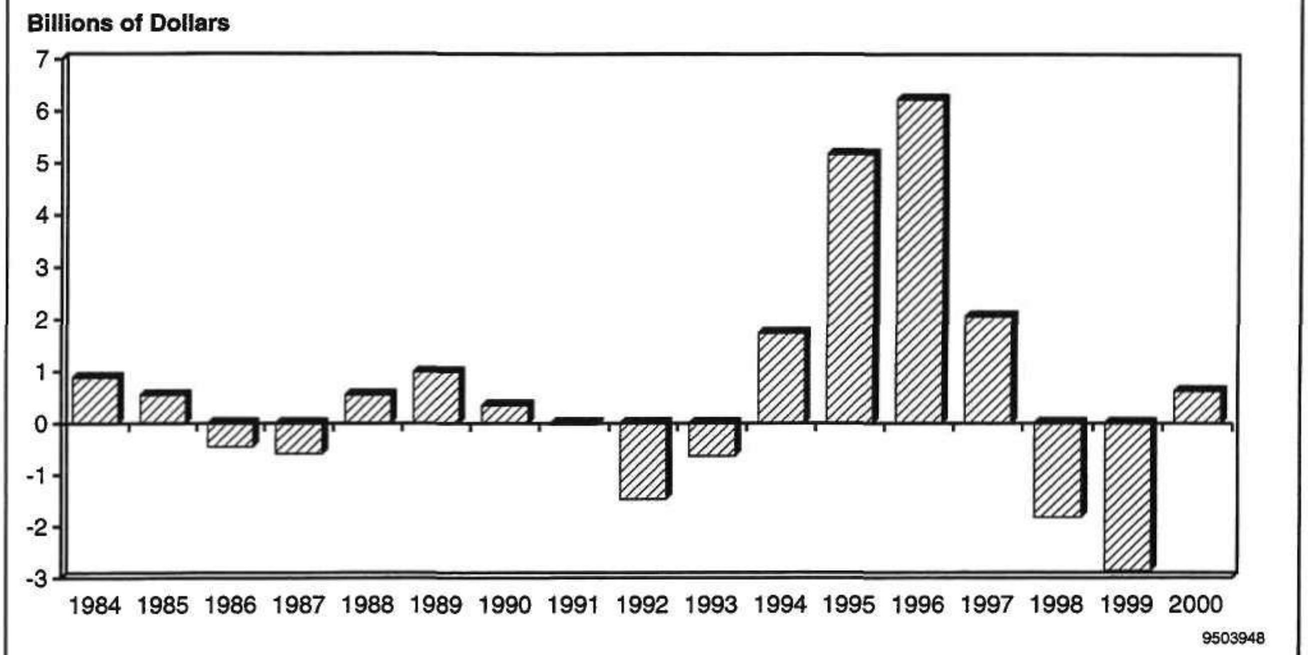
To review, our methodology starts with a few key assumptions and baselines:

- Long-term growth rates for semiconductors and wafer fab equipment are correlated. In other words, semiconductor revenue and profits are needed before money can be spent on equipment, and vise versa.
- Also, NCI equals zero over time, meaning that in a noncyclical environment where annual growth rates are constant, investment and capacity are at equilibrium at all times. Of course, our industry cycles through over- and underinvestment.
- The output is a tangible number and is in dollars of over- or underinvestment at year-end. However, the more useful output of the model divides this gross dollar number by the wafer fab equipment market size. The result is a percentage of market figure that is repeatable in levels from cycle to cycle.
- To take into consideration the long-term growth of the semiconductor and equipment industries changing over time, the model has a factor allowing the fundamentals of the industry to change over time.

A net positive or negative investment is calculated relative to the long-term growth baseline annually and then added to the prior year. The calculation resulted in a dollar value net cumulative over- or underinvestment and has correlated well with historical patterns.

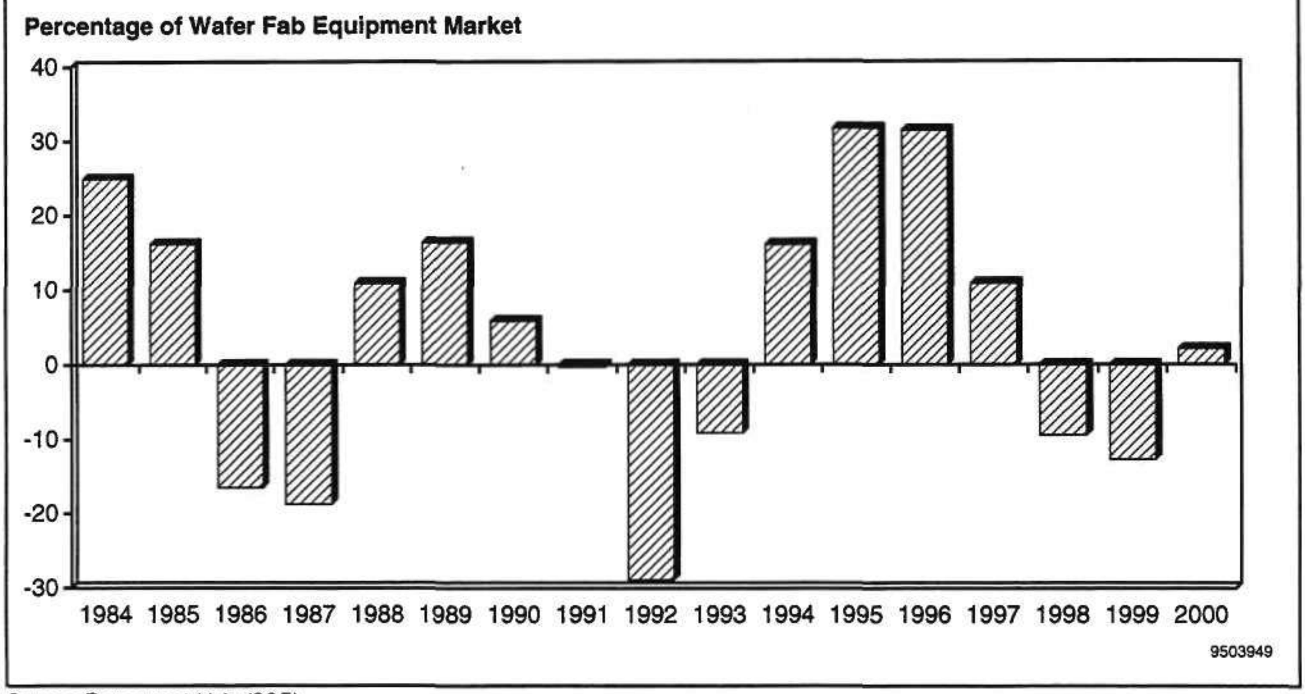
Figures 3-1 and 3-2 show the most recent results of the model. In absolute dollar terms, by the end of 1995 the industry will be $5.2 billion overinvested, or 31.7 percent of the wafer fab equipment market, exceeding levels witnessed during the 1984 and 1989 peaks. These levels are being driven by two basic causes. First, the PC unit demand is continuing to

Figure 3-1
Net Cumulative Over- and Underinvestment of Semiconductor Wafer Fab Equipment



Source: Dataquest (July 1995)

Figure 3-2
Net Cumulative Over- and Underinvestment of Semiconductor Wafer Fab Equipment as a Percentage of Wafer Fab Equipment Market



Source: Dataquest (July 1995)

grow at high-teen annual growth. About one-third of the semiconductor industry, and over one-half of the capital spending on new capacity, is to support this demand.

Second, the DRAM market has not yet converted to run the more silicon-efficient 16Mb DRAM, placing this investment cycle about seven years behind the last cycle. DRAM bit demand generally runs at 50 percent annually, and DRAM manufacturing has depended upon increasing unit densities (increasing the bits per square inch) to meet this demand. Shrinks of existing generations alone only bring 15 to 25 percent annual bit-per-square-inch efficiencies, while converting a fab running 4Mb DRAMs to 16Mb DRAMs would increase bits per square inch by two to three times. As low yields are holding back the economic conversion of the market, top line bit demand is translating to square inch demand (silicon) and the equipment to run it. Because the equipment being installed is fully "convertible" to run 16Mb DRAMs, we can think of these fabs building "pent-up supply" in bits. Once 16Mb DRAM yields (for the 1Mx16 configuration) exceed 60 to 65 percent, it will be more economical to run these lines, and DRAM prices will erode. The current view is that this will not occur until well into 1996.

We have factored into the model an investment in a few 300mm fabs starting in 1997 through 1999, with the bulk in 1998. This is considered an equipment "bubble demand" because the equipment will be shipped into a nonproductive fab (meaning no semiconductor revenue will be initially generated).

With our forecast for a momentum style growth in 1996 and two pause years in 1997 and 1998, the model indicates a reacceleration of equipment spending starting in 1999.

Highlights of Key Equipment Segment Markets and Forecasts

Steppers and Track

From 1989, the peak year of stepper shipments at more than 950 units, the market tumbled to less than 400 tools in 1992 before recovering. During this DRAM-sensitive ramp, we believe the industry will see its first 1,000-stepper year. In fact, we believe over 1,150 steppers will be shipped in 1995. Shifts in the product mix toward higher-priced i-line systems and wide field lenses have also driven up average selling prices (ASPs). This, along with the strong yen, yields a forecast revenue increase of 63 percent on a dollar basis.

Stepper revenue is forecast to grow at a 17.2 percent CAGR, slightly below the market average for 1994 through 2000. Our forecast for stepper unit growth over the five-year forecast horizon remains modest but higher than what we have seen in the past, about 7 percent in a CAGR between 1994 and 2000.

With the adoption of phase shift mask technology, off-axis illumination techniques as well as conventional i-line tools with variable NA, i-line is clearly a viable technology down to the 0.35-micron regime and will continue to dominate the overall stepper technology mix through the 2000. Excimer/deep-UV steppers will begin to represent a more significant portion of the product mix from 1997 onward for use in 0.25-micron (and below) devices, and ICs with large chip areas such as advanced microprocessors, which require large field size capability. Dataquest believes that field size pressures accompanied by shrinking geometry will drive the industry toward step-and-scan (or step-and-stitch) technologies for the majority of excimer/deep-UV shipments, beginning in 1997.

Track equipment is forecast to grow at a 19.9 percent CAGR between 1994 and 2000, slightly ahead of the industry growth of 18.4 percent. While we believe that the rapid shift in the product mix toward higher priced systems has been recently completed, we do expect another product shift to occur in the track market, and higher ASPs, associated with the ramp of deep-UV steppers, which require more sophisticated environmental control systems.

Etch and Clean: Dry Etch and Chemical Mechanical Polishing (CMP)

Dataquest began covering the chemical mechanical polishing (CMP) market in 1993, a year that saw sales increase 121 percent to over $44 million. Dataquest includes the post-CMP clean system, usually sold in conjunction with a CMP tool as part of the cleaning segment and not in the CMP segment. The year 1994 was expected to be another high-growth year, but the market has really been disappointing—growing at a rate slower than the market average to approach $65 million (or 49 percent growth).

The year 1995 holds much the same for the CMP systems, growing about 46 percent to $95 million. We believe that the early adopters are continuing to buy but, risk averse, have been slow to purchase initial or follow-on systems. Also, the application appears to be limited to devices with at least three levels of metal and tends to exclude the DRAM market.

These systems are used to remove material from the surface of the wafer to result in a flat surface over the entire wafer. This global planarization, primarily of dielectric layers, is required to achieve high yields in devices where three or more levels of metal are used. Today's advanced logic and ASIC devices are fueling this market growth, but a key to the near-term success of the market will be how dedicated foundry companies will be to handling their 0.5-micron triple-level metal standard processes. Until recently, most foundries we have talked with will not put CMP into that standard process. With TSMC's recent acceptance of the AMD 486 microprocessors and its disclosure of a CMP tool purchase, this may change; then again TSMC may only run it for the AMD wafers.

Dataquest believes that this technology and market will become a major part of semiconductor manufacturing in the long run but, as with most new technologies, take a bit longer than people would wish. If we were to make a forecast based purely on technology driving the market, we would not be slowing the CMP market forecast in 1997 to 1998. However, we believe those years will see some holding back of capital investment, and history has shown us that even advanced, emerging technologies are rarely spared in a capital slowdown. Nonetheless, CMP is our fastest-growing segment with a 31.9 percent CAGR for the years 1994 through 2000.

Dry etch systems continue to exhibit strong revenue growth, with a CAGR of 19.5 percent forecast for the years 1994 through 2000. Unit shipments are expected to grow as greater multilevel interconnect process capacity is brought on line, increasing the need for dielectric and metal capacity. Relatively strong ASP growth will lend additional momentum to dry etch revenue growth as new high-density plasma systems for 0.35-micron applications enter the market, and multichamber cluster tools continue to increase their presence.

Wet process equipment is forecast to show revenue growth of 17.6 percent annually from 1994 through 2000, basically on par with overall equipment market growth. This market is more heavily dependent on the brick and mortar part of the capital investment dollar, as wafer cleaning is a fundamental in all parts of the fab. Automated wet stations dominate this segment, now accounting for nearly 70 percent of the clean process systems. Emerging areas of cleaning tools include (in order of size) spray processors, post-CMP clean, and vapor phase cleaning. As manufacturers look to novel ways to increase yields, we would expect these and other new techniques to evolve and emerge in importance.

Deposition: CVD, PVD, and Silicon Epitaxy

CVD equipment sales are predicted to grow at an 18.6 percent annualized rate from 1994 through 2000, on par with overall equipment growth. The steady growth in multilevel interconnect capacity will continue to generate demand for dielectric and metal CVD systems. ASP growth will also contribute to revenue growth, as more highly integrated systems with improved productivity and particle control appear in the marketplace. Advanced dielectric deposition systems utilizing HDP sources will be introduced for intermetal dielectric (IMD) applications for sub-0.5-micron processes. Most systems will be introduced on multichamber cluster platforms. Metal CVD will continue to exhibit strong growth, driven by blanket tungsten for contact and via plugs, CVD barrier metals such as CVD titanium nitride, and dichlorosilane (DCS) tungsten silicide for shrink 16Mb and 64Mb DRAMs. For these reasons, the forecast for non-tube CVD systems outperforms tube furnaces.

Sputter deposition systems are also forecast to grow at an annualized rate of 18.6 percent for the years 1994 through 2000. As in the case of dry etch and CVD equipment, continued expansion of multilevel interconnect process capacity is the primary driver behind sputter system growth. Rapid growth in average system ASP has helped drive total revenue growth in 1994, primarily from the quick and expanding dominance of Applied Materials in the market. With Applied now accounting for more than 50 percent of the market, the bulk of the ASP increases are behind us. Revolutionary changes in system architecture, pioneered by the Applied Materials Endura system, will continue to yield improvements in film properties, equipment productivity, and defect density. This is a market segment that will be somewhat buffered from a slowdown in DRAM investment, as the fundamental growth in the number of metal layers in ASICs and logic devices drive a more stable outlook.

The shift from batch- to single-wafer epitaxial systems has been the primary driver on epitaxial deposition systems, as a result of the need for 200mm epitaxial wafer capacity. In 1994 we saw the Applied Materials system become an "Intel accepted supplier," so silicon companies are investing to add this capacity. However, this capacity is more expensive than wafer suppliers would like, so we expect the concept of "mini-batches" to emerge as a viable production strategy, as it has in CVD. Moore Technologies is known to be in the processing of releasing such a new product. A strong automotive and discrete market has increased demand for the specialty batch units. An increased product mix of logic semiconductors, sustained demand for discretes, and 200mm wafer capacity addition will be the primary drivers for epitaxial deposition equipment growth beyond 1995.

Diffusion and RTP

Diffusion systems are expected to demonstrate a CAGR of 17.5 percent for 1994 through 2000. This segment is DRAM- and capital spending-sensitive and therefore tends to be cyclic. The years 1993 through 1995 are dramatic growth years, while 1997 will actually witness some decline.

The displacement of horizontal tube systems by vertical tube reactors will continue. Newer vertical systems will be configurable as multitube clusters with integrated dry clean capability to compete with single wafer cluster tools. Tube systems will also incorporate small batch capabilities to offer greater flexibility for custom and semicustom circuit manufacturers.

RTP will grow at an annualized rate of 25.5 percent for 1994 through 2000. This market grew much faster than we anticipated, nearly doubling in 1994. The real growth for this segment will come from the transition of the thermal "nondepositing" processes away from diffusion tubes and into single-wafer RTP systems for 300mm wafers. We have factored in a large complement of systems into initial 300mm facilities starting in 1997, largely contributing to the higher-than-the-market growth. RTP systems are primarily used today for salicide anneals and are primarily driven by logic and ASIC capacity. Dataquest believes that batch tube systems will continue to resist penetration by RTP in areas such as well drive, BPSG reflow, and thermal oxidation because of the demonstrated cost-of-ownership benefits in these areas, at least through 200mm wafers.

Ion Implantation

Overall ion implantation system revenue is forecast to grow at a CAGR of 17.7 percent for the years 1994 through 2000. This market segment will continue to be the most volatile, because of the highly device-specific nature of the implant segments. The fastest-growing segment is expected to be high-energy implantation, which is evoking intense interest because of its potential for process simplification and manufacturing cost reduction. The first year of true production ramp is expected to occur in 1998 as 0.4-micron technologies become mainstream, although early adopters such as Samsung have placed high-voltage implant into 16Mb DRAMs. The market strength in 1995 has resulted from two impacts. First, Japanese companies are beginning to take interest in applying the technology, and second, the first penetration into logic application is under way.

New implant systems will continue to offer improvement in uniformity, particle control, charging, and wafer throughput. The number of implant steps requiring medium-current ion sources is expected to grow faster than high-dose implant steps, again driven by the higher proportion of the worldwide semiconductor market that is logic, with the shallow junctions preferentially driving the trend toward medium-current implant system sales.

Segments and Tools of Emerging Importance

Yield enhancement is the talk of the moment. If a piece of equipment enhances yield directly in any way, particularly if it is an incremental concept and on the lower end of the price scale, it will gain immediate acceptance. This appears to be the case in three specific areas: photostabilizers, a tool we refer to currently as a pull dryer, and emerging issues in process control/overlay.

Photostabilizers are relatively small systems, selling for perhaps $200,000, that employ a UV-curing technique to treat exposed photoresist on the wafer before placing the wafer into the etcher. Fusion Systems in the United States has been one of the leaders in this area. The system improves the quality of the photoresist in preparation for etch and thus dramatically improves the etch system performance. Samsung is known to have installed many units, and the product segment is starting to attract major interest.

A visit to Steag AG in Germany recently introduced us to the concept of what we currently refer to as a pull dryer. These systems are replacing the spin dryers currently employed within the automated wet stations today. Wafers are placed in the system after a wet cleaning process to dry, but they do not spin. Instead, they are pulled from a bath of IPA/water in a controlled fashion into an IPA vapor atmosphere. As the wafer is pulled out of the liquid sheets off the surface in such a way as to not leave *any* water spots, which often hold killer residue defects. Micron Technology is known to have purchased many of these systems, and we expect this technology to be introduced by several companies in the wafer cleaning area.

Process control systems are the core of the yield enhancement movement, and it is estimated that approximately 80 percent of the failures in ICs (killer defects) may be attributed to particulate contamination. Therefore, pre- and postprocess particle and defect monitoring and characterization are key to increasing yield. There are several key developments to watch currently in the equipment segments of process control that we believe will experience very strong growth in the years ahead. These segments include wafer inspection and review, CD metrology, and thin-film measurement.

Patterned wafer inspection stations have led the way to in-line use in fabs. Demand for unpatterned wafer inspection is also gaining momentum in the applications such as post-CMP inspection. Defect review technology has evolved from microscope-based systems to automated stations that characterize defects at the coordinates provided by wafer inspection systems. Laser-based systems, such as Ultrapointe's recently introduced product, address the throughput issue along with increased resolution. With higher throughput and automated capabilities, defect review stations should follow the inspection segment to be used in-line.

The CD-SEM market has grown tremendously in the past several years, with the major thrust being the introduction of high-throughput automated SEM systems introduced several years ago. Operator "interpretation" of SEM data and measurement has always been a problem in CD metrology, and today's SEM systems have made qualitative improvement to the electron emission source and are equipped with pattern recognition software and hardware, thus automating the interpretation function. In turn, the ASPs have increased twofold in a range of $1.2 million. ASPs will continue to grow along with demand for these automated high-throughput systems.

Thin-film measurement is key to intra- and interlevel metal interconnect and storage capacitance applications. Thin-film measurement systems are used in-line to monitor the in etch, lithography (photoresist), deposition, and diffusion steps. Although this market was driven by logic applications more than memory production, in the past several years DRAM manufacturers have begun integrating thin-film measurement stations into their process lines.

Dataquest Perspective

Wafer fab equipment spending in 1995 will grow 52 percent worldwide, driven by massive spending in the Asia/Pacific region and a PC production boom in Europe. A DRAM-sensitive investment in Japan and continued healthy investment in North America round out this third boom year. Segment growth in 1994 and 1995 is being led by DRAM- or capital spending-sensitive equipment, with steppers, high-current and high-voltage implant, wafer inspection, and polysilicon etch exhibiting significantly stronger growth than market average. We expect no major segment declines in 1995, as capacity additions are broad-based and worldwide. We have increased our forecast growth in 1996 to 21.5 percent in the worldwide wafer fab equipment market, based on backlog and bookings momentum from the 1995 surge and several new Asian company projects coming on line in 1996.

The NCI model that measures the net cumulative under- or overinvestment indicates that by the end of 1995, the semiconductor manufacturing world will be overinvested in wafer fab equipment to the tune of $5.2 billion, or 31.7 percent, exceeding peaks exhibited in 1984 and 1989.

After four strong expansion years in 1993 through 1996, equipment purchases in 1997 should decline modestly, followed by a relatively flat growth in 1998. Investment in DRAM capacity will be curtailed as producers elect to convert their 4Mb DRAM capacity to 16Mb, which adds bit capacity through the instant increase in bits per square inch. Also, many Japanese DRAM facilities now running 150mm wafers will convert to 200mm wafers, further delaying the need for new equipment. DRAM-sensitive equipment technologies or capital-intensive segments such as steppers, implantation, diffusion, and polysilicon etch will be affected more than logic-sensitive technologies such as sputtering, epitaxial reactors, RTP, nontube CVD, or metal etch. The next expansion should kick in by 1999, driven by 0.35- to 0.4-micron capacity expansion.

We have factored in an infrastructure investment in equipment for late 1997 through 1999, which will affect the forecast size of the markets positively. This additional investment will be for initial equipment to fill a few 300mm fabs to run silicon by 1998 and 1999. However, our outlook for a significant 300mm equipment market will wait until after 2000.

Yield enhancement is the trend of the time. Any system technology that can be relatively low-priced and has a direct impact on yield will gain immediate acceptance in volume. Areas particularly important today are cleaning technology, photostabilizers, and process control metrology.

Chapter 4
Silicon Wafer Forecast

Dataquest's current forecast and the underlying assumptions behind our expectations for regional silicon wafer demand reflect significant silicon wafer growth in 1995 and 1996, with upward revisions to the 1997 through 2000 forecast, in line with an increased semiconductor consumption forecasts worldwide. Our latest forecast, along with highlights of some of the key factors affecting the regional markets, are presented here.

Silicon Forecast Tables

Tables in this chapter include Dataquest's most recent forecasts of regional unit silicon wafer consumption. Five tables (4-1 through 4-5) detail unit consumption by region. Individual forecasts of major product segments such as prime, epitaxial, and test and monitor wafers are included. In addition, five tables (4-6 through 4-10) of regional forecasts for wafer size distribution are presented.

The 200mm Wafer Ramps Up

Dataquest has been studying the subject of 200mm wafers and their ramp rate closely over the last year, particularly in light of the massive announcements in fab capacity over the next few years. There are currently 58 new 200mm fabs announced, which will come on line in the three years from 1995 through 1997, and there probably will be several more to come. Half of those announced will come on line in 1996 alone. Wafer suppliers have answered the need with several new wafer plants and billions of dollars of committed investment. We continue to believe that the ramp of 200mm wafers will be somewhat supply-constrained through 1997, that is to say that the industry cannot convert from 150mm at will. In this forecast update, we have revised the forecast—again upward—to reflect expected fab activity in each region and supply increases in place.

While we are stopping short of calling a shortage of 200mm wafers, buyers of wafers will experience firm to rising prices and will be placed on allocation from time to time over the next several years. In an upcoming report, Dataquest will take a closer look at potential shortage issues in the wafer market. In fact, the 200mm wafer may be in the best supply situation compared to other areas in a few years.

The demand for test and monitor wafers will explode with the ramping of the 200mm wafer. Test wafers account for about 15 to 20 percent of wafers at 150mm, but this number is expected to exceed 50 percent for 200mm wafers during the early stages of ramping (estimates for 1994 are about 60 percent). We do expect the percent usage to subside to the one-third level as 200mm processing becomes mature, yet the near-term crunch exacerbates the supply issues.

What about 300mm Wafers?

Now that the wafer size has been settled, and the time horizon for the first 300m plant(s) has been proposed, we are initiating a forecast for consumption of 300mm wafers. The level is still commercially zero before the year

Table 4-1
Forecast of Captive and Merchant Silicon* and Merchant Epitaxial Wafers by Region (Millions of Square Inches)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
Worldwide Total Silicon + Epi	2,449.7	2,919.0	3,409.0	3,987.2	4,478.1	4,742.9	5,132.5	5,680.6	11.7
Merchant and Captive Silicon*	2,157.1	2,535.3	2,951.4	3,468.1	3,917.2	4,126.7	4,453.9	4,920.2	11.7
Epitaxial Silicon	292.6	383.7	457.6	519.1	560.9	616.2	678.6	760.4	12.1
North America Total Silicon + Epi	720.0	832.1	952.3	1,050.1	1,126.8	1,204.0	1,334.6	1,477.8	10.0
Merchant and Captive Silicon*	565.5	641.9	725.9	794.1	849.7	896.2	992.3	1,093.4	9.3
Epitaxial Silicon	154.5	190.2	226.4	256.0	277.1	307.8	342.3	384.4	12.4
Japan Total Silicon + Epi	1,127.3	1,279.7	1,457.2	1,686.2	1,892.4	1,947.7	2,054.4	2,219.0	9.6
Merchant and Captive Silicon*	1,038.3	1,160.2	1,317.7	1,530.5	1,726.3	1,768.5	1,860.2	2,005.0	9.5
Epitaxial Silicon	89.0	119.5	139.5	155.7	166.1	179.2	194.2	214.0	10.2
Europe Total Silicon + Epi	291.2	351.2	414.0	488.7	561.4	609.5	646.9	702.4	12.2
Merchant and Captive Silicon*	255.1	296.7	347.2	411.1	476.7	516.4	545.6	588.9	12.1
Epitaxial Silicon	36.1	54.5	66.8	77.6	84.7	93.1	101.3	113.5	13.0
Asia/Pacific-ROW Total Silicon + Epi	311.2	456.0	585.5	762.2	897.5	981.7	1,096.6	1,281.4	18.8
Merchant and Captive Silicon*	298.2	436.5	560.6	732.4	864.5	945.6	1,055.8	1,232.9	18.9
Epitaxial Silicon	13.0	19.5	24.9	29.8	33.0	36.1	40.8	48.5	16.4

*Includes prime, test, and monitor wafers
Source: Dataquest (July 1995)

Table 4-2
Forecast Growth Rates of Captive and Merchant Silicon* and Merchant Epitaxial Wafers by Region (Percent of MSI)

	1993	1994	1995	1996	1997	1998	1999	2000
Worldwide Total Silicon + Epi	16.8	19.2	16.8	17.0	12.3	5.9	8.2	10.7
Merchant and Captive Silicon*	16.7	17.5	16.4	17.5	12.9	5.3	7.9	10.5
Epitaxial Silicon	17.7	31.1	19.3	13.4	8.1	9.9	10.1	12.1
North America Total Silicon + Epi	10.6	15.6	14.4	10.3	7.3	6.9	10.8	10.7
Merchant and Captive Silicon*	8.2	13.5	13.1	9.4	7.0	5.5	10.7	10.2
Epitaxial Silicon	20.6	23.1	19.0	13.1	8.2	11.1	11.2	12.3
Japan Total Silicon + Epi	15.9	13.5	13.9	15.7	12.2	2.9	5.5	8.0
Merchant and Captive Silicon*	17.2	11.7	13.6	16.1	12.8	2.4	5.2	7.8
Epitaxial Silicon	2.3	34.3	16.7	11.6	6.7	7.9	8.4	10.2
Europe Total Silicon + Epi	23.9	20.6	17.9	18.0	14.9	8.6	6.1	8.6
Merchant and Captive Silicon*	20.8	16.3	17.0	18.4	16.0	8.3	5.7	7.9
Epitaxial Silicon	51.0	51.0	22.6	16.2	9.1	9.9	8.8	12.0
Asia/Pacific-ROW Total Silicon + Epi	30.8	46.5	28.4	30.2	17.8	9.4	11.7	16.9
Merchant & Captive Silicon*	30.5	46.4	28.4	30.6	18.0	9.4	11.7	16.8
Epitaxial Silicon	36.8	50.0	27.7	19.7	10.7	9.4	13.0	18.9

*Includes prime, test, and monitor wafers
Source: Dataquest (July 1995)

2000; however, the recent goal of a fab to come on line by 1998 or 1999 means that 300mm wafers will be made and that significant activity will be occurring in R&D. Although no company has stated a firm commitment, we would expect something to be announced among Samsung, Motorola, Intel, or perhaps one Japanese company (NEC?) by the end of this year toward a 300mm fab. We are assuming that there will be at least two plants, perhaps three, based on who decides to cooperate with whom (we are not forecasting the partnerships).

Further details and issues regarding the move toward 300mm wafers are included in a recent Market Analysis newsletter (SEMM-WW-MA-9503). Please refer to that newsletter for a more detailed discussion.

We believe the first commercially productive plant will be started in the 2000-to-2002 time frame (after the feasibility noted before), with serious volume ramp-up in the years 2002 to 2004. This would be consistent with 0.25-micron technology being primarily produced on 300mm wafers. This means that 200mm wafers represent a two-technology-generation wafer size, and fabs being built today may have longer lives than history would indicate.

Highlights of the North American Silicon Wafer Market and Forecast

Silicon consumption in North America is forecast to grow 14.4 percent in 1995 to 952 million square inches (MSI), followed by a mild 10.3 percent growth in 1996 to 1,050 MSI. Microprocessor and other logic chip demand have been and will continue to be key drivers behind increased silicon

Table 4-3
Forecast of Captive and Merchant Silicon* Wafers by Region
(Millions of Square Inches)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
Worldwide Total Silicon*	2,157.1	2,535.3	2,951.4	3,468.1	3,917.2	4,126.7	4,453.9	4,920.2	11.7
Merchant Silicon	2,032.1	2,398.3	2,814.4	3,331.1	3,780.2	3,989.7	4,316.9	4,783.2	12.2
Captive Silicon	125.0	137.0	137.0	137.0	137.0	137.0	137.0	137.0	0
North America Total Silicon*	565.5	641.9	725.9	794.1	849.7	896.2	992.3	1093.4	9.3
Merchant Silicon	487.5	551.9	635.9	704.1	759.7	806.2	902.3	1,003.4	10.5
Captive Silicon	78.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	0
Japan Total Silicon*	1,038.3	1,160.2	1,317.7	1,530.5	1,726.3	1,768.5	1,860.2	2,005.0	9.5
Merchant Silicon	1,003.3	1,125.2	1,282.7	1,495.5	1,691.3	1,733.5	1825.2	1970	9.8
Captive Silicon	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	0
Europe Total Silicon*	255.1	296.7	347.2	411.1	476.7	516.4	545.6	588.9	12.1
Merchant Silicon	250.1	291.7	342.2	406.1	471.7	511.4	540.6	583.9	12.3
Captive Silicon	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	0
Asia/Pacific-ROW Total Silicon*	298.2	436.5	560.6	732.4	864.5	945.6	1,055.8	1,232.9	18.9
Merchant Silicon	291.2	429.5	553.6	725.4	857.5	938.6	1,048.8	1,225.9	19.1
Captive Silicon	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	0

*Includes prime, test, and monitor wafers
Source: Dataquest (July 1995)

Table 4-4
Forecast Growth Rates of Captive and Merchant Silicon* by Region (Percent of MSI)

	1993	1994	1995	1996	1997	1998	1999	2000
Worldwide Total Silicon*	16.7	17.5	16.4	17.5	12.9	5.3	7.9	10.5
Merchant Silicon	17.6	18.0	17.3	18.4	13.5	5.5	8.2	10.8
Captive Silicon	4.2	9.6	0	0	0	0	0	0
North America Total Silicon*	8.2	13.5	13.1	9.4	7.0	5.5	10.7	10.2
Merchant Silicon	8.1	13.2	15.2	10.7	7.9	6.1	11.9	11.2
Captive Silicon	8.3	15.4	0	0	0	0	0	0
Japan Total Silicon*	17.2	11.7	13.6	16.1	12.8	2.4	5.2	7.8
Merchant Silicon	18.2	12.1	14.0	16.6	13.1	2.5	5.3	7.9
Captive Silicon	-5.4	0	0	0	0	0	0	0
Europe Total Silicon*	20.8	16.3	17.0	18.4	16.0	8.3	5.7	7.9
Merchant Silicon	21.3	16.6	17.3	18.7	16.2	8.4	5.7	8.0
Captive Silicon	0	0	0	0	0	0	0	0
Asia/Pacific-ROW Total Silicon*	30.5	46.4	28.4	30.6	18.0	9.4	11.7	16.8
Merchant Silicon	30.9	47.5	28.9	31.0	18.2	9.5	11.7	16.9
Captive Silicon	16.7	0	0	0	0	0	0	0

*Includes prime, test, and monitor wafers
Source: Dataquest (July 1995)

demand in North America, and epitaxial wafer demand is expected to grow faster than the overall market throughout this decade.

Merchant epi wafer consumption will increase 19 percent to 226 MSI, driven in large part by microprocessor manufacturers, such as Intel and AMD, which build their microprocessors on epi wafers. Strength in the automotive and discrete segments of the chip market have also been a bit stronger than expected. By 1998, epitaxial silicon will account for 25 percent of the square inches consumed in North America—the highest concentration in any region.

Dataquest's longer-term forecast for North American silicon consumption has remained steady despite the overall semiconductor market upward revision since the last update. The primary reason for the conservative forecast comes from the belief that most of the incremental growth in production will be targeted in the European and Asia/Pacific regions (see Chapter 6). We are projecting that total silicon MSI will grow at a 10 percent CAGR for the period of 1994 through 2000.

Highlights of the Japanese Silicon Wafer Market and Forecast

Our forecast for Japan's silicon consumption remains basically unchanged from our last update, with the silicon market growing 13.9 percent to 1,457 MSI in 1995 with continued strong growth in 1996 and softening in 1997 and 1998. The persistent high price of 4Mb DRAMs through 1995, with low yields not allowing the more silicon-efficient 16Mb density to be produced economically, is the reason for the continued near-term optimism. As the conversion to the 16Mb density occurs, silicon square inch demand will ease.

Table 4-5
Forecast of Merchant Prime and Test/Monitor Wafers by Region
(Millions of Square Inches)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
Worldwide Merchant Silicon	2,032.1	2,398.3	2,814.4	3,331.1	3,780.2	3,989.7	4,316.9	4,783.2	12.2
Growth Rate (%)	17.6	18.0	17.3	18.4	13.5	5.5	8.2	10.8	-
Prime	1,616.8	1,892.6	2,187.1	2,560.5	2,903.1	3,062.9	3,328.5	3,714.2	11.9
Test and Monitor	415.3	505.7	627.3	770.6	877.1	926.8	988.4	1069.0	13.3
North America Merchant Silicon	487.5	551.9	635.9	704.1	759.7	806.2	902.3	1003.4	10.5
Growth Rate (%)	8.1	13.2	15.2	10.7	7.9	6.1	11.9	11.2	-
Prime	385.1	430.5	466.8	512.5	558.1	589.8	660.1	743.8	9.5
Test and Monitor	102.4	121.4	169.1	191.6	201.6	216.4	242.2	259.6	13.5
Japan Merchant Silicon	1,003.3	1,125.2	1,282.7	1,495.5	1,691.3	1,733.5	1,825.2	1,970.0	9.8
Growth Rate (%)	18.2	12.1	14.0	16.6	13.1	2.5	5.3	7.9	-
Prime	800.1	894.5	1,024.5	1,184.9	1,338.7	1,376.4	1,458.9	1,579.0	9.9
Test and Monitor	203.2	230.7	258.2	310.6	352.6	357.1	366.3	391.0	9.2
Europe Merchant Silicon	250.1	291.7	342.2	406.1	471.7	511.4	540.6	583.9	12.3
Growth Rate (%)	21.3	16.6	17.3	18.7	16.2	8.4	5.7	8.0	-
Prime	200.1	230.4	270.6	316.4	366.1	396.0	420.2	456.7	12.1
Test and Monitor	50.0	61.3	71.6	89.7	105.6	115.4	120.4	127.2	12.9
Asia/Pacific-ROW Merchant Silicon	291.2	429.5	553.6	725.4	857.5	938.6	1,048.8	1,225.9	19.1
Growth Rate (%)	30.9	47.5	28.9	31.0	18.2	9.5	11.7	16.9	-
Prime	231.5	337.2	425.2	546.7	640.2	700.7	789.3	934.7	18.5
Test and Monitor	59.7	92.3	128.4	178.7	217.3	237.9	259.5	291.2	21.1

Source: Dataquest (July 1995)

Table 4-6
Worldwide Wafer Size Distribution Forecast, 1993-2000
(Percent Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (sq .in.)	1993	1994	1995	1996	1997	1998	1999	2000
Percent Square Inches by Diameter									
2 Inches	3.14	0.1	0.1	0.1	0.1	0	0	0	0
3 Inches	7.07	1.6	1.4	1.2	1.0	0.8	0.7	0.6	0.5
100mm	12.17	16.1	14.8	13.2	11.6	10.3	9.5	9.0	8.4
125mm	19.02	28.8	24.7	22.6	19.8	17.8	16.6	15.4	14.3
150mm	27.38	49.6	48.0	46.5	46.2	45.0	43.8	42.5	41.2
200mm	48.67	3.6	11.0	16.4	21.4	26.1	29.3	32.3	35.5
300mm	109.56	0	0	0	0	0	0	0.1	0.1
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total MSI		2,450	2,919	3,409	3,987	4,478	4,743	5,133	5,681
Growth (%)		16.8	19.2	16.8	16.9	12.3	5.9	8.2	10.7
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 Inches	3.14	1.0	1.1	1.2	0.7	0.6	0.6	0.3	0
3 Inches	7.07	5.6	5.7	5.9	5.7	5.3	4.7	4.6	4.0
100mm	12.17	32.5	35.5	36.8	37.9	37.9	37.1	38.0	39.1
125mm	19.02	37.1	37.9	40.5	41.4	41.9	41.4	41.5	42.6
150mm	27.38	44.4	51.2	58.0	67.3	73.5	75.9	79.7	85.5
200mm	48.67	1.8	6.6	11.5	17.5	24.0	28.6	34.0	41.5
300mm	109.56	0	0	0	0	0	0.02	0.06	0.07
Total Wafers		122.5	138.0	153.9	170.6	183.2	188.3	198.3	212.8
Average Wafer Diameter (Inches)		5.05	5.19	5.31	5.45	5.58	5.66	5.74	5.83

Source: Dataquest (July 1995)

Unlike North America, with its sizable CMOS epi wafer market, Japan's merchant epitaxial wafer market is more focused on discrete and bipolar applications. Therefore, a recovery in the economy will have more of an effect on the growth of Japan's epi wafer market. Epitaxial demand is expected to grow nearly 17 percent in 1995, after a 34 percent increase in 1994. Another good growth year is expected in 1996.

Dataquest remains moderately conservative with its longer-term growth scenario for silicon wafer demand in Japan, as the country continues to work through economic and semiconductor production infrastructure (too heavily dependent on the DRAM) difficulties. Recent investment patterns, however, indicate that the Japanese semiconductor manufacturer is willing to come to the table and invest, preserving their stake in the memory business against the Koreans. The desired shift of the Japanese product mix to higher value-added semiconductors is apparently on the back burner until the current memory cycle subsides, but will again come to the

Table 4-7
North American Wafer Size Distribution Forecast, 1993-2000
(Percent Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (sq. in.)	1993	1994	1995	1996	1997	1998	1999	2000
Percent Square Inches by Diameter									
2 Inches	3.14	0.1	0.1	0.1	0	0	0	0	0
3 Inches	7.07	1.2	1.1	1.0	0.9	0.7	0.6	0.5	0.3
100mm	12.17	22.4	20.1	17.2	15.3	14.1	13.2	12.7	11.9
125mm	19.02	26.5	21.7	19.1	17.2	16.0	14.9	13.7	12.5
150mm	27.38	44.0	42.2	39.6	39.6	39.4	38.2	35.9	35.6
200mm	48.67	5.8	14.8	23.0	27.0	29.8	33.0	37.0	39.5
300mm	109.56	0	0	0	0	0	0.1	0.2	0.2
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total MSI		720	832	952	1,050	1,127	1,204	1,335	1,478
Growth (%)		10.6	15.6	14.4	10.3	7.3	6.9	10.8	10.7
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 Inches	3.14	0.2	0.3	0.3	0	0	0	0	0
3 Inches	7.07	1.2	1.3	1.3	1.3	1.1	1.0	0.9	0.6
100mm	12.17	13.3	13.7	13.5	13.2	13.1	13.1	13.9	14.5
125mm	19.02	10	9.5	9.6	9.5	9.5	9.4	9.6	9.7
150mm	27.38	11.6	12.8	13.8	15.2	16.2	16.8	17.5	19.2
200mm	48.67	0.9	2.5	4.5	5.8	6.9	8.2	10.1	12.0
300mm	109.56	0	0	0	0	0	0.1	0.2	0.3
Total Wafers		37.2	40.2	42.9	45.0	46.8	48.5	52.2	56.0
Average Wafer Diameter (Inches)		4.97	5.14	5.31	5.45	5.54	5.62	5.71	5.79

Source: Dataquest (July 1995)

forefront soon. We are estimating that silicon demand will grow at a 9.6 percent CAGR for the years 1994 through 2000, the slowest growth of all regions.

Highlights of the European Silicon Wafer Market and Forecast

Demand for silicon wafers in Europe, as well as wafer fabrication equipment, remains heavily dependent on the fab activities of foreign semiconductor companies. With increased presence from European companies, the outlook for silicon consumption has brightened.

European silicon demand is forecast to be 414 MSI in 1995, up just under 18 percent from 1994 levels. Siemens' Dresden and other DRAM production and U.S. multinationals Intel, Motorola, and Texas Instruments will continue to ramp to answer the PC production boom in Europe, helping silicon consumption grow another 18 percent in 1996. These driving forces have caused us to call Europe the second fastest-growing region for silicon consumption, growing at a CAGR of 12.2 percent through the year 2000.

Table 4-8
Japanese Wafer Size Distribution Forecast, 1993-2000
(Percent Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (sq. in.)	1993	1994	1995	1996	1997	1998	1999	2000
Percent Square Inches by Diameter									
2 Inches	3.14	0	0	0	0	0	0	0	0
3 Inches	7.07	1.5	1.4	1.3	1.0	0.9	0.8	0.8	0.7
100mm	12.17	11.5	10.8	10	9.3	8.2	7.6	7.1	6.8
125mm	19.02	32.2	29.9	28.3	25.2	22.7	21.7	20.5	19.5
150mm	27.38	53.3	51.6	51.6	51.5	51.5	51.2	50.7	48.9
200mm	48.67	1.5	6.3	8.8	13.0	16.7	18.7	20.8	24.0
300mm	109.56	0	0	0	0	0	0	0.1	0.1
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total MSI		1,127	1,280	1,457	1,686	1,892	1,948	2,054	2,219
Growth (%)		15.9	13.5	13.9	15.7	12.2	2.9	5.5	8.0
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 Inches	3.14	0	0	0	0	0	0	0	0
3 Inches	7.07	2.4	2.5	2.7	2.4	2.4	2.2	2.3	2.2
100mm	12.17	10.7	11.4	12.0	12.9	12.8	12.2	12.0	12.4
125mm	19.02	19.1	20.1	21.7	22.3	22.6	22.2	22.1	22.8
150mm	27.38	21.9	24.1	27.5	31.7	35.6	36.4	38.0	39.6
200mm	48.67	0.3	1.7	2.6	4.5	6.5	7.5	8.8	10.9
300mm	109.56	0	0	0	0	0	0	0.2	0.2
Total Wafers		54.4	59.8	66.4	73.8	79.8	80.5	83.3	87.9
Average Wafer Diameter (Inches)		5.14	5.22	5.28	5.39	5.49	5.55	5.60	5.67

Source: Dataquest (July 1995)

Epitaxial wafer demand in the region will increase from 36 MSI in 1993 to 67 MSI in 1995, a nearly doubling in consumption in two years, a direct result of Intel in Ireland. Beyond 1995, epitaxial wafer demand will come from European producers, leading to a CAGR just 1 percentage point above polished bare wafer consumption through the decade.

Highlights of the Asia/Pacific-ROW Silicon Wafer Market and Forecast

Silicon consumption is growing at a 28.4 percent pace in 1995, the largest growth rate of any other region in the world. Production is expanding at a fierce pace, and not expected to ease through 1997, as many large 200mm fab projects are in various stages of construction and start-up. As the Asia/Pacific region collects the largest proportion of 1995 capital moneys, the trend for high silicon consumption growth will continue unabated. The phenomenal growth in silicon consumption Asia/Pacific in 1995 is tied directly to the manufacturing activities of the Korean DRAM producers. Future growth will be seen here, but increased production in Taiwan,

Table 4-9
European Wafer Size Distribution Forecast, 1993-2000
(Percent Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (sq. in.)	1993	1994	1995	1996	1997	1998	1999	2000
Percent Square Inches by Diameter									
2 Inches	3.14	0.2	0.1	0.1	0	0	0	0	0
3 Inches	7.07	1.7	0.7	0.5	0.4	0.2	0.1	0.1	0.1
100mm	12.17	22.0	20.5	19.7	17.0	15.0	13.5	12.5	11.8
125mm	19.02	30.1	21.7	20.8	18.0	15.7	14.2	13.2	12.5
150mm	27.38	42.3	43.0	44.1	45.1	45.2	44.7	44.2	42.9
200mm	48.67	3.7	14.0	14.8	19.5	23.9	27.5	30	32.7
300mm	109.56	0	0	0	0	0	0	0	0
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total MSI		291	351	414	489	561	610	647	702
Growth (%)		23.9	20.6	17.9	18.0	14.9	8.6	6.1	8.6
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 Inches	3.14	0.2	0.1	0.1	0	0	0	0	0
3 Inches	7.07	0.7	0.3	0.3	0.3	0.2	0.1	0.1	0.1
100mm	12.17	5.3	5.9	6.7	6.8	6.9	6.8	6.6	6.8
125mm	19.02	4.6	4.0	4.5	4.6	4.6	4.6	4.5	4.6
150mm	27.38	4.5	5.5	6.7	8.0	9.3	10	10.4	11.0
200mm	48.67	0.2	1.0	1.3	2.0	2.8	3.4	4.0	4.7
300mm	109.56	0	0	0	0	0	0	0	0
Total Wafers		15.5	16.9	19.6	21.7	23.7	24.8	25.7	27.3
Average Wafer Diameter (Inches)		4.89	5.14	5.19	5.35	5.49	5.59	5.67	5.73

Source: Dataquest (July 1995)

Singapore, and most recently announced Thailand foundries will also contribute to the growth. Foundry-related capital spending in these Asia/Pacific countries has exploded, increasing from about $900 million in 1994 to over $1.6 billion in 1995. As these fabs come on line in 1995 and beyond, they will provide some regional consumption stability as memory-related silicon consumption cools in 1997 and 1998. Taiwan, with its many new DRAM producers coming on line in 1996, will cause silicon consumption to grow by more than 30 percent again in 1996. Asia/Pacific-ROW remains the fastest-growing silicon consumer, with a five-year CAGR forecast of 16.9 percent.

Dataquest's First Silicon Revenue Forecast

Dataquest has been tracking silicon wafer revenue and market share since 1985 but has always provided forecast information in terms of square inch area and unit wafer size distributions. With the announcement of the initial public offering of MEMC Electronic Materials (during July 1995),

Table 4-10
Asia/Pacific-ROW Wafer Size Distribution Forecast, 1993-2000
(Percent Square Inches by Diameter and Unit Distribution by Wafer Starts)

Diameter	Area (sq. in.)	1993	1994	1995	1996	1997	1998	1999	2000
Percent Square Inches by Diameter									
2 Inches	3.14	0.6	0.5	0.4	0.3	0.2	0.2	0.1	0
3 Inches	7.07	2.9	2.4	1.9	1.6	1.3	1.0	0.8	0.6
100mm	12.17	13.0	12.0	9.8	7.9	7.0	6.4	6.0	5.2
125mm	19.02	20.8	17.8	15.4	12.4	11.0	10	9.2	8.2
150mm	27.38	56.3	52.3	47.0	44.3	38.0	35.4	34.3	33.4
200mm	48.67	6.4	15.0	25.5	33.5	42.5	46.9	49.4	52.4
300mm	109.56	0	0	0	0	0	0.1	0.2	0.2
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total MSI		311	456	586	762	898	982	1,097	1,281
Growth (%)		30.8	46.5	28.4	30.2	17.8	9.4	11.7	16.9
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 Inches	3.14	0.6	0.7	0.7	0.7	0.6	0.6	0.3	0
3 Inches	7.07	1.3	1.5	1.6	1.7	1.7	1.4	1.2	1.1
100mm	12.17	3.3	4.5	4.7	4.9	5.2	5.2	5.4	5.5
125mm	19.02	3.4	4.3	4.7	5.0	5.2	5.2	5.3	5.5
150mm	27.38	6.4	8.7	10.1	12.3	12.5	12.7	13.7	15.6
200mm	48.67	0.4	1.4	3.1	5.2	7.8	9.5	11.1	13.8
300mm	109.56	0	0	0	0	0	0.1	0.2	0.2
Total Wafers		15.4	21.2	24.9	29.9	32.9	34.5	37.2	41.5
Average Wafer Diameter (Inches)		5.07	5.24	5.47	5.69	5.90	6.02	6.13	6.27

Source: Dataquest (July 1995)

we believe it is now important to consider the revenue-generating capability of the industry.

We believe a revenue forecast will benefit our clients, gaining increased visibility to the capital markets for the industry. Table 4-11 contains the revenue forecast for silicon wafers worldwide. In our analysis, we have concluded that the revenue forecast would resemble the semiconductor industry more closely than the capital spending markets. The concept of semiconductor revenue per square inch is more closely tied to silicon consumption than raw wafer capacity of the industry. The six-year CAGR of 15.3 percent is about 1 percentage point below the semiconductor forecast of 16.2 percent, consistent with the model that semiconductor manufacturers will try to control the costs associated with manufacturing, which includes using silicon more efficiently in the future.

Table 4-11
Worldwide Merchant Silicon Wafer Revenue Forecast, 1992-2000
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
Worldwide	2,991	3,554	4,592	5,591	6,778	7,837	8,537	9,444	10,793	15.3
Percent Growth	2.7	18.8	29.2	21.8	21.2	15.6	8.9	10.6	14.3	-

Note: This table's data includes polished, virgin test, and epitaxial silicon.
Source: Dataquest (July 1995)

Dataquest Perspective

The silicon market, driven by a stronger long-term picture for semiconductors in general, will grow faster over the next six years than the recent past. As the industry transforms into a 200mm baseline, the outlook for silicon wafer manufacturers becomes brighter. Silicon manufacturers have answered the call for 200mm capacity, and the semiconductor market has again responded with the cry "More, more!" We believe silicon manufacturers ramp plans in 200mm have been strategically and smartly measured, because the overcapacity situations of 1985 and after are still remembered.

While there will be activity with 300mm wafers, this is expected to be R&D-focused and low volumes until after the turn of the decade.

Chapter 5
Semiconductor Consumption Forecast

This chapter presents data on the worldwide semiconductor market by region. The regional semiconductor market, or regional semiconductor consumption, deals with where chips are consumed; this contrasts with regional semiconductor production, which deals with where chips are manufactured. The data presented here is for the merchant market and does not include the value of chips made by captive semiconductor manufacturers for internal use.

This is an excerpt from the *Semiconductor Five-Year Forecast*, published by Dataquest in April (SCND-WW-MT-9501). Further details regarding this forecast can be found in that publication.

Yearly exchange rate variations can have a significant effect on the 1988 through 1994 data in the following tables. For more information about the exchange rates used and their effects, refer to Appendix B.

Semiconductor Consumption

Table 5-1 shows revenue and growth from semiconductor shipments for the years 1988 through 1998, broken down by region. Table 5-2 shows revenue and growth from semiconductor shipments for the years 1994 through 2000, broken down by region.

Table 5-1
Worldwide Semiconductor Consumption* by Region (Millions of U.S. Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1994
North America	15,844	17,070	16,540	16,990	20,430	27,926	35,939	16.1
Percent Growth	23.2	7.7	-3.1	2.7	20.2	36.7	28.7	-
Japan	20,772	21,491	20,257	22,496	20,579	24,645	31,010	7.6
Percent Growth	39.2	3.5	-5.7	11.1	-8.5	19.8	25.8	-
Europe	8,491	9,498	10,415	11,014	12,218	15,461	20,819	17.0
Percent Growth	30.7	11.9	9.7	5.8	10.9	26.5	34.7	-
Asia/Pacific-ROW	5,752	6,280	7,333	9,194	12,034	17,486	22,812	29.4
Percent Growth	45.0	9.2	16.8	25.4	30.9	45.3	30.5	-
Worldwide	50,859	54,339	54,545	59,694	65,261	85,518	110,580	15.3
Percent Growth	33.0	6.8	0.4	9.4	9.3	31.0	29.3	-

* Includes merchant semiconductor companies only
NA = Not applicable
Source: Dataquest (July 1995)

Table 5-2
Worldwide Semiconductor Consumption* by Region (Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
North America	35,939	45,307	53,570	61,770	72,163	83,191	98,414	18.3
Percent Growth	28.7	26.1	18.2	15.3	16.8	15.3	18.3	-
Japan	31,010	35,897	39,599	41,945	45,087	49,905	54,896	10.0
Percent Growth	25.8	15.8	10.3	5.9	7.5	10.7	10.0	-
Europe	20,819	26,088	28,932	32,860	37,671	42,607	49,168	15.4
Percent Growth	34.7	25.3	10.9	13.6	14.6	13.1	15.4	-
Asia/Pacific-ROW	22,812	28,525	33,879	39,481	47,923	58,543	70,661	20.7
Percent Growth	30.5	25.0	18.8	16.5	21.4	22.2	20.7	-
Worldwide	110,580	135,817	155,980	176,056	202,844	234,246	273,139	16.3
Percent Growth	29.3	22.8	14.8	12.9	15.2	15.5	16.6	-

* Merchant semiconductor sales only
Source: Dataquest (July 1995)

Chapter 6
Semiconductor Production Forecast

This chapter presents data on the worldwide semiconductor production by region. Semiconductor production is defined by the place where the wafers are fabricated. Regional semiconductor production includes all production in the region, including merchant and captive producers and all foreign producers. For instance, North American semiconductor production includes Digital Equipment and Delco fabs as well as Japanese company and European company fabs in North America.

Yearly exchange rate variations can have a significant effect on the 1988 through 1994 data in the following tables. For more information about the exchange rates used and their effects, refer to Appendix B.

The semiconductor industry has a global manufacturing business. Production of semiconductors is constantly shifting among regions, as new capital money is flowing toward areas of relative lower capital cost, and higher-growth areas of consumption. Dataquest reviews some of the trends and potential impacts for the future.

Historical Semiconductor Production

Table 6-1 shows the historical semiconductor production for the years 1988 through 1994 broken down by region. Dataquest follows a methodology that employs the use of our fab database, estimating the memory, microcomponent, and logic production components separately, and estimating net production among regions for foundry activity. This approach provides insight in observing and forecasting production trends.

Because of the reclassification of the MOS portion of IBM Microelectronics' business as merchant, the captive production figures changed dramatically in 1993. However, IBM's bipolar production, which is consumed internally, is still classified as captive.

Captive Semiconductor Production

Semiconductor production from captive manufacturers is estimated to be $1.98 billion in 1994, down from just over $2 billion in 1993. IBM restructured and entered the merchant semiconductor market as of 1993. Dataquest has reclassified IBM's MOS semiconductor production to merchant, but the bipolar products (exclusively used internally) are still reported as captive. This part of IBM's business, which will be converted to MOS over the next four to five years, resulted in a lower production figure for captive production in 1994 and for future years.

Many captive producers may consider the move to merchant to take better advantage of the worldwide growth of semiconductors, leveraging their sunk costs in plant and equipment for higher return in a larger end-user base. Still others may elect to take advantage of the now evolving and maturing foundry business, electing to contract out their manufacturing rather than invest in expensive new facilities for their relatively small production base. We have not, however, included any such movement to merchant or fabless in our captive production forecast.

Table 6-1
Worldwide Semiconductor Production* by Region, 1988-1994 (Millions of U.S. Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1988-1994
Total North America	20,533	22,232	24,202	26,039	29,457	33,446	40,268	11.9
Percent Growth	20.8	8.3	8.9	7.6	13.1	13.5	20.4	-
Percent Worldwide	37.3	37.6	40.8	40.4	41.8	38.2	35.8	-
Merchant	17,326	18,464	20,453	22,275	25,248	31,745	38,508	14.2
Captive	3,207	3,768	3,749	3,764	4,209	1,701	1,760	-9.5
Total Japan	26,732	28,527	26,384	28,338	28,023	34,744	44,670	8.9
Percent Growth	40.5	6.7	-7.5	7.4	-1.1	24.0	28.6	-
Percent Worldwide	48.6	48.2	44.5	44.0	39.8	39.7	39.7	-
Merchant	26,388	28,119	25,977	27,925	27,664	34,744	44,670	9.2
Captive	344	408	407	413	359	0	0	-100.0
Total Europe	5,854	6,451	6,350	6,979	8,589	11,772	15,780	18.0
Percent Growth	23.9	10.2	-1.6	9.9	23.1	37.1	34.0	-
Percent Worldwide	10.6	10.9	10.7	10.8	12.2	13.4	14.0	-
Merchant	5,277	5,782	5,723	6,396	7,957	11,452	15,560	19.7
Captive	577	669	627	583	632	320	220	-14.8
Total Asia/Pacific-ROW	1,868	1,974	2,392	3,097	4,391	7,577	11,842	36.0
Percent Growth	71.8	5.7	21.2	29.5	41.8	72.6	56.3	-
Percent Worldwide	3.4	3.3	4.0	4.8	6.2	8.7	10.5	-
Merchant	1,868	1,974	2,392	3,097	4,391	7,577	11,842	36.0
Captive	NA	NA	NA	NA	NA	NA	NA	-
Worldwide	54,987	59,184	59,328	64,453	70,460	87,539	112,560	12.7
Percent Growth	31.4	7.6	0.2	8.6	9.3	24.2	28.6	-
Merchant	50,859	54,339	54,545	59,693	65,260	85,518	110,580	13.8
Percent Growth	33.0	6.8	0.4	9.4	9.3	31.0	29.3	-
Captive	4,128	4,845	4,783	4,760	5,200	2,021	1,980	-11.5
Percent Growth	15.2	17.4	-1.3	-0.5	9.2	-61.1	-2.0	-

* Includes only merchant and captive semiconductor company sales
NA = Not applicable
Source: Dataquest (July 1995)

The Start of a Trend: Europe a Production Mecca?

The production trends of the last three years may contain two or three surprises to some. Of no surprise is the strong growth in Asia/Pacific production, breaking over 10 percent of worldwide production in 1994. The strength in Asian DRAM producers and the emergence of the foundry market have been, and will continue to be, the key drivers in that growth. Increased and somewhat uninhibited capital spending recently will certainly keep this trend in place.

What may be surprise No. 1 is the strength in European production, expanding from just under 11 percent of the semiconductors produced in 1991 to 14 percent in 1994. This is additionally remarkable in that growth in the last three years have been good overall, resulting in a more than doubling of the region's production in three years. Very high capital spending growth in 1995 will keep this trend intact for a few more years at least. Why the move to Europe? With the region's economies recovering and the PC boom ongoing, Europe has attracted PC production, particularly in the United Kingdom. Semiconductor production has moved along with the PC, with Intel and DRAM producers worldwide taking part. In addition, the acceleration of telecommunications-related semiconductor production benefits the European companies.

What may be surprise No. 2 is the relative decline in the percentage of the world's production being done in the United States. Over the last two years, North American production decreased from about 42 to 36 percent of the world's production overall. Several factors are at work here. First, North American multinational companies have been investing heavily overseas. North America has been a net exporter of capital for several years now, and foreign companies have yet to balance the scales with investments inside the United States. This trend should stabilize over the next several years, as Japanese and Korean companies have started to accelerate their investment in the United States.

Second, while U.S. companies are recognized as technology leaders, they have recently begun calling upon foreign producers to manufacture their products in the foundry market. While fabless companies have been the majority of the market to this point, starting in 1994 we saw a major shift in the "integrated device manufacturer," or IDM (a merchant supplier of semiconductors that has a fab), to increase the use of foundries. In 1995, we expect the U.S. IDMs to increase their foundry purchases by 100 percent, with most of this production overseas.

And third, while Japanese and European companies have invested somewhat outside their own country, these companies have remained "patriots" of the domestic economy and have kept the vast majority of investment within the region. This, along with the strong DRAM market over the last two years, has stabilized the Japanese production proportion over the last two years, keeping the same approximate 40 percent share of the production market (this could be surprise No. 3). However, the DRAM market is cyclical, and Japanese foundries will feel pressure from Asian producers, so we expect a resumption of the gradual decay in the base of production in Japan through the rest of the decade.

Semiconductor Production Trends: Accelerating Shift to Asia/Pacific

Table 6-2 shows forecast semiconductor production by region for the period from 1994 through 2000. The major trend is the growth of the Asia/Pacific region at mostly the expense of Japan. Companies like TSMC in Taiwan, Chartered Semiconductor in Singapore, and SubMicron Technology in Thailand will accelerate capacity rapidly beginning in 1996 and beyond. Furthermore, new DRAM companies (Vanguard, PowerChip, and Nan Ya) have sprung up in Taiwan, likely to further erode Japanese DRAM share. By 2000, Dataquest believes that Asia/Pacific-ROW will expand to over 14 percent on a revenue basis.

North America will remain steady on a percentage basis, with Europe's expanding with a product mix shifting to contain a higher memory

Table 6-2
Worldwide Semiconductor Production* by Region, 1994-2000 (Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-2000
Total North America	40,268	48,156	54,698	61,157	71,229	83,692	97,305	15.8
Percent Growth	20.4	19.6	13.6	11.8	16.5	17.5	16.3	-
Percent Worldwide	35.8	35.0	34.7	34.4	34.8	35.5	35.4	-
Merchant	38,508	46,449	53,033	59,507	69,575	81,986	95,599	16.4
Captive	1,760	1,707	1,665	1,650	1,654	1,706	1,706	-0.5
Total Japan	44,670	53,919	60,520	66,901	75,053	85,500	96,964	13.8
Percent Growth	28.6	20.7	12.2	10.5	12.2	13.9	13.4	-
Percent Worldwide	39.7	39.2	38.4	37.6	36.7	36.2	35.3	-
Merchant	44,670	53,919	60,520	66,901	75,053	85,500	96,964	13.8
Captive	NA	NA	NA	NA	NA	NA	NA	-
Total Europe	15,780	19,718	23,509	27,545	32,300	36,338	41,820	17.6
Percent Growth	34.0	25.0	19.2	17.2	17.3	12.5	15.1	-
Percent Worldwide	14.0	14.3	14.9	15.5	15.8	15.4	15.2	-
Merchant	15,560	19,558	23,397	27,465	32,252	36,308	41,790	17.9
Captive	220	160	112	80	48	30	30	-28.3
Total Asia/Pacific-ROW	11,842	15,891	19,030	22,183	25,964	30,452	38,786	21.9
Percent Growth	56.3	34.2	19.8	16.6	17.0	17.3	27.4	-
Percent Worldwide	10.5	11.5	12.1	12.5	12.7	12.9	14.1	-
Merchant	11,842	15,891	19,030	22,183	25,964	30,452	38,786	21.9
Captive	NA	NA	NA	NA	NA	NA	NA	NA
Worldwide	112,560	137,684	157,757	177,786	204,546	235,982	274,875	16.0
Percent Growth	28.6	22.3	14.6	12.7	15.1	15.4	16.5	-
Merchant	110,580	135,817	155,980	176,056	202,844	234,246	273,139	16.3
Percent Growth	29.3	22.8	14.8	12.9	15.2	15.5	16.6	-
Captive	1,980	1,867	1,777	1,730	1,702	1,736	1,736	-2.2
Percent Growth	-2.0	-5.7	-4.8	-2.6	-1.6	2.0	0	-

* Includes merchant and captive semiconductor company sales
NA = Not applicable
Source: Dataquest (July 1995)

component, driven by the need for proximity to PC production, as more DRAM capacity is added by large internationals over the next several years.

Dataquest Perspective

Where the PC goes, so go semiconductors. This is true from the perspective of the business forecast, as well as the production line. Europe and Asia/Pacific, with very large capital spending upticks over the last several years and continuing in 1995, will continue to gain share in world production over the next several years.

The shifts and currents in semiconductor production trends mean that equipment and material suppliers will absolutely need a global presence in every sense of the word to remain competitive in the market. Product supply and support can no longer concentrate on local trends, as all major semiconductor companies have made it clear that they are investing on a worldwide basis.

We see evidence of these trends as Lam Research and Watkins-Johnson set up direct offices in Japan, Tokyo Electron Ltd. (TEL) acquires the Varian half of Varian/TEL to go direct in Europe and North America, and as ASM Lithography accelerates penetration into Asia/Pacific. Silicon plants are now being strategically placed, such as SEH's Malaysian plant, Komatsu's joint venture with Formosa Plastics in Taiwan, and MEMC's joint ventures in both Korea (Posco-Huls) and Taiwan (Taisil).

Furthermore, the concept of contract manufacturing in semiconductors is clearly here to stay. Equipment and material suppliers could find themselves selling their technical products to an international team from several companies, including the manufacturer and the designer. However, the emergence of the dedicated foundry company, taking ownership of the process and manufacturing flow, will tend to centralize this activity.

Appendix A
Economic Assumptions, Second Quarter of 1995

Worldwide Business Expectations Weaken as Outlooks for Business Sales and Net Profits Show Moderate Declines

The Dun & Bradstreet Corporation's most recent quarterly survey of more than 11,000 global business executives in 16 countries revealed that small gains were expected in Europe while declines were expected in North America and the Pacific region. The overall picture is one of slightly lower expectations just below the peaks set at the end of last year. Survey results indicate that devaluation of the Mexican peso and recent softness in the dollar are not expected to cause a broad downturn in the global economy. However, the results, together with the ongoing uncertainty generated by continuing turmoil in foreign exchange markets, suggest that growth in the world economy is just past its peak.

A summary of gross national product and consumer price index forecasts are in Tables A-1 and A-2, respectively.

Net Sales and Net Profits Decline in Nearly All Regions

Dun & Bradstreet's measures of the worldwide outlook for net sales and net profits declined moderately from year opening levels. Both net sales and net profit measures moved down four points to 50 and 39, respectively. The sharpest declines were recorded in the Pacific region, driven by sharp drops in Japan and Australia. Here, the Net Sales Index fell 10 points to 39, and the Net Profits Index dropped from its year opening level of 38 to 29. In the Americas, weakened economic performance was expected. The North American Net Profits Index fell five points to 48 and the Net Sales Index dropped four points to 44. In Brazil, the two indices lost 21 and 23 points, respectively. In Europe, executives expected a slight gain sales with the Net Sales Index rising two points from 47 to 49, but they did not anticipate an increase in net profits, and the Net Profits Index edged down one point to 30.

Table A-1
GDP/GNP Growth Rates with Constant Prices and Exchange Rates, Local Currencies (Percent)

Year	United States	Canada	Japan	France	Germany	Italy	United Kingdom
1990	1.2	-0.2	4.8	2.5	5.9	2.1	0.6
1991	-0.6	-1.8	4.3	0.8	5.0	1.3	-2.3
1992	2.6	0.6	1.1	1.2	2.2	0.7	-0.5
1993	3.1	2.2	-0.2	-1.0	-1.1	-0.7	2.1
1994	4.1	4.5	0.6	2.5	2.9	2.3	3.9
1995	3.1	4.0	1.2	3.2	3.1	3.0	3.2
1996	3.2	3.0	2.3	2.9	3.3	2.7	3.0
1997	3.7	3.0	3.0	3.0	3.3	2.6	2.9
1998	3.2	2.8	3.5	3.1	3.2	2.5	2.7
1999	2.9	2.8	3.5	3.2	3.2	2.5	2.7

Source: Dataquest (July 1995)

Table A-2
Consumer Price Index Growth Rates (Percentage Change)

Year	United States	Canada	Japan	France	Germany	Italy	United Kingdom
1990	5.4	4.8	3.1	3.4	2.7	6.1	9.5
1991	4.2	5.6	3.3	3.1	3.5	6.4	5.9
1992	3.0	1.5	1.6	2.4	4.0	5.4	3.7
1993	2.9	1.8	1.3	2.1	4.2	4.2	1.6
1994	2.6	0.2	0.7	1.7	3.0	3.9	2.4
1995	2.9	2.2	0.4	2.0	2.3	5.1	3.6
1996	3.5	2.6	0.8	2.3	2.8	4.6	3.5
1997	3.3	2.5	1.1	2.3	2.9	4.3	3.2
1998	3.0	2.3	1.2	2.1	2.7	3.9	3.0
1999	2.8	2.2	1.2	1.7	2.5	3.2	2.7

Source: Dataquest (July 1995)

North America: Increasing Concerns about Mexico in Light of Steep Declines in Net Sales and Net Profits

Expectations for both Net Sales and Net Profits plummeted from their year opening levels. Both the Net Profits and Net Sales Indices fell 91 points to 10 and minus 3, respectively. Three months ago in Mexico, business executives were almost unanimous in their expectations that sales would increase. Now, more businesses are expecting sales to decline rather than increase. Interestingly, Mexico's Selling Prices Index remained unchanged from its year opening level, suggesting Mexico's rate of inflation may be higher than expected in 1995.

In the United States, both the Net Sales and Net Profits Indices declined somewhat. The Net Profits Index declined three points to 53 while the Net Sales Index declined two points to 60. In contrast, both indices rose five points in Canada, the Net Profits Index rising to 47 and the Net Sales Index rising to 53. Growth rate forecasts are as follows:

- Mexico's real gross domestic product (GDP) is forecast to contract 2.5 percent in 1995, following 3.5 percent growth in 1994. Positive growth of 2.0 percent is expected in 1996. Growth is then anticipated to accelerate to between 4.0 and 5.0 percent through 1999.
- The United States' GDP is forecast to grow 3.1 percent in 1995, decelerating from 4.1 percent in 1994. Growth is expected to accelerate somewhat in 1996 to 3.2 percent and is anticipated to remain at or near this level through 1999.
- Canada's GDP is forecast to grow 4.0 percent in 1995, decelerating from 4.5 percent in 1994. Growth is expected to further decelerate to 3.0 percent in 1996 and is anticipated to remain at this level through 1999.

Europe: Conditions Expected to Remain Quite Healthy

Survey results indicate that inflation expectations are down slightly, and hiring plans are up. Although overall growth may not continue to accelerate, conditions should remain healthy. Interestingly, European survey results varied greatly by country. While expectations for rising profits were relatively stable in most nations, the Net Profits Index for Germany, the Netherlands, and Switzerland climbed 6, 7, and 23 points, respectively, to 15, 49, and 6. Additionally, the Net Sales Index rose 4 points in the Netherlands and 13 points in Switzerland, but fell 3 points in Germany. Growth rate forecasts are as follows:

- Germany's real GDP is forecast to grow 3.1 percent in 1995, accelerating from 2.9 percent growth in 1994. Growth is expected to accelerate further to 3.3 percent in 1996 and then slow to slightly below this rate through 1999.
- France's real GDP is forecast to grow 3.2 percent in 1995, accelerating from 2.5 percent growth in 1994. Growth is anticipated to slow somewhat to 2.9 percent in 1996 but then to accelerate to 3.1 percent through 1999.
- Italy's real GDP is forecast to grow 3.0 percent in 1995, accelerating from 2.5 percent in 1994. Growth is expected to decelerate somewhat to 2.7 percent in 1996 and then slow to around 2.5 percent through 1999.
- The United Kingdom's real GDP is forecast to grow 3.2 percent in 1995, decelerating from 3.9 percent growth in 1994. Growth is anticipated to decelerate to 3.0 percent in 1996 and slow still further to 2.8 percent through 1999.

Japan and Pacific Rim: Strong Yen Expected to Exact a Toll on Japan

Although expected sales levels remain fairly high, the strong yen is expected to exact a heavy toll on Japan's export-dependent sales. True, expectations are still above their levels a year ago, but the currency situation has considerably dampened Japan's recovery. Reflecting this, both the Net Sales Index and Net Profits Index fell from year opening levels in Japan, the Net Sales Index falling 12 points to 23, and the Net Profits Index declining eight points to 3. As noted earlier, however, these values are still well above last year's levels when they stood at minus 7 and minus 18, respectively. Elsewhere, expectations also declined sharply in Australia. Here, the Net Sales Index declined 14 points to 39, and the Net Profits Index dropped 12 points to 33. Expectations remain more or less stable in New Zealand with the Net Sales Index remaining unchanged at 57 and the Net Profits Index gaining one point to 47. Growth rate forecasts are as follows:

- Japan's real GDP is expected to grow at 1.2 percent in 1995, accelerating from 0.6 percent in 1994. Growth is anticipated to accelerate to 2.3 percent in 1996 and then quicken to 3.3 percent through 1999.
- Australia's real GDP is expected to grow at 3.8 percent in 1995, decelerating from 5.1 percent in 1994. Growth is expected to slow to 3.2 percent in 1996 and then decelerate further to 2.9 percent through 1999.
- China's real GDP is expected to grow at 9.5 percent in 1995, decelerating from 11.8 percent in 1994. growth is expected to slow to 9.0 percent in 1996 and then decelerate further to 8.0 percent through 1999.

- Taiwan's real GDP is expected to grow at 6.5 percent in 1995, unchanged from 1994. Growth is anticipated to remain at 6.5 percent through 1999.
- South Korea's real GDP is expected to grow at 8.0 percent in 1995, decelerating from 8.4 percent in 1994. Growth is anticipated to slow to 7.0 percent in 1996 and remain at that level through 1999.

The quarterly International Survey of Business Expectations is modeled on D&B's quarterly Survey of U.S. Business Expectations, which has been conducted in the United States since 1947. The survey participants are asked if they expect increases, decreases, or no change in their sales, profits, prices, inventories, and employment levels in the upcoming quarter, compared with the same quarter a year ago. Results of the U.S. survey have proven highly accurate, with quarterly forecasts closely paralleling actual performance.

(The current surveys, completed in March, use similar sampling and interviewing procedures in all countries. Hence, the results provide unique "apples-to-apples" comparisons of trends in business expectations worldwide. The D&B index figures used here represent the net percentage of survey respondents expecting higher sales, profits, and so on. The indices are calculated by subtracting the percentage of respondents expecting decreases from those expecting increases. GDP growth rates noted here are D&B's most current forecasts from June.)

Appendix B
Exchange Rates

Dataquest does not forecast exchange rates per se; however, we do forecast semiconductor markets in several regions of the world, and we use the U.S. dollar as a common currency for intermarket comparisons and aggregation. In general, in the forecast period Dataquest assumes that the actual exchange rate of the full month prior to the month in which the forecast input assumptions are set will apply throughout all future months of the forecast interval. For the current iteration of the semiconductor consumption forecast:

- Actual monthly exchange rates are used for all months in the historical interval up to May 1995.
- The May 1995 exchange rate is assumed to hold for the months June through December 1995, and throughout all future years 1996 to 2000.

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar values. Table B-1 outlines these rates.

Table B-1
Average 1994 and 1995 Exchange Rates per U.S. Dollar

Country	1994	1995*	U.S. Expected Appreciation (Percent)
Argentina (Peso)	NA	1.00	NM
Australia (Dollar)	NA	1.37	NM
Austria (Schilling)	11.40	9.97	-12.56
Belgium (Franc)	33.36	29.20	-12.47
Brazil (Real)	NA	0.90	NM
Chile (Peso)	NA	390.26	NM
China (Renminbi)	8.5384	8.3747	-1.92
Colombia (Peso)	NA	872.5278	NM
Denmark (Krone)	6.3508	5.5758	-12.20
European Community (ECU)	0.844	0.769	-8.82
Finland (Markka)	5.2061	4.3755	-15.96
France (Franc)	5.5367	4.9927	-9.83
Germany (Mark)	1.6203	1.4196	-12.38
Great Britain (Pound)	0.6536	0.6259	-4.24
Greece (Drachma)	242.06	228.36	-5.66
Hong Kong (Dollar)	7.7276	7.7371	0.12
India (Rupee)	31.1520	31.4208	0.86
Indonesia (RP)	NA	2,226.7442	NM
Ireland (Punt)	0.6670	0.6195	-7.12
Italy (Lira)	1,609.34	1,657.10	2.97
Japan (Yen)	101.81	87.46	-14.10

(Continued)

Table B-1 (Continued)
Average 1994 and 1995 Exchange Rates per U.S. Dollar

Country	1994	1995*	U.S. Expected Appreciation (Percent)
Malaysia (Ringgit)	2.5016	2.4914	-0.41
Mexico (Peso)	NA	6.0349	NM
Netherlands (Guilder)	1.8169	1.5889	-12.55
Norway (Krone)	7.0440	6.3212	-10.26
Peru (New Sol)	NA	2.2355	NM
Philippines (Peso)	NA	25.7297	NM
Portugal (Escudo)	165.63	149.23	-9.90
Singapore (Dollar)	1.5263	1.4067	-7.84
South Korea (Won)	802.84	767.27	-4.43
Spain (Peseta)	133.48	124.85	-6.47
Sweden (Krona)	7.6962	7.3402	-4.63
Switzerland (Franc)	1.3660	1.1769	-13.84
Taiwan (NT Dollar)	26.45	25.70	-2.85
Thailand (Baht)	25.36	24.72	-2.54
Turkey (Lira)	NA	42,040.64	NM
Venezuela (Bolivar)	NA	169.80	NM

*Estimated
NA = Not available prior to 1995
NM = Not meaningful
Source: The Dun & Bradstreet Corporation

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1994 Wafer Fab Equipment Market Share Estimates

Market Statistics

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
Product Code: SEMM-WW-MS-9502
Publication Date: June 26, 1995
Filing: Market Analysis

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Table of Contents

List of Tables

Note: All tables show estimated data.

List of Tables (Continued)

Note: All tables show estimated data.

List of Tables (Continued)

Note: All tables show estimated data.

List of Tables (Continued)

Note: All tables show estimated data.

List of Tables (Continued)

Note: All tables show estimated data.

Chapter 1
Introduction to the Wafer Fab Equipment Database

Introduction

This document contains detailed information on Dataquest's estimates of the semiconductor wafer fabrication equipment market for the years 1990 through 1994. Each year, Dataquest surveys semiconductor equipment vendors to estimate their annual revenue derived from front-end semiconductor equipment sales. The 1994 survey covered about 140 semiconductor equipment vendors worldwide (this number of companies varies year to year according to mergers, acquisitions, liquidations, and start-ups, among others) by 30-plus individual semiconductor equipment product categories (excluding subtotals), in five world regions. This exercise helps Dataquest maintain its dynamic database of semiconductor equipment supply by company, and semiconductor equipment shipment by world region and product. The information gained is supplemented and cross-checked with Dataquest's various other information sources. Dataquest conducts this research on an annual basis.

Market

Dataquest has organized the wafer fab equipment market into 11 major categories of front-end processing equipment. These categories, along with key subcategories, are shown in Table 1-1. (Appendix A presents a semiconductor equipment product category hierarchy.)

Wafer fab equipment is used to perform five key tasks in the semiconductor device fabrication process, as follows:

- Patterning of a thin film (lithography and automatic photoresist processing equipment)
- Etching and cleaning of thin films or substrate surfaces and plananization of thin film surfaces (cleaning processes, dry strip, dry etch, and chemical mechanical polishing equipment)
- Depositing a thin film (chemical vapor deposition, physical vapor deposition, silicon epitaxy, and other deposition equipment)
- Modifying the properties of a thin film or substrate (diffusion and ion implantation)
- Verifying that all previous steps in the fabrication process have been performed correctly (process control equipment including optical critical dimension (CD) measurement, CD scanning electron microscopy (SEM), patterned wafer inspection and review, and thin film measurement equipment)

Capital spending by the world's merchant and captive semiconductor manufacturers consists of four components: spending for front-end, or wafer fab equipment; spending for back-end, or assembly and test equipment; spending for CIM/software and computer control systems;

Table 1-1
Wafer Fab Equipment Categories

Category
Lithography
Contact/Proximity
Projection Aligners
Steppers
Direct-Write Lithography
Maskmaking Lithography
X-Ray
Automatic Photoresist Processing Equipment
Etch and Clean
Auto Wet Stations (Immersion)
Spray Processors
Post-CMP Clean
Vapor Phase Clean
Other Clean Processes
Dry Strip
Dry Etch
Chemical Mechanical Polishing (CMP)
Deposition
Chemical Vapor Deposition
Sputtering
Silicon Epitaxy
Other Deposition
Diffusion
Rapid Thermal Processing
Ion Implantation
Medium Current
High Current
High Voltage
Process Control
Optical CD Metrology
CD SEM
Patterned Wafer Inspection and Review
Other Process Control
Factory Automation
Other Equipment

Source: Dataquest (June 1995)

and spending for property and plant. The total world market for the categories of wafer fab equipment as defined in this database is equal to the total capital spending for front-end equipment by the world's semiconductor manufacturers.

Most of the equipment categories are self-explanatory; however, a few categories require further definition. The "Other Process Control" category represents a broad market that includes mask inspection and repair equipment, process monitoring equipment, surface analysis equipment, and analytical instrumentation. This is a highly fragmented market with dozens of companies selling into a multitude of noncompetitive market niches.

Factory Automation includes wafer transport systems including automatic guided vehicles, robotics, rail transport systems, minienvironment systems, and other wafer transport and storage automated systems.

"Other Equipment" is a general, catchall category that includes the other capital equipment used throughout the fab but not classified with the other 10 major types of wafer processing equipment. Included in this segment are decontamination systems, wafer markers, gas analyzers, ion milling, and other types of equipment.

General Sales Definitions

The data in the tables represents end-user revenue for calendar year shipments, organized by company or by region. For companies with a different fiscal year, calendar year shipments have been estimated.

All sales are reported according to customer location, that is, shipping destination. These destinations are defined regionally. The regions are North America, Europe, Japan, and Asia/Pacific-Rest of World. (Appendix B lists the specific countries that compose these major geographical regions). Sales do not include spare parts or service but do include retrofits and upgrades. Our market estimates only include equipment used in the front-end wafer fabrication process. We do not include equipment used in other market applications such as flat-panel display manufacturing, thin-film head manufacturing, or multichip modules. Finally, as part of our convention to report end-user revenue, the revenue associated with equipment kits sent from one company to be fabricated and assembled by another company is valued at the full system shipment price paid by the semiconductor manufacturer. This revenue is assigned to the company that originated the kits, with the exception of implant joint ventures. Thus, for public companies, the sales reported here may differ from the sales reported in annual reports.

Exchange Rates

Worldwide market share estimates combine data from many countries, each of which has different and fluctuating exchange rates. Estimates of non-U.S. market consumption or revenue are based upon the average exchange rate for the given year. As a rule, our estimates are calculated in local currencies and then converted to U.S. dollars. Appendix C lists 1994 exchange rates for various currencies.

Equipment Companies

Table 1-2 presents a list of the equipment companies found in the database tables, by region of company ownership. (Please note that Table 1-2 includes companies now active in the wafer fab equipment industry and those companies that, for whatever reason, are no longer participants.) This historical database includes a total of 224 companies: 109 North American equipment companies, 71 Japanese companies, 36 European companies, and eight joint venture companies. These companies account for virtually all of the world's wafer processing equipment for lithography, automatic photoresist processing, etch and clean, deposition, diffusion, rapid thermal processing, ion implantation, and CD/wafer inspection.

Table 1-3 summarizes recent mergers and acquisitions in the wafer fab equipment industry. Merger and acquisition activity is often accompanied by a change in company name. These changes have been incorporated in our market share tables.

Notes on Market Share

In the process of conducting data collection and evaluating market statistics, Dataquest will sometimes consolidate or revise previously published market estimates. We revise beyond one year of history only in those situations when an individual company's market position or the size of a given regional market for a segment of wafer fab equipment would be altered significantly.

Dataquest believes that the estimates presented within this document are the most accurate and meaningful statistics available.

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

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Table 1-2
Wafer Fab Equipment Companies

	North American Companies	
Advanced Crystal Sciences	Gemini	Process Products
Advantage Production Technology	General Signal Thinfilm Company	Process Technology Ltd.
AG Associates	Genus	Prometrix
Alameda Instruments	Hampshire Instruments	Pure Aire Corporation
Amray	High Temperature Engineering	Rapro
Angstrom Measurements	Innotec	Reichert-McBain
Anicon	Inspex	Rudolph Research
Applied Materials	Insystems	S&K Products International
Ateq	Integrated Air Systems	Santa Clara Plastics
Athens	Intevac	SCI Manufacturing
Biorad	Ion Tech	Semiconductor Systems Inc.
Bjorne Enterprises	IPEC	Semifab
Branson/IPC	IPEC/Westech	Semitherm
BTU International	IVS Inc.	Semitool
CFM Technology	KLA Instruments	Silicon Valley Group
CHA Industries	Kurt J. Lesker	SiScan Systems
Circuit Processing Apparatus	Lam Research	Solitec
Concept Systems Design	LFE	Spectrum CVD
CPA	Machine Technology Inc.	Speedfam
Crystal Specialties	MRC	Spire
CVC Products	Matrix	Sputtered Films
CVD Equipment	Mattson Technologies	Strasbaugh
Cybeq Systems	Metrologix	SubMicron Systems Inc.
Denton Vacuum	Micronix	Tegal
Dexon	Moore	Tempress
Drytek	MR Semicon	Tencor Instruments
Eaton	Nanometrics	Therma-Wave
Emcore	Nanosil	Thermco
Epitaxy Inc.	Novellus Systems Inc.	Tylan
Estek	Opal	Tystar
Etec	Optical Specialties Inc.	Ultrapointe
Focus Semiconductor	Pacific Western	Ultratech
FSI International	Peak Systems	Universal Plastics
Fusion Semiconductor Systems	Plasma & Materials Technologies	Varian
Gasonics	Plasma-Therm	Veeco
GCA	Poly-Flow Engineering	Verteq
		Watkins-Johnson
	Japanese Companies	
ABT Corporation	Japan Production Engineering	Sankyo Engineering
Amaya	Japan Storage Battery	Seiden Sha
Advanced Film Technology Inc.	JEOL	Seiko

(Continued)

Table 1-2 (Continued)
Wafer Fab Equipment Companies

Anelva	Kaijo Denki	Shibaura Engineering Works
Canon	Kokusai Electric	Shimada Rika (also known as SPC Electronics)
Chemitronics	Bruce Technologies (Kokusai)	
Chlorine Engineers	Koyo Lindberg	Shinko Electric
Daido Sanso	Kuwano Electric	Shinko Seiki
Dainippon Screen	Kyoritsu	Sugai
Daiwa Semiconductor	Lasertec Corporation	Sumitomo Metals
Dalton Corporation	Maruwa	Tazmo
Dan Science Co. Ltd.	Matsushita Electric Ind.	Tohokasei
Denko Systems	MC Electronics	Tokuda
Disco	MRC (Sony)	Tokyo Electron Ltd.
Ebara Corporation	Musashi	Topcon
Eiko	Nidek	Tokyo Aircraft Instruments
Elionix	Nikon	Tokyo Ohka Kogyo
Enya	Nippon EMC	Toray
Ergo Plasma Systems	Nippon Sanso	Toshiba
ETE Company Ltd.	Nissin Electric	Toyoko Kagaku
Fuji Electric	Plasma Systems	Ulvac
Fujikoshi	Ramco	Ushio
Hitachi	Ryokosha	Yamato Semico Co. Ltd.
Holon	Samco	Yuasa
	European Companies	
AET Thermal	Helmut Seier	Oxford Instruments
Aixtron	ISA Riber	Pokorny
ASM International	Jenoptik	Sapi Equipements
ASM Lithography	Jipelec	Sitesa
AST Electronic GmbH	Karl Suss	Steag Microtech (formerly Pokorny)
Balzers	Leica	
BCT Spectrum	Leica Lasertechnik	Temescal
Centrotherm	Leybold-Heraeus	Thomas Schwonn
Convac	LPE	VG Instruments
CVT	Micro-Controle	Vickers Instrument
EEV	Nano-Master	Wellman Furnaces
E.T. Electrotech	Orbot	Zeiss
Heidelberg Instruments		
	Joint-Venture Companies	
Alcan Technology	Sumitomo/Eaton Nova	Ulvac/BTU
BTU/Ulvac	TEL/Thermco	Varian/TEL
m.FSI	TEL/Varian	

Source: Dataquest (June 1995)

Table 1-3
Summary of Mergers and Acquisitions Incorporated in the Wafer Fab Equipment Database, by Year and Company

Company	Action	Company	Now Identified As	First Year Change Noted in Database
Addax	Name change	AET Thermal	AET Thermal (in 1994)	1994
Convac	Acquired by	Fairchild	Fairchild-Convac	1994
ETE Company Ltd.	Name change	ETS Company Ltd.	ETS Company Ltd.	1994
Metrologix	Acquired by	KLA Instruments	KLA Instruments	1994
Oxford Plasma Technology	Name change	Oxford Instruments Inc.	Oxford Instruments Inc.	1994
Peak Systems	Acquired by	Mattson Technology	Mattson Technology	1994
Universal Plastics	Acquired by	SubMicron Systems Inc.	SubMicron Systems Inc.	1994
Drytek	Acquired by	Lam Research	Lam Research	1993
Prometrix	Acquired by	Tencor Instruments	Tencor Instruments	1993
Ramco	Acquired by	MC Electronics	MC Electronics	1993
Ultratech Stepper	Management buyout from	General Signal	Ultratech Stepper	1993
Westech	Acquired by	IPEC	IPEC/Westech	1993
Yamato Semico	Merged with	ETE	ETE	1993
Angstrom Measurement	Acquired by	IVS Inc.	IVS Inc.	1992
Ateq Corporation	Merged with	Etec Systems	Etec Systems	1992
BCT Spectrum	Acquired by	MRC Sony	MRC Sony	1992
BTU International (front-end equipment)	Acquired by	Kokusai Electric	Bruce Technologies	1992
Insystems	Merged with	Optical Specialties Inc.	Optical Specialties Inc.	1992
Musashi	Acquired by	Sumitomo Precision Products	Musashi	1992
Tempress (GSTC)	Management buyout from	General Signal Thinfilm	Tempress	1992
ABT Corporation	Acquired by	Toshiba	Topcon	1991
Branson	Merged by	Gasonics	Gasonics	1991
BTU/Ulvac	Acquired by	Ulvac	Ulvac	1991
Denko Systems	Acquired by	Shinko Electric	Shinko Electric	1991

(Continued)

Table 1-3 (Continued)
Summary of Mergers and Acquisitions Incorporated in the Wafer Fab Equipment Database, by Year and Company

Company	Action	Company	Now Identified As	First Year Change Noted in Database
Micro-Controle	Name change to	-	Nano-Master	1991
Semiconductor Systems Inc.	Management buyout from	General Signal	Semiconductor Systems Inc.	1991
Sitesa S.A.	Acquired by	Addax Technologies	Addax Technologies	1991
Solitec (CVD operations)	Acquired by	Advanced Crystal Science	Advanced Crystal Science	1991
Spectrum CVD	Acquired by	Balzers AG	BCT Spectrum	1991
Tokuda	Acquired by	Shibaura	Shibaura	1991
Ulvac/BTU	Acquired by	Ulvac	Ulvac	1991
ASM Lithography (e-beam lithography group)	Acquired by	Cambridge Instruments	Leica	1990
Circuits Processing Apparatus (GSTC)	Management buyout from	General Signal Thin Film	CPA	1990
Materials Research Corp.	Acquired by	Sony	Materials Research Corp.	1990
Nanoquest	Name change to	-	BioRad Micromeasurements	1990
Perkim-Elmer (e-beam lithography group)	Acquired by	Industry consortium	Etec Systems Inc.	1990
Perkim-Elmer (optical lithography group)	Acquired by	Silicon Valley Group	SVG Lithography	1990
Wild Leitz	Merged with	Cambridge Instruments	Leica	1990
Wild Leitz Instruments	Name change to	-	Leica Lasertechnik	1990
ASM Lithography (50% of joint venture)	Acquired by	Philips	ASM Lithography	1989
Cambridge Instruments (MOCVD group)	Acquired by	MR Semicon	MR Semicon	1989
Estek (wet processing equipment group)	Acquired by	Verteq	Verteq	1989
GCA Corporation	Acquired by	General Signal	GCA Corporation	1989
Heidelberg Instruments	Acquired by	Wild Leitz	Wild Leitz Instruments	1989
TEL/Thermco	Acquired by	Tokyo Electron Ltd.	Tokyo Electron Ltd.	1989
Thermco	Acquired by	Silicon Valley Group	Silicon Valley Group	1989
Tylan (diffusion and CVD group)	Management buyout from	Tylan	Tystar	1989
Vickers Instruments	Acquired by	BioRad	Nanoquest	1989

Source: Dataquest (June 1995)

Chapter 2
Wafer Fab Equipment—Summary Data by Category

This section of the equipment database consists of two summary tables for the worldwide fab equipment market. Both tables present sales by equipment category for the years 1990 to 1994. In Table 2-1, the annual sales for each equipment category are organized by region of equipment sales; in Table 2-2, annual sales for each equipment category are organized by equipment vendor nationality (United States, Japan, and Europe). Joint venture equipment companies have their own listing.

For example, the total worldwide sales for projection aligners of $93.4 million in 1990 is the same in both Table 2-1 and Table 2-2; however, whereas Table 2-1 breaks the sales down by region, Table 2-2 breaks the sales down by nationality of the companies supplying the aligners.

In Table 2-2, the subtotal fab equipment line item designates that portion of the total worldwide fab equipment market for which detailed company data are available. For some of the categories in Table 2-2 (Contact/Proximity, Other Wet Process, Thin Film Measurement, and Other Process Control), only partial detailed company data is available. For other categories in Table 2-2 (Ion Milling, Other Deposition, Factory Automation, and Other Equipment), no detailed company data is available. For these categories, top-down estimates of unavailable company detail have been made and included in Tables 2-1 and 2-2 so that world fab equipment sales are consistent across all tables. Detailed company data is available for about 91 percent of the total worldwide wafer fab equipment market for 1994.

Table 2-1
Revenue from Shipments of Wafer Fab Equipment into Each Region by Equipment Category (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Lithography						
Contact/Proximity						
North American Market	6.2	2.6	3.5	3.2	3.7	-12.1
Japanese Market	8.6	11.9	2.8	4.0	2.6	-25.8
European Market	5.3	7.0	6.2	5.4	8.0	10.8
Asia/Pacific-ROW Market	3.9	3.3	3.2	3.4	3.6	-2.0
Total Contact/Proximity	24.0	24.8	15.7	16.0	17.9	-7.1
Projection Aligners						
North American Market	24.8	16.4	9.7	9.1	8.3	-23.9
Japanese Market	36.9	42.0	28.1	38.4	20.2	-14.0
European Market	15.1	7.3	3.4	6.3	13.1	-3.5
Asia/Pacific-ROW Market	16.6	12.7	7.0	3.4	2.6	-37.1
Total Projection	93.4	78.4	48.2	57.2	44.2	-17.1
Total Steppers						
North American Market	289.0	263.5	207.1	316.2	568.2	18.4
Japanese Market	535.5	487.3	249.4	378.8	581.2	2.1
European Market	131.8	85.6	69.0	107.7	246.5	16.9
Asia/Pacific-ROW Market	95.9	142.8	120.9	211.7	442.5	46.6
Total Steppers	1,052.2	979.2	646.4	1,014.4	1,838.4	15.0
Direct-Write Lithography						
North American Market	15.9	4.3	3.9	6.2	7.9	-16.0
Japanese Market	27.1	35.6	12.7	10.8	23.6	-3.4
European Market	24.1	6.9	5.2	6.0	7.3	-25.8
Asia/Pacific-ROW Market	9.1	3.4	4.0	0	0	-100.0
Total Direct-Write	76.2	50.2	25.8	23.0	38.8	-15.5
Maskmaking Lithography						
North American Market	14.7	9.5	13.2	19.0	19.3	7.0
Japanese Market	22.9	27.3	29.6	16.2	30.2	7.2
European Market	3.5	5.4	5.0	9.8	8.0	23.0
Asia/Pacific-ROW Market	6.0	5.6	4.9	7.0	20.1	35.3
Total Maskmaking	47.1	47.8	52.7	52.0	77.6	13.3
X-Ray						
North American Market	0	2.4	5.0	13.4	11.2	NM
Japanese Market	0	1.8	0	0	0	NM
European Market	1.6	0	0	0	0	-100.0
Asia/Pacific-ROW Market	0	0	0	0	0	NM
Total X-Ray	1.6	4.2	5.0	13.4	11.2	62.7

(Continued)

Table 2-1 (Continued)
Revenue from Shipments of Wafer Fab Equipment into Each Region by Equipment Category (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Total Lithography						
North American Market	350.6	298.7	242.4	367.1	618.6	15.3
Japanese Market	631.0	605.9	322.6	448.2	657.8	1.0
European Market	181.4	112.2	88.8	135.2	282.9	11.8
Asia/Pacific-ROW Market	131.5	167.8	140.0	225.5	468.8	37.4
Total Lithography	1,294.5	1,184.6	793.8	1,176.0	2,028.1	11.9
Automatic Photoresist Processing						
North American Market	84.7	108.7	127.1	171.3	188.1	22.1
Japanese Market	171.4	179.3	141.6	155.9	245.8	9.4
European Market	32.5	36.5	41.6	107.4	89.8	28.9
Asia/Pacific-ROW Market	28.4	39.6	42.9	72.7	187.0	60.2
Total Track	317.0	364.1	353.2	507.3	710.7	22.4
Etch and Clean						
Automated Wet Stations						
North American Market	36.3	62.9	70.6	90.2	149.6	42.5
Japanese Market	179.2	158.7	150.0	100.8	185.8	0.9
European Market	26.0	23.0	24.3	29.4	34.3	7.2
Asia/Pacific-ROW Market	26.3	46.0	40.8	65.0	148.8	54.2
Total Auto Wet Stations	267.8	290.6	285.7	285.4	518.5	18.0
Spray Processors						
North American Market	NA	NA	NA	NA	33.5	NM
Japanese Market	NA	NA	NA	NA	17.8	NM
European Market	NA	NA	NA	NA	10.4	NM
Asia/Pacific-ROW Market	NA	NA	NA	NA	5.4	NM
Total Auto Wet Stations	NA	NA	NA	NA	67.1	NM
Vapor Phase Clean						
North American Market	NS	NS	0.9	1.7	4.0	NM
Japanese Market	NS	NS	0	1.7	2.2	NM
European Market	NS	NS	0.6	0	0.9	NM
Asia/Pacific-ROW Market	NS	NS	0.9	2.2	2.7	NM
Total Vapor Phase Clean	NS	NS	2.4	5.6	9.8	NM
Post-CMP						
North American Market	NS	0.4	1.6	5.3	17.1	NM
Japanese Market	NS	0	0	0.8	2.8	NM
European Market	NS	0	0.8	2.4	4.7	NM
Asia/Pacific-ROW Market	NS	0	0	0.4	1.8	NM
Total Post-CMP	NS	0.4	2.4	8.9	26.4	NM

(Continued)

Table 2-1 (Continued)
Revenue from Shipments of Wafer Fab Equipment into Each Region by Equipment Category (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Other Clean Process[1]						
North American Market	NA	NA	NA	NA	43.4	NM
Japanese Market	NA	NA	NA	NA	51.1	NM
European Market	NA	NA	NA	NA	14.6	NM
Asia/Pacific-ROW Market	NA	NA	NA	NA	20.7	NM
Total Other Clean Process[1]	NA	NA	NA	NA	129.8	NM
Other Wet Process[2]						
North American Market	38.6	47.6	38.1	58.9	NA	NA
Japanese Market	66.6	66.1	35.6	70.3	NA	NA
European Market	18.0	18.8	14.7	17.8	NA	NA
Asia/Pacific-ROW Market	9.0	10.4	9.8	36.5	NA	NA
Total Other Wet Process[2]	132.2	142.9	98.2	183.5	NA	NA
Dry Strip						
North American Market	25.1	32.2	29.5	35.6	55.4	21.9
Japanese Market	75.5	62.1	58.9	52.1	69.0	-2.2
European Market	9.3	9.2	7.2	20.0	23.3	25.8
Asia/Pacific-ROW Market	7.8	15.6	26.9	30.4	54.7	62.7
Total Dry Strip	117.7	119.1	122.5	138.1	202.4	14.5
Dry Etch						
North American Market	184.5	173.1	211.3	323.4	421.0	22.9
Japanese Market	365.9	369.3	280.3	398.9	540.2	10.2
European Market	95.6	77.8	103.0	153.5	208.6	21.5
Asia/Pacific-ROW Market	44.4	97.2	86.9	220.2	384.7	71.6
Total Dry Etch	690.4	717.4	681.5	1,096.0	1,554.5	22.5
Chemical Mechanical Polishing						
North American Market	NS	8.4	15.7	29.7	40.6	NM
Japanese Market	NS	0	1.2	7.6	13.8	NM
European Market	NS	2.1	2.8	4.8	8.8	NM
Asia/Pacific-ROW Market	NS	0.3	0	1.5	1.6	NM
Total CMP	NS	10.8	19.7	43.6	64.8	NM
Ion Milling						
North American Market	3.0	3.8	3.3	3.0	NS	NA
Japanese Market	5.0	7.0	5.0	3.0	NS	NA
European Market	3.0	2.1	1.7	2.0	NS	NA
Asia/Pacific-ROW Market	2.0	3.8	3.3	4.0	NS	NA
Total Ion Milling	13.0	16.7	13.3	12.0	NS	NA

(Continued)

Table 2-1 (Continued)
Revenue from Shipments of Wafer Fab Equipment into Each Region by Equipment Category (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Total Etch and Clean						
North American Market	287.5	328.4	371.0	547.8	764.6	27.7
Japanese Market	692.2	663.2	531.0	635.2	882.7	6.3
European Market	151.9	133.0	155.1	229.9	305.6	19.1
Asia/Pacific-ROW Market	89.5	173.3	168.6	360.2	620.4	62.3
Total Etch and Clean	1,221.1	1,297.9	1,225.7	1,773.1	2,573.3	20.5
Deposition						
CVD						
North American Market	224.5	203.4	222.6	260.2	376.2	13.8
Japanese Market	343.4	343.0	247.4	279.8	419.1	5.1
European Market	90.6	84.7	83.1	143.9	201.7	22.2
Asia/Pacific-ROW Market	57.0	111.4	97.2	184.6	351.9	57.6
Total CVD	715.5	742.5	650.3	868.5	1,348.9	17.2
Sputter						
North American Market	115.1	108.8	152.4	221.7	348.3	31.9
Japanese Market	177.5	209.1	148.6	199.9	348.8	18.4
European Market	43.5	38.6	57.9	71.1	117.6	28.2
Asia/Pacific-ROW Market	23.1	68.7	87.5	91.5	210.4	73.7
Total Sputter	359.2	425.2	446.4	584.2	1,025.1	30.0
Silicon Epitaxy						
North American Market	35.7	25.2	26.8	31.6	37.6	1.3
Japanese Market	18.2	46.1	46.3	25.4	27.0	10.4
European Market	11.9	11.0	6.9	20.9	28.5	24.4
Asia/Pacific-ROW Market	2.4	6.7	4.0	4.7	7.1	31.1
Total Silicon Epitaxy	68.2	89.0	84.0	82.6	100.2	10.1
Other Deposition						
North American Market	38.6	38.9	37.2	40.6	35.5	-2.1
Japanese Market	62.8	66.2	45.2	35.1	31.5	-15.8
European Market	32.9	25.0	22.2	21.9	18.8	-13.1
Asia/Pacific-ROW Market	18.7	16.5	14.7	17.1	15.0	-5.4
Total Other Deposition	153.0	146.6	119.3	114.7	100.8	-9.9
Total Deposition						
North American Market	413.9	376.3	439.0	554.1	797.6	17.8
Japanese Market	601.9	664.4	487.5	540.2	826.4	8.2
European Market	178.9	159.3	170.1	257.8	366.6	19.6
Asia/Pacific-ROW Market	101.2	203.3	203.4	297.9	584.4	55.0
Total Deposition	1,295.9	1,403.3	1,300.0	1,650.0	2,575.0	18.7

(Continued)

Table 2-1 (Continued)
Revenue from Shipments of Wafer Fab Equipment into Each Region by Equipment Category (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Diffusion						
North American Market	77.1	73.1	56.1	89.4	130.4	14.0
Japanese Market	173.5	158.7	129.7	116.2	163.0	-1.5
European Market	41.1	35.3	22.6	67.9	75.1	16.3
Asia/Pacific-ROW Market	33.0	59.3	37.8	68.8	123.3	39.0
Total Diffusion	324.7	326.4	246.2	342.3	491.8	10.9
Rapid Thermal Processing						
North American Market	14.6	17.4	14.5	18.7	32.9	22.5
Japanese Market	9.2	15.9	11.7	13.1	26.9	30.8
European Market	6.5	10.3	7.5	9.1	9.0	8.5
Asia/Pacific-ROW Market	2.8	2.2	2.6	4.3	10.9	40.5
Total RTP	33.1	45.8	36.3	45.2	79.7	24.6
Ion Implantation						
Medium Current						
North American Market	17.2	16.3	10.3	26.5	58.5	35.8
Japanese Market	69.7	59.6	48.8	45.9	93.4	7.6
European Market	7.9	13.7	7.7	15.5	38.1	48.2
Asia/Pacific-ROW Market	18.7	17.9	16.6	20.0	43.7	23.6
Total Medium Current	113.5	107.5	83.4	107.9	233.7	19.8
High Current						
North American Market	58.4	38.6	44.9	57.1	112.6	17.8
Japanese Market	136.1	129.7	70.3	95.0	133.9	-0.4
European Market	27.1	26.5	26.5	36.8	70.2	26.9
Asia/Pacific-ROW Market	27.9	33.5	22.1	44.2	74.5	27.8
Total High Current	249.5	228.3	163.8	233.1	391.2	11.9
High Voltage						
North American Market	2.6	2.9	7.2	3.0	0	-100.0
Japanese Market	4.2	11.4	5.8	5.6	9.8	23.6
European Market	0	3.3	2.7	2.9	3.0	NM
Asia/Pacific-ROW Market	0	0	0	6.6	16.5	NM
Total High Voltage	6.8	17.6	15.7	18.1	29.3	44.1
Total Implantation						
North American Market	78.2	57.8	62.4	86.6	171.1	21.6
Japanese Market	210.0	200.7	124.9	146.5	237.1	3.1
European Market	35.0	43.5	36.9	55.2	111.3	33.5
Asia/Pacific-ROW Market	46.6	51.4	38.7	70.8	134.7	30.4
Total Implantation	369.8	353.4	262.9	359.1	654.2	15.3

(Continued)

Table 2-1 (Continued)
Revenue from Shipments of Wafer Fab Equipment into Each Region by Equipment Category (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Process Control						
Optical CD Metrology[3]						
North American Market	20.8	17.3	11.3	13.8	23.6	3.2
Japanese Market	18.6	23.6	13.6	15.3	21.4	3.6
European Market	15.1	11.3	9.7	7.4	8.0	-14.7
Asia/Pacific-ROW Market	4.2	6.5	5.3	6.4	12.2	30.6
Total Optical CD Metrology[3]	58.7	58.7	39.9	42.9	65.2	2.7
CD SEM						
North American Market	23.2	17.9	25.7	27.1	38.1	13.2
Japanese Market	54.5	57.3	35.3	35.4	76.4	8.8
European Market	6.8	5.4	4.4	3.6	9.1	7.6
Asia/Pacific-ROW Market	3.1	12.0	13.0	16.6	52.8	103.2
Total CD SEM	87.6	92.6	78.4	82.7	176.4	19.1
Patterned Wafer Inspection and Review						
North American Market	41.6	38.7	47.6	53.1	105.6	26.2
Japanese Market	59.6	61.2	43.9	70.5	128.3	21.1
European Market	24.0	20.8	22.0	23.6	36.7	11.2
Asia/Pacific-ROW Market	10.7	13.8	22.6	33.5	79.5	65.1
Total Patterned Wafer Inspection and Review	135.9	134.5	136.1	180.7	350.1	26.7
Thin Film Measurement						
North American Market	NS	13.6	23.9	32.8	39.8	NM
Japanese Market	NS	16.7	20.2	16.4	24.7	NM
European Market	NS	6.4	9.5	11.4	10.3	NM
Asia/Pacific-ROW Market	NS	5.9	4.2	11.0	23.1	NM
Total Thin Film Measurement	NS	42.6	57.8	71.6	97.9	NM
Other Process Control						
North American Market	106.1	100.5	77.9	91.1	117.6	2.6
Japanese Market	151.6	143.4	88.3	84.8	103.6	-9.1
European Market	39.3	28.5	25.1	29.9	38.3	-0.6
Asia/Pacific-ROW Market	25.9	42.2	40.3	50.6	68.0	27.3
Total Other Process Control	322.9	314.6	231.6	256.4	327.5	0.4

(Continued)

Table 2-1 (Continued)
Revenue from Shipments of Wafer Fab Equipment into Each Region by Equipment Category (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Total Process Control						
North American Market	191.7	188.0	186.4	217.9	324.7	14.1
Japanese Market	284.3	302.2	201.3	222.4	354.4	5.7
European Market	85.2	72.4	70.7	75.9	102.4	4.7
Asia/Pacific-ROW Market	43.9	80.4	85.4	118.1	235.6	52.2
Total Process Control	605.1	643.0	543.8	634.3	1,017.1	13.9
Factory Automation						
North American Market	40.0	36.0	39.0	45.0	70.0	15.0
Japanese Market	121.0	132.0	87.0	116.0	174.0	9.5
European Market	27.0	23.0	23.0	23.0	25.0	-1.9
Asia/Pacific-ROW Market	28.0	36.0	45.0	66.0	143.0	50.3
Total Automation	216.0	227.0	194.0	250.0	412.0	17.5
Other Equipment						
North American Market	50.8	39.1	31.8	31.5	42.5	-4.4
Japanese Market	97.1	84.3	58.8	65.9	100.0	0.7
European Market	24.8	15.6	17.2	16.7	16.9	-9.1
Asia/Pacific-ROW Market	16.7	29.5	25.0	24.7	53.5	33.8
Total Other Equipment	189.4	168.5	132.8	138.8	212.9	3.0
Total Wafer Fab Equipment						
North American Market	1,589.1	1,523.5	1,569.7	2,129.4	3,140.5	18.6
Japanese Market	2,991.6	3,006.6	2,096.1	2,459.6	3,668.1	5.2
European Market	764.3	641.1	633.5	978.1	1,384.6	16.0
Asia/Pacific-ROW Market	521.6	842.8	789.4	1,309.0	2,561.6	48.9
Total Fab Equipment	5,866.6	6,014.0	5,088.7	6,876.1	10,754.8	16.4

NM = Not meaningful
NS = Not surveyed
NA = Not applicable
[1]The category of Other Clean Process equipment includes Manual Wet Benches, Rinser/Dryers, Megasonic Cleaners and Scrubbers.
[2]The category of Other Wet Process equipment includes Manual Wet Benches, Rinser/Dryers, Acid Processors, Megasonic Cleaners, and Scrubbers.
[3]The category of Optical CD Metrology includes Dedicated Overlay Tools, in addition to Joint Linewidth/Overlay Measurement Systems.
Source: Dataquest (June 1995)

Table 2-2
Revenue from Shipments of Wafer Fab Equipment for Each Regional Company Base by Equipment Category (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Fab Equipment Market	5,866.6	6,014.0	5,088.7	6,876.1	10,754.8	16.4
Contact/Proximity						
North American Companies	0	0	NS	NS	NS	NA
Japanese Companies	10.5	11.9	NS	NS	NS	NA
European Companies	13.5	12.9	NS	NS	NS	NA
Joint-Venture Companies	0	0	NS	NS	NS	NA
Total Projection	24.0	24.8	NS	NS	NS	NA
Projection Aligners						
North American Companies	37.0	22.2	11.6	22.1	27.1	-7.5
Japanese Companies	56.4	56.2	36.6	35.1	17.1	-25.8
European Companies	0	0	0	0	0	NM
Joint-Venture Companies	0	0	0	0	0	NM
Total Projection	93.4	78.4	48.2	57.2	44.2	-17.1
Steppers						
North American Companies	136.8	101.8	75.9	61.1	85.8	-11.0
Japanese Companies	824.4	806.1	468.5	783.4	1,479.8	15.7
European Companies	91.0	71.3	102.0	169.9	272.8	31.6
Joint-Venture Companies	0	0	0	0	0	NM
Total Steppers	1,052.2	979.2	646.4	1,014.4	1,838.4	15.0
Direct-Write Lithography						
North American Companies	10.5	0	8.0	0	2.0	-33.9
Japanese Companies	54.9	44.6	11.9	14.4	25.5	-17.4
European Companies	10.8	5.6	5.9	8.6	11.3	1.1
Joint-Venture Companies	0	0	0	0	0	NM
Total Direct-Write	76.2	50.2	25.8	23.0	38.8	-15.5
Maskmaking Lithography						
North American Companies	28.0	25.5	28.8	34.6	48.7	14.8
Japanese Companies	16.6	17.8	18.2	8.1	21.0	6.1
European Companies	2.5	4.5	5.7	9.3	7.9	33.3
Joint-Venture Companies	0	0	0	0	0	NM
Total Maskmaking	47.1	47.8	52.7	52.0	77.6	13.3
X-Ray						
North American Companies	0	2.4	0	11.4	11.2	NM
Japanese Companies	0	0	0	0	0	NM
European Companies	1.6	1.8	5.0	2.0	0	-100.0
Joint-Venture Companies	0	0	0	0	0	NM
Total X-Ray	1.6	4.2	5.0	13.4	11.2	62.7

(Continued)

Table 2-2 (Continued)
Revenue from Shipments of Wafer Fab Equipment for Each Regional Company Base by Equipment Category (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Automatic Photoresist Processing						
North American Companies	89.5	96.0	105.0	148.9	152.8	14.3
Japanese Companies	198.3	229.1	201.6	276.7	480.1	24.7
European Companies	15.4	15.0	16.6	17.6	19.7	6.3
Joint-Venture Companies	13.8	24.0	30.0	64.1	58.1	43.2
Total Track	317.0	364.1	353.2	507.3	710.7	22.4
Automated Wet Stations						
North American Companies	36.0	53.1	85.0	106.8	124.1	36.3
Japanese Companies	222.6	228.9	193.5	163.1	381.2	14.4
European Companies	9.2	8.6	7.2	15.5	13.2	9.4
Joint-Venture Companies	0	0	0	0	0	NM
Total Auto Wet Stations	267.8	290.6	285.7	285.4	518.5	18.0
Spray Processors						
North American Companies	NA	NA	NA	NA	56.2	NM
Japanese Companies	NA	NA	NA	NA	10.9	NM
European Companies	NA	NA	NA	NA	0	NM
Joint-Venture Companies	NA	NA	NA	NA	0	NM
Total Spray Processors	NA	NA	NA	NA	67.1	NM
Vapor Phase Clean						
North American Companies	NS	NS	2.4	5.6	8.5	NM
Japanese Companies	NS	NS	0	0	1.3	NM
European Companies	NS	NS	0	0	0	NM
Joint-Venture Companies	NS	NS	0	0	0	NM
Total Vapor Phase Clean	NS	NS	2.4	5.6	9.8	NM
Post-CMP						
North American Companies	NS	0.4	2.4	8.9	19.3	NM
Japanese Companies	NS	0	0	0	7.1	NM
European Companies	NS	0	0	0	0	NM
Joint-Venture Companies	NS	0	0	0	0	NM
Total Post-CMP	NS	0.4	2.4	8.9	26.4	NM
Other Clean Processes[1]						
North American Companies	NA	NA	NA	NA	50.1	NM
Japanese Companies	NA	NA	NA	NA	76.0	NM
European Companies	NA	NA	NA	NA	3.7	NM
Joint-Venture Companies	NA	NA	NA	NA	0	NM
Total Other Clean Processes	NA	NA	NA	NA	129.8	NM

(Continued)

Table 2-2 (Continued)
Revenue from Shipments of Wafer Fab Equipment for Each Regional Company Base by Equipment Category (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Other Wet Processes[2]						
North American Companies	60.2	65.1	18.4	75.6	NA	NA
Japanese Companies	69	75.1	26.2	95.2	NA	NA
European Companies	3	2.7	0	1	NA	NA
Joint-Venture Companies	0	0	4.2	11.7	NA	NA
Total Other Wet Processes	132.2	142.9	48.8	183.5	NA	NA
Dry Strip						
North American Companies	37.8	38.8	38.4	57.7	96.4	26.4
Japanese Companies	68.2	59.4	67.5	63.6	80.2	4.1
European Companies	0	0	0	0	0	NM
Joint-Venture Companies	11.7	20.9	16.6	16.8	25.8	21.9
Total Dry Strip	117.7	119.1	122.5	138.1	202.4	14.5
Dry Etch						
North American Companies	358.7	356.2	412.1	697.9	997.7	29.1
Japanese Companies	294.6	326.4	248.2	357.6	529.1	15.8
European Companies	23.0	18.3	10.4	17.9	13.0	-13.3
Joint-Venture Companies	14.1	16.5	10.8	22.6	14.7	1.0
Total Dry Etch	690.4	717.4	681.5	1,096.0	1,554.5	22.5
Chemical Mechanical Polishing						
North American Companies	NS	10.6	19.4	42.8	58.2	NM
Japanese Companies	NS	0	0	0.3	5.4	NM
European Companies	NS	0.2	0.3	0.5	1.2	NM
Joint-Venture Companies	NS	0	0	0	0	NM
Total CMP	NS	10.8	19.7	43.6	64.8	NM
CVD						
North American Companies	415.6	415.1	385.1	539.8	826.7	18.8
Japanese Companies	170.4	193.9	162.8	219.3	345.0	19.3
European Companies	101.9	97.1	67.7	64.3	80.3	-5.8
Joint-Venture Companies	27.6	36.4	34.7	45.1	96.9	36.9
Total CVD	715.5	742.5	650.3	868.5	1,348.9	17.2
Sputter						
North American Companies	112.3	160.7	211.2	351.3	672.5	56.4
Japanese Companies	218.5	248.1	228.0	223.0	324.1	10.4
European Companies	28.4	16.4	7.2	9.9	28.5	0.1
Joint-Venture Companies	0	0	0	0	0	NM
Total Sputter	359.2	425.2	446.4	584.2	1,025.1	30.0

(Continued)

Table 2-2 (Continued)
Revenue from Shipments of Wafer Fab Equipment for Each Regional Company Base by Equipment Category (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Silicon Epitaxy						
North American Companies	36.8	35.7	29.1	30.9	46.6	6.1
Japanese Companies	6.7	18.4	20.6	9.1	8.1	4.9
European Companies	24.7	34.9	34.3	42.6	45.5	16.5
Joint-Venture Companies	0	0	0	0	0	NM
Total Silicon Epitaxy	68.2	89.0	84.0	82.6	100.2	10.1
Diffusion						
North American Companies	100.3	75.3	49.4	54.5	95.2	-1.3
Japanese Companies	168.6	208.4	169.8	241.7	346.2	19.7
European Companies	33.0	28.9	19.9	18.6	10.5	-24.9
Joint-Venture Companies	22.8	13.8	7.1	27.5	39.9	15.0
Total Diffusion	324.7	326.4	246.2	342.3	491.8	10.9
Rapid Thermal Processing						
North American Companies	25.0	35.6	24.6	26.4	38.8	11.6
Japanese Companies	3.0	4.4	4.8	6.9	19.3	59.3
European Companies	5.1	5.8	6.9	11.9	21.6	43.5
Joint-Venture Companies	0	0	0	0	0	NM
Total RTP	33.1	45.8	36.3	45.2	79.7	24.6
Ion Implantation						
North American Companies	199.7	191.6	173.9	242.8	457.9	23.1
Japanese Companies	64.8	73.7	29.8	42.0	59.4	-2.2
European Companies	0	0	0	0	0	NM
Joint-Venture Companies	105.3	88.1	59.2	74.3	136.9	6.8
Total Ion Impantation	369.8	353.4	262.9	359.1	654.2	15.3
Optical CD Metrology[3]						
North American Companies	30.5	33.6	26.0	37.0	57.5	17.2
Japanese Companies	15.5	16.8	5.8	5.0	7.7	-16.0
European Companies	12.7	8.3	8.1	0.9	0	-100.0
Joint-Venture Companies	0	0	0	0	0	NM
Total Optical CD Metrology	58.7	58.7	39.9	42.9	65.2	2.7
CD SEM						
North American Companies	11.5	12.9	14.9	23.0	33.6	30.7
Japanese Companies	76.1	79.7	63.5	59.7	142.1	16.9
European Companies	0	0	0	0	0.7	NM
Joint-Venture Companies	0	0	0	0	0	NM
Total CD SEM	87.6	92.6	78.4	82.7	176.4	19.1

(Continued)

Table 2-2 (Continued)
Revenue from Shipments of Wafer Fab Equipment for Each Regional Company Base by Equipment Category (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Patterned Wafer Inspection and Review						
North American Companies	79.2	65.8	92.9	125.9	255.2	34.0
Japanese Companies	43.4	56.9	30.7	43.9	62.1	9.4
European Companies	13.3	11.8	12.5	10.9	32.8	25.3
Joint-Venture Companies	0	0	0	0	0	NM
Total Patterned Wafer Insp. and Review	135.9	134.5	136.1	180.7	350.1	26.7
Thin Film Measurement						
North American Companies	NS	30.8	42.8	61.2	88.7	NM
Japanese Companies	NS	7.0	10.6	6.7	5.7	NM
European Companies	NS	1.8	1.9	1.9	1.4	NM
Joint-Venture Companies	NS	0	0	0	0	NM
Total Thin Film Measurement	NS	39.6	55.3	69.8	95.8	NM
Other Process Control						
North American Companies	105.2	107.1	65.6	79.4	118.5	3.0
Japanese Companies	0	6.5	4.0	2.2	0	NM
European Companies	0	0	0	0	0	NM
Joint-Venture Companies	0	0	0	0	0	NM
Total Other Process Control	105.2	113.6	69.6	81.6	118.5	3.0
Subtotal Fab Equipment[4]						
North American Companies	1,910.6	1,936.3	1,922.9	2,845.6	4,429.3	23.4
Japanese Companies	2,582.5	2,769.3	2,002.6	2,657.0	4,434.4	14.5
European Companies	389.1	345.9	311.6	403.3	564.1	9.7
Joint-Venture Companies	195.3	199.7	162.6	262.1	372.3	17.5
Subtotal Fab Equipment	5,077.5	5,251.2	4,399.7	6,168.0	9,800.1	17.9
Contact/Proximity						
Other Companies	0	0	15.7	16.0	17.9	NM
Other Wet Process[3]						
Other Companies	0	0	49.4	0	NA	NM
Thin Film Measurement						
Other Companies	NS	3.0	2.5	1.8	2.1	NM
Other Process Control						
Other Companies	217.7	201.0	162.0	174.8	209.0	-1.0
Ion Milling						
All Companies	13.0	16.7	13.3	12.0	NS	NA

(Continued)

Table 2-2 (Continued)
Revenue from Shipments of Wafer Fab Equipment for Each Regional Company Base by Equipment Category (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Other Deposition						
All Companies	153.0	146.6	119.3	114.7	100.8	-9.9
Factory Automation						
All Companies	216.0	227.0	194.0	250.0	412.0	17.5
Other Equipment						
All Companies	189.4	168.5	132.8	138.8	212.9	3.0
Total Fab Equipment	5,866.6	6,014.0	5,088.7	6,876.1	10,754.8	16.4

NM = Not meaningful
NS = Not surveyed
NA = Not applicable
[1]The category of Other Clean Process equipment includes Manual Wet Benches, Rinser/Dryers, Megasonic Cleaners and Scrubbers.
[2]The category of Other Wet Process equipment includes Manual Wet Benches, Rinser/Dryers, Acid Processors, Megasonic Cleaners and Scrubbers.
[3]The category of Optical CD Metrology includes dedicated overlay tools in addition to joint linewidth/overlay measurement systems.
[4]Subtotal Fab Equipment includes the activities of all surveyed companies. Data reported for Other Companies in the categories of Contact/Proximity, Other Wet Process, Thin Film Measurement, and Other Process Control is an estimate of additional unsurveyed activity in these categories. Data reported for All Companies in the categories of Ion Milling, Other Deposition, Factory Automation, and Other Equipment is an aggregate estimate of activity in these categories. Data for each is added to provide a consistent total for the worldwide wafer fab equipment market.
Source: Dataquest (June 1995)

Chapter 3
Wafer Fab Equipment—Import/Export Data

This section of the equipment database consists of two summary tables that provide information on the import/export markets for the worldwide wafer fab equipment market. In both Table 3-1 and Table 3-2, the worldwide fab equipment market total in millions of U.S. dollars is listed at the beginning of the table and followed by the subtotal for fab equipment. The subtotal fab equipment line item includes all of the front-end equipment categories for which detailed company data is available and accounts for 91 percent of all front-end equipment for 1994. For some equipment categories (Contact/Proximity, Other Wet Process, Thin Film Measurement, and Other Process Control), only partial detailed company data is available. For other categories (Ion Milling, Other Deposition, Factory Automation, and Other Equipment), no detailed company data is available. For these categories, which account for the remaining 9 percent of wafer fab equipment, top-down estimates of unavailable company detail have been made and included in Tables 3-1 and 3-2 so that worldwide fab equipment sales are consistent across all tables.

The subtotal fab equipment market includes all of the major wafer fab equipment categories and accounts for the majority of all import/export activity in the worldwide fab equipment market. Significant import/export analysis of the fab equipment market can be performed with the aid of the data in Tables 3-1 and 3-2.

Table 3-1
Revenue from Shipments of Wafer Fab Equipment for Each Regional Company Base by Market Region (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Fab Equipment Market	5,866.6	6,014.0	5,088.7	6,876.1	10,754.8	16.4
Subtotal Fab Equipment[1]	5,077.5	5,251.2	4,399.7	6,168.0	9,800.1	17.9
Subtotal Percentage	86.5	87.3	86.5	89.7	91.1	NA
Subtotal Fab Equipment						
North America						
North American Company Sales	977.1	890.8	949.8	1,300.8	1,883.8	17.8
Japanese Company Sales	263.8	307.6	260.9	386.1	694.6	27.4
European Company Sales	131.1	114.0	123.0	176.0	232.6	15.4
Joint-Venture Company Sales	17.3	37.4	39.5	81.9	105.3	57.1
Total North America Market	1,389.3	1,349.8	1,373.2	1,944.8	2,916.3	20.4
Japan						
North American Company Sales	410.3	473.6	358.5	468.9	772.7	17.1
Japanese Company Sales	1,961.9	1,947.9	1,331.2	1,549.7	2,267.6	3.7
European Company Sales	57.8	55.5	32.4	31.1	53.4	-2.0
Joint-Venture Company Sales	155.2	129.5	96.0	117.0	183.8	4.3
Total Japan Market	2,585.2	2,606.5	1,818.1	2,166.7	3,277.5	6.1
Europe						
North American Company Sales	303.7	295.7	315.8	527.1	761.4	25.8
Japanese Company Sales	167.9	121.3	98.3	186.7	302.7	15.9
European Company Sales	164.0	120.0	106.7	129.0	192.4	4.1
Joint-Venture Company Sales	22.8	28.5	22.3	53.1	44.7	18.3
Total Europe Market	658.4	565.5	543.1	895.9	1,301.2	18.6
Asia/Pacific-ROW						
North American Company Sales	198.8	256.2	284.4	519.5	971.2	48.7
Japanese Company Sales	184.2	386.4	308.3	507.1	1,152.3	58.1
European Company Sales	34.4	53.8	49.5	67.2	85.7	25.6
Joint-Venture Company Sales	0	4.3	4.8	10.1	38.5	NM
Total Asia/Pacific-ROW Market	417.4	700.7	647.0	1,103.9	2,247.7	52.3
Worldwide						
North American Company Sales	1,910.6	1,936.3	1,922.9	2,845.6	4,429.3	23.4
Japanese Company Sales	2,582.5	2,769.3	2,002.6	2,657.0	4,434.4	14.5
European Company Sales	389.1	345.9	311.6	403.3	564.1	9.7
Joint-Venture Company Sales	195.3	199.7	162.6	262.1	372.3	17.5
Subtotal Fab Equipment Worldwide	5,077.5	5,251.2	4,399.7	6,168.0	9,800.1	17.9

(Continued)

Table 3-1 (Continued)
Revenue from Shipments of Wafer Fab Equipment for Each Regional Company Base by Market Region (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Contact/Proximity						
Other Companies	0	0	15.7	16.0	17.9	NM
Other Wet Process[2]						
Other Companies	0	0	49.4	0	NA	NA
Thin Film Measurement						
Other Companies	NS	3.0	2.5	1.8	2.1	NM
Other Process Control						
Other Companies	217.7	201.0	162.0	174.8	209.0	-1.0
Ion Milling						
All Companies	13.0	16.7	13.3	12.0	NS	NM
Other Deposition						
All Companies	153.0	146.6	119.3	114.7	100.8	-9.9
Factory Automation						
All Companies	216.0	227.0	194.0	250.0	412.0	17.5
Other Equipment						
All Companies	189.4	168.5	132.8	138.8	212.9	3.0
Total Fab Equipment	5,866.6	6,014.0	5,088.7	6,876.1	10,754.8	16.4

NM = Not meaningful
NA = Not applicable
NS = Not surveyed
[1]Subtotal Fab Equipment includes the activities of all surveyed companies. Data reported for Other Companies in the categories of Contact/Proximity, Other Wet Process, Thin Film Measurement, and Other Process Control is an estimate of additional unsurveyed activity in these categories. Data reported for All Companies in the categories of Ion Milling, Other Deposition, Factory Automation, and Other Equipment is an aggregate estimate of activity in these categories. Data for each is added to provide a consistent total for the worldwide wafer fab equipment market.
[2]The category of Other Wet Process equipment includes Manual Wet Benches, Rinser/Dryers, Acid Processors, Megasonic Cleaners and Scrubbers.
Source: Dataquest (June 1995)

Table 3-2
Revenue from Shipments of Wafer Fab Equipment into Each Region by Regional Company Base (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Fab Equipment Market	5,866.6	6,014.0	5,088.7	6,876.1	10,754.8	16.4
Subtotal Fab Equipment[1]	5,077.5	5,251.2	4,399.7	6,168.0	9,800.1	17.9
Subtotal Percentage	86.5	87.3	86.5	89.7	91.1	NA
Subtotal Fab Equipment						
North American Equipment Companies						
Sales in North America	977.1	890.8	949.8	1,300.8	1,883.8	17.8
Sales in Japan	410.3	473.6	358.5	468.9	772.7	17.1
Sales in Europe	303.7	295.7	315.8	527.1	761.4	25.8
Sales in Asia/Pacific-ROW	219.5	276.2	298.8	548.8	1,011.4	46.5
Total North American Companies	1,910.6	1,936.3	1,922.9	2,845.6	4,429.3	23.4
Japanese Equipment Companies						
Sales in North America	263.8	307.6	260.9	386.1	694.6	27.4
Sales in Japan	1,961.9	1,947.9	1,331.2	1,549.7	2,267.6	3.7
Sales in Europe	167.9	121.3	98.3	186.7	302.7	15.9
Sales in Asia/Pacific-ROW	188.9	392.5	312.2	534.5	1,169.5	57.7
Total Japanese Companies	2,582.5	2,769.3	2,002.6	2,657.0	4,434.4	14.5
European Equipment Companies						
Sales in North America	131.1	114.0	123.0	176.0	232.6	15.4
Sales in Japan	57.8	55.5	32.4	31.1	53.4	-2.0
Sales in Europe	164.0	120.0	106.7	129.0	192.4	4.1
Sales in Asia/Pacific-ROW	36.2	56.4	49.5	67.2	85.7	24.0
Total European Companies	389.1	345.9	311.6	403.3	564.1	9.7
Joint Venture Equipment Companies						
Sales in North America	17.3	37.4	39.5	81.9	105.3	57.1
Sales in Japan	155.2	129.5	96.0	117.0	183.8	4.3
Sales in Europe	22.8	28.5	22.3	53.1	44.7	18.3
Sales in Asia/Pacific-ROW	0	4.3	4.8	10.1	38.5	NM
Total JV Companies	195.3	199.7	162.6	262.1	372.3	17.5
Subtotal Fab Equipment[1]	5,077.5	5,251.2	4,399.7	6,168.0	9,800.1	17.9
Contact/Proximity						
Other Companies	0	0	15.7	16.0	17.9	NM
Other Wet Process[2]						
Other Companies	0	0	49.4	0	NA	NA
Thin Film Measurement						
Other Companies	NS	3.0	2.5	1.8	2.1	NM

(Continued)

Table 3-2 (Continued)
Revenue from Shipments of Wafer Fab Equipment into Each Region by Regional Company Base (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Other Process Control						
Other Companies	217.7	201.0	162.0	174.8	209.0	-1.0
Ion Milling						
All Companies	13.0	16.7	13.3	12.0	NS	NM
Other Deposition						
All Companies	153.0	146.6	119.3	114.7	100.8	-9.9
Factory Automation						
All Companies	216.0	227.0	194.0	250.0	412.0	17.5
Other Equipment						
All Companies	189.4	168.5	132.8	138.8	212.9	3.0
Total Fab Equipment	5,866.6	6,014.0	5,088.7	6,876.1	10,754.8	16.4

NM = Not meaningful
NA = Not applicable
NS = Not surveyed
[1]Subtotal Fab Equipment includes the activities of all surveyed companies. Data reported for Other Companies in the categories of Contact/Proximity, Other Wet Process, Thin Film Measurement and Other Process Control are estimates of additional unsurveyed activity in these categories. Data reported for All Companies in categories of Ion Milling, Other Deposition, Factory Automation and Other Equipment are aggregate estimates of activity in these categories. Both data are added to provide a consistent total for the worldwide wafer fab equipment market.
[2]The category of Other Wet Process equipment includes manual wet benches, rinser/dryers, acid processors, megasonic cleaners and scrubbers.
Source: Dataquest (June 1995)

Chapter 4
Wafer Fab Equipment—Company Shares by Category

This section of the equipment database contains detailed company market share data by region for the major front-end equipment categories as shown in Tables 4-1 through 4-73. All of the companies that participate in an equipment segment are listed for each region, regardless of whether or not they have sales in a particular region. Although this approach results in a large number of zeros in the tables, it also indicates that Dataquest has not recorded any sales for the company in that region. We believe that this format gives more positive information than eliminating a company with no sales in a given region.

At the beginning of each table, the total world market for a particular equipment category is presented. This total is the same for each category as the total listed in Tables 2-1 and 2-2 in Chapter 2. Thus, all tables are completely consistent as one proceeds from the summary tables to the detailed tables presented in this section.

Table 4-1
Each Company's Revenue from Shipments of Lithography Equipment to the World by Equipment Category (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Lithography Market	1,294.5	1,184.6	793.8	1,176.0	2,028.1	11.9
Contact/Proximity						
Canon	10.5	11.9	NS	NS	NS	
Karl Suss	13.5	12.9	NS	NS	NS	
Total Contact/Proximity	24.0	24.8	15.7	16.0	17.9	-7.1
Projection Aligners						
Canon	56.4	56.2	36.6	35.1	17.1	
SVG Lithography	37.0	22.2	11.6	22.1	27.1	
Total Projection	93.4	78.4	48.2	57.2	44.2	-17.1
Steppers						
ASM Lithography	91.0	71.3	102.0	169.9	272.8	
Canon	202.2	181.2	137.6	267.7	468.6	
GCA	78.2	46.8	33.5	0	0	
Hitachi	103.8	86.7	39.8	25.2	0	
Nikon	518.4	538.2	291.1	490.5	1,011.2	
SVG Lithography	30.6	30.4	23.2	29.4	29.4	
Ultratech	28.0	24.6	19.2	31.7	56.4	
Total Steppers	1,052.2	979.2	646.4	1,014.4	1,838.4	15.0
Direct-Write Lithography						
Etec	10.5	0	8.0	0	2.0	
Hitachi	19.5	17.8	3.2	7.2	17.7	
JEOL	35.4	26.8	8.7	7.2	7.8	
Jenoptik	0	0	0	3.2	3.3	
Leica	10.8	5.6	5.9	5.4	8.0	
Total Direct-Write	76.2	50.2	25.8	23.0	38.8	-15.5
Maskmaking Lithography						
Ateq	14.0	15.0	0	0	0	
Etec	14.0	10.5	28.8	34.6	48.7	
Hitachi	6.2	6.7	7.1	8.1	9.8	
JEOL	10.4	11.1	11.1	0	9.2	
Jenoptik	0	0	0	4.3	5.0	
Leica	2.5	4.5	5.7	5.0	2.9	
Toshiba	0	0	0	0	2.0	
Total	47.1	47.8	52.7	52.0	77.6	13.3

(Continued)

Table 4-1 (Continued)
Each Company's Revenue from Shipments of Lithography Equipment to the World by Equipment Category (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
X-Ray						
Hampshire Instruments	0	2.4	0	0	0	
SVG Lithography	0	0	0	11.4	11.2	
Karl Suss	1.6	1.8	5.0	2.0	0	
Total X-Ray	1.6	4.2	5.0	13.4	11.2	62.7
Total Lithography	1,294.5	1,184.6	793.8	1,176.0	2,028.1	11.9

NS = Not surveyed. In Dataquest's 1992 Market Statistics program for wafer fabrication equipment, company activities in the category of contact/proximity equipment were not surveyed.
Source: Dataquest (June 1995)

Table 4-2
Each Company's Revenue from Shipments of Projection Aligner Equipment to Each Region (Factory Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Projection Market	93.4	78.4	48.2	57.2	44.2	-17.1
North America						
Canon	14.6	5.7	3.5	1.2	0	
SVG Lithography	10.2	10.7	6.2	7.9	8.3	
Total North America	24.8	16.4	9.7	9.1	8.3	-23.9
Japan						
Canon	27.7	35.9	25.2	33.9	17.1	
SVG Lithography	9.2	6.1	2.9	4.5	3.1	
Total Japan	36.9	42.0	28.1	38.4	20.2	-14.0
Europe						
Canon	4.9	1.9	0.9	0	0	
SVG Lithography	10.2	5.4	2.5	6.3	13.1	
Total Europe	15.1	7.3	3.4	6.3	13.1	-3.5
Asia-Pacific/ROW						
Canon	9.2	12.7	7.0	0	0	
SVG Lithography	7.4	0	0	3.4	2.6	
Total Asia/Pacific-ROW	16.6	12.7	7.0	3.4	2.6	-37.1
Worldwide						
Canon	56.4	56.2	36.6	35.1	17.1	
SVG Lithography	37.0	22.2	11.6	22.1	27.1	
Total Worldwide	93.4	78.4	48.2	57.2	44.2	-17.1

Source: Dataquest (June 1995)

Table 4-3
Each Company's Revenue from Shipments of Stepper Equipment to Each Region (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Stepper Market	1,052.2	979.2	646.4	1,014.4	1,838.4	15.0
North America						
ASM Lithography	49.7	40.7	56.0	98.9	141.1	
Canon	41.7	41.4	32.8	62.6	139.9	
GCA	68.2	38.2	27.5	0	0	
Hitachi	6.2	0	3.3	3.6	0	
Nikon	75.6	117.8	62.9	107.6	239.0	
SVG Lithography	30.6	15.0	15.4	25.2	25.2	
Ultratech	17.0	10.4	9.2	18.3	23.0	
Total North America	289.0	263.5	207.1	316.2	568.2	18.4
Japan						
ASM Lithography	0	0	0	0	0	
Canon	92.4	83.0	48.1	110.1	181.7	
GCA	0	1.7	0.4	0	0	
Hitachi	96.4	50.7	29.9	10.8	0	
Nikon	344.2	334.9	163.1	254.5	391.5	
SVG Lithography	0	7.8	3.8	0	0	
Ultratech	2.5	9.2	4.1	3.4	8.0	
Total Japan	535.5	487.3	249.4	378.8	581.2	2.1
Europe						
ASM Lithography	27.1	9.0	14.3	22.5	60.3	
Canon	41.7	22.2	14.8	34.6	62.7	
GCA	4.5	5.2	2.3	0	0	
Hitachi	0	0	0	3.6	0	
Nikon	54.0	39.1	31.2	41.0	115.7	
SVG Lithography	0	7.6	4.0	0	0	
Ultratech	4.5	2.5	2.4	6.0	7.8	
Total Europe	131.8	85.6	69.0	107.7	246.5	16.9
Asia/Pacific-ROW						
ASM Lithography	14.2	21.6	31.7	48.5	71.4	
Canon	26.4	34.6	41.9	60.4	84.3	
GCA	5.5	1.7	3.3	0	0	
Hitachi	1.2	36.0	6.6	7.2	0	
Nikon	44.6	46.4	33.9	87.4	265.0	
SVG Lithography	0	0	0	4.2	4.2	
Ultratech	4.0	2.5	3.5	4.0	17.6	
Total Asia/Pacific-ROW	95.9	142.8	120.9	211.7	442.5	46.6

(Continued)

Table 4-3 (Continued)
Each Company's Revenue from Shipments of Stepper Equipment to Each Region (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Worldwide						
ASM Lithography	91.0	71.3	102.0	169.9	272.8	
Canon	202.2	181.2	137.6	267.7	468.6	
GCA	78.2	46.8	33.5	0	0	
Hitachi	103.8	86.7	39.8	25.2	0	
Nikon	518.4	538.2	291.1	490.5	1,011.2	
SVG Lithography	30.6	30.4	23.2	29.4	29.4	
Ultratech	28.0	24.6	19.2	31.7	56.4	
Total Worldwide	1,052.2	979.2	646.4	1,014.4	1,838.4	15.0

Source: Dataquest (June 1995)

Table 4-4
Each Company's Unit Shipments of Stepper Equipment to Each Region (Units)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Stepper Market	771	647	397	532	827	1.8
North America						
ASM Lithography	33	23	28	39	54	
Canon	30	25	20	33	63	
GCA	44	26	16	0	0	
Hitachi	5	0	2	2	0	
Nikon	56	80	40	58	101	
SVG Lithography	9	4	4	6	6	
Ultratech	20	14	12	21	28	
Total North America	197	172	122	159	252	6.3
Japan						
ASM Lithography	0	0	0	0	0	
Canon	70	54	30	57	83	
GCA	0	1	0	0	0	
Hitachi	78	38	18	6	0	
Nikon	255	215	108	137	170	
SVG Lithography	0	2	1	0	0	
Ultratech	3	12	5	4	11	
Total Japan	406	322	162	204	264	-10.2
Europe						
ASM Lithography	15	5	7	9	24	
Canon	30	16	10	19	29	
GCA	4	3	0	0	0	
Hitachi	0	0	0	2	0	
Nikon	40	25	20	22	50	
SVG Lithography	0	2	1	0	0	
Ultratech	6	3	3	7	12	
Total Europe	95	54	41	59	115	4.9
Asia/Pacific-ROW						
ASM Lithography	10	12	16	21	29	
Canon	20	25	26	32	40	
GCA	4	1	0	0	0	
Hitachi	1	27	4	4	0	
Nikon	33	30	22	48	110	
SVG Lithography	0	0	0	1	1	
Ultratech	5	4	4	4	16	
Total Asia/Pacific-ROW	73	99	72	110	196	28.0

(Continued)

Table 4-4 (Continued)
Each Company's Unit Shipments of Stepper Equipment to Each Region
(Units)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Worldwide						
ASM Lithography	58	40	51	69	107	
Canon	150	120	86	141	215	
GCA	52	31	16	0	0	
Hitachi	84	65	24	14	0	
Nikon	384	350	190	265	431	
SVG Lithography	9	8	6	7	7	
Ultratech	34	33	24	36	67	
Total Worldwide	771	647	397	532	827	1.8

Source: Dataquest (June 1995)

Table 4-5
Each Company's Revenue from Shipments of Direct-Write Lithography Equipment to Each Region (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Direct-Write Market	76.2	50.2	25.8	23.0	38.8	-15.5
North America						
Etec	0	0	0	0	2.0	
Hitachi	5.6	0	0	0	0	
Jenoptik	0	0	0	0	0	
JEOL	8.3	3.0	3.2	3.6	3.9	
Leica	2.0	1.3	0.7	2.6	2.0	
Total North America	15.9	4.3	3.9	6.2	7.9	-16.0
Japan						
Etec	0	0	4.0	0	0	
Hitachi	8.3	17.8	3.2	7.2	17.7	
Leica	0	0	0	0	2.0	
Jenoptik	0	0	0	0	0	
JEOL	18.8	17.8	5.5	3.6	3.9	
Total Japan	27.1	35.6	12.7	10.8	23.6	-3.4
Europe						
Etec	7.0	0	0	0	0	
Hitachi	0	0	0	0	0	
Jenoptik	0	0	0	3.2	3.3	
JEOL	8.3	3.0	0	0	0	
Leica	8.8	3.9	5.2	2.8	4.0	
Total Europe	24.1	6.9	5.2	6.0	7.3	-25.8
Asia/Pacific-ROW						
Etec	3.5	0	4.0	0	0	
Hitachi	5.6	0	0	0	0	
Jenoptik	0	0	0	0	0	
JEOL	0	3.0	0	0	0	
Leica	0	0.4	0	0	0	
Total Asia/Pacific-ROW	9.1	3.4	4.0	0	0	NM
Worldwide						
Etec	10.5	0	8.0	0	2.0	
Hitachi	19.5	17.8	3.2	7.2	17.7	
Jenoptik	0	0	0	3.2	3.3	
JEOL	35.4	26.8	8.7	7.2	7.8	
Leica	10.8	5.6	5.9	5.4	8.0	
Total Worldwide	76.2	50.2	25.8	23.0	38.8	-15.5

Source: Dataquest (June 1995)

Table 4-6
Each Company's Revenue from Shipments of Maskmaking Lithography Equipment to Each Region (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Maskmaking Market	47.1	47.8	52.7	52.0	77.6	13.3
North America						
Ateq	11.2	6.0	0	0	0	
Etec Systems	3.5	3.5	13.2	16.5	19.3	
Hitachi	0	0	0	0	0	
Jenoptik	0	0	0	0	0	
JEOL	0	0	0	0	0	
Leica	0	0	0	2.5	0	
Toshiba	0	0	0	0	0	
Total North America	14.7	9.5	13.2	19.0	19.3	7.0
Japan						
Ateq	2.8	6.0	0	0	0	
Etec Systems	3.5	3.5	11.4	12.1	14.1	
Hitachi	6.2	6.7	7.1	4.1	4.9	
Jenoptik	0	0	0	0	0	
JEOL	10.4	11.1	11.1	0	9.2	
Leica	0	0	0	0	0	
Toshiba	0	0	0	0	2.0	
Total Japan	22.9	27.3	29.6	16.2	30.2	7.2
Europe						
Ateq	0	3.0	0	0	0	
Etec Systems	3.5	0	0	3.0	2.9	
Hitachi	0	0	0	0	0	
Jenoptik	0	0	0	4.3	2.2	
JEOL	0	0	0	0	0	
Leica	0	2.4	5.0	2.5	2.9	
Toshiba	0	0	0	0	0	
Total Europe	3.5	5.4	5.0	9.8	8.0	23.0
Asia/Pacific-ROW						
Ateq	0	0	0	0	0	
Etec Systems	3.5	3.5	4.2	3.0	12.4	
Hitachi	0	0	0	4.0	4.9	
Jenoptik	0	0	0	0	2.8	
JEOL	0	0	0	0	0	
Leica	2.5	2.1	0.7	0	0	
Toshiba	0	0	0	0	0	
Total Asia/Pacific-ROW	6.0	5.6	4.9	7.0	20.1	35.3

(Continued)

Table 4-6 (Continued)
Each Company's Revenue from Shipments of Maskmaking Lithography Equipment to Each Region (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Worldwide						
Ateq	14.0	15.0	0	0	0	
Etec Systems	14.0	10.5	28.8	34.6	48.7	
Hitachi	6.2	6.7	7.1	8.1	9.8	
Jenoptik	0	0	0	4.3	5.0	
JEOL	10.4	11.1	11.1	0	9.2	
Leica	2.5	4.5	5.7	5.0	2.9	
Toshiba	0	0	0	0	2.0	
Total Worldwide	47.1	47.8	52.7	52.0	77.6	13.3

Source: Dataquest (June 1995)

Table 4-7
Each Company's Revenue from Shipments of Direct-Write and Maskmaking Lithography Equipment to Each Region (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Direct-Write and Maskmaking Lithography Market	123.3	98.0	78.5	75.0	116.4	-1.4
North America						
Ateq	11.2	6.0	0	0	0	
Etec	3.5	3.5	13.2	16.5	21.3	
Hitachi	5.6	0	0	0	0	
Jenoptik	0	0	0	0	0	
JEOL	8.3	3.0	3.2	3.6	3.9	
Leica	2.0	1.3	0.7	5.1	2.0	
Toshiba	0	0	0	0	0	
Total North America	30.6	13.8	17.1	25.2	27.2	-2.9
Japan						
Ateq	2.8	6.0	0	0	0	
Etec	3.5	3.5	15.4	12.1	14.1	
Hitachi	14.5	24.5	10.3	11.3	22.6	
Jenoptik	0	0	0	0	0	
JEOL	29.2	28.9	16.6	3.6	13.1	
Leica	0	0	0	0	2.0	
Toshiba	0	0	0	0	2.0	
Total Japan	50.0	62.9	42.3	27.0	53.8	1.8
Europe						
Ateq	0	3.0	0	0	0	
Etec	10.5	0	0	3.0	2.9	
Hitachi	0	0	0	0	0	
Jenoptik	0	0	0	7.5	5.5	
JEOL	8.3	3.0	0	0	0	
Leica	8.8	6.3	10.2	5.3	6.9	
Toshiba	0	0	0	0	0	
Total Europe	27.6	12.3	10.2	15.8	15.3	-13.7
Asia/Pacific-ROW						
Ateq	0	0	0	0	0	
Etec	7.0	3.5	8.2	3.0	12.4	
Hitachi	5.6	0	0	4.0	4.9	
Jenoptik	0	0	0	0	2.8	
JEOL	0	3.0	0	0	0	
Leica	2.5	2.5	0.7	0	0	
Toshiba	0	0	0	0	0	
Total Asia/Pacific-ROW	15.1	9.0	8.9	7.0	20.1	7.4

(Continued)

Table 4-7 (Continued)
Each Company's Revenue from Shipments of Direct-Write and Maskmaking Lithography Equipment to Each Region (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Worldwide Market						
Ateq	14.0	15.0	0	0	0	
Etec	24.5	10.5	36.8	34.6	50.7	
Hitachi	25.7	24.5	10.3	15.3	27.5	
Jenoptik	0	0	0	7.5	8.3	
JEOL	45.8	37.9	19.8	7.2	17.0	
Leica	13.3	10.1	11.6	10.4	10.9	
Toshiba	0	0	0	0	2.0	
Total Worldwide	123.3	98.0	78.5	75.0	116.4	-1.4

Source: Dataquest (June 1995)

Table 4-8
Each Company's Revenue from Shipments of X-Ray Aligners to Each Region (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World X-Ray Market	1.6	4.2	5.0	13.4	11.2	62.7
North America						
Hampshire Instruments	0	2.4	0	0	0	
Silicon Valley Group	0	0	0	11.4	11.2	
Karl Suss	0	0	5.0	2.0	0	
Total North America	0	2.4	5.0	13.4	11.2	NM
Japan						
Hampshire Instruments	0	0	0	0	0	
Silicon Valley Group	0	0	0	0	0	
Karl Suss	0	1.8	0	0	0	
Total Japan	0	1.8	0	0	0	NM
Europe						
Hampshire Instruments	0	0	0	0	0	
Silicon Valley Group	0	0	0	0	0	
Karl Suss	1.6	0	0	0	0	
Total Europe	1.6	0	0	0	0	-100.0
Asia/Pacific-ROW						
Hampshire Instruments	0	0	0	0	0	
Silicon Valley Group	0	0	0	0	0	
Karl Suss	0	0	0	0	0	
Total Asia/Pacific-ROW	0	0	0	0	0	NM
Worldwide						
Hampshire Instruments	0	2.4	0	0	0	
Silicon Valley Group	0	0	0	11.4	11.2	
Karl Suss	1.6	1.8	5.0	2.0	0	
Total Worldwide	1.6	4.2	5.0	13.4	11.2	62.7

NM = Not meaningful
Source: Dataquest (June 1995)

Table 4-9
Each Company's Revenue from Shipments of Automatic Photoresist Processing Equipment (Track) to Each Region (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Track Market	317.0	364.1	353.2	507.3	710.7	22.4
North America						
Canon	1.1	0	0	0	0	
Convac	7.1	8.0	9.0	3.4	5.3	
Dainippon Screen	6.2	11.1	16.4	24.1	36.9	
Eaton	1.5	0.3	0.4	0.3	0	
FSI International	0	5.1	15.6	21.0	27.2	
Machine Technology	17.5	18.5	7.2	6.2	0	
Semiconductor Systems	14.0	17.2	20.9	21.3	23.2	
Silicon Valley Group	23.7	29.3	33.5	51.6	48.9	
Solitec	5.0	3.0	2.5	0.9	0	
Tazmo	1.7	1.5	2.1	4.5	3.5	
Tokyo Electron Ltd	0	0	0	0	0	
Varian/TEL	6.9	13.2	19.5	35.3	37.2	
Yuasa	0	1.5	0	2.7	5.9	
Total North America	84.7	108.7	127.1	171.3	188.1	22.1
Japan						
Canon	6.2	12.3	11.1	10.8	14.7	
Convac	0	0	0	0	0	
Dainippon Screen	48.1	51.3	47.1	38.9	48.1	
Eaton	0	0	0	0	0	
FSI International	0	0	0	0	0	
Machine Technology	0	1.6	0.5	0	0	
Semiconductor Systems	0	0	0	0	0	
Silicon Valley Group	0.5	0	0.5	0	0	
Solitec	0	0	0	0	0	
Tazmo	15.3	11.9	7.0	11.7	5.9	
Tokyo Electron Ltd.	95.5	97.8	73.0	90.9	173.2	
Varian/TEL	0	0	0	0	0	
Yuasa	5.8	4.4	2.4	3.6	3.9	
Total Japan	171.4	179.3	141.6	155.9	245.8	9.4
Europe						
Canon	0	0	2.8	0	0	
Convac	8.3	6.5	6.8	13.1	12.6	
Dainippon Screen	2.1	4.8	4.7	23.1	16.0	
Eaton	1.0	2.2	0.1	0	0	
FSI International	0	0	0	0	1.5	
Machine Technology	3.5	6.5	9.0	6.5	0	
Semiconductor Systems	0	0	0	0	0	

(Continued)

Table 4-9 (Continued)
Each Company's Revenue from Shipments of Automatic Photoresist Processing Equipment (Track) to Each Region (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Silicon Valley Group	8.8	4.2	7.2	34.0	37.3	
Solitec	0.4	1.5	0.2	0.1	0	
Tazmo	0	0	0.3	0	0	
Tokyo Electron Ltd.	0	0	0	0	0	
Varian/TEL	6.9	10.8	10.5	28.8	20.9	
Yuasa	1.5	0	0	1.8	1.5	
Total Europe	32.5	36.5	41.6	107.4	89.8	28.9
Asia/Pacific-ROW						
Canon	1.1	0	1.2	1.8	0	
Convac	0	0.5	0.8	1.1	1.8	
Dainippon Screen	2.8	0	0	21.4	37.7	
Eaton	2.2	1.7	2.1	1.8	0	
FSI International	0	0	1.0	0	6.8	
Machine Technology	0	0	0	0.5	0	
Semiconductor Systems	0	0	0	0.6	0.8	
Silicon Valley Group	11.0	4.5	3.6	4.0	7.1	
Solitec	0.4	0.4	0.2	0.1	0	
Tazmo	0.5	1.8	0.6	1.8	3.5	
Tokyo Electron Ltd.	10.4	28.4	23.7	39.6	129.3	
Varian/TEL	0	0	0	0	0	
Yuasa	0	0	0	0	0	
Total Asia/Pacific-ROW	28.4	37.3	33.2	72.7	187.0	60.2
Worldwide						
Canon	8.4	12.3	15.1	12.6	14.7	
Convac	15.4	15.0	16.6	17.6	19.7	
Dainippon Screen	59.2	69.5	77.4	107.5	138.7	
Eaton	4.7	4.2	2.6	2.1	0	
FSI International	0	5.1	16.6	21.0	35.5	
Machine Technology	21.0	26.6	17.2	13.2	0	
Semiconductor Systems	14.0	17.2	20.9	21.9	24.0	
Silicon Valley Group	44.0	38.0	44.8	89.6	93.3	
Solitec	5.8	4.9	2.9	1.1	0	
Tazmo	17.5	15.2	10.0	18.0	12.9	
Tokyo Electron Ltd.	105.9	126.2	96.7	130.5	302.5	
Varian/TEL	13.8	24.0	30.0	64.1	58.1	
Yuasa	7.3	5.9	2.4	8.1	11.3	
Total Worldwide	317.0	364.1	353.2	507.3	710.7	22.4

Source: Dataquest (June 1995)

Table 4-10
Each Company's Revenue from Shipments of Auto Wet (Immersion) Stations to the North American Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Auto Wet Stations	267.8	290.6	285.7	285.4	518.5	18.0
CFM Technology	2.1	2.3	3.2	7.3	6.2	
Dainippon Screen	0	8.8	0	2.2	26.8	
Dalton Corporation	0	0	0	0	0	
Dan Science Company Ltd.	0	0	0	0	0	
Dexon	0.5	0	0	0	0	
ETS Company Ltd.	0	0	0	0	0	
Enya	1.4	0	1.1	0	0	
Fuji Electric	0	0	0	0	0	
Kaijo Denki	0	6.7	0	1.5	7.6	
Kuwano Electric	2.0	0	0	0	0	
Maruwa	0	0	0	0	0	
Musashi	0	0	0	0	0	
Pure-Aire	1.0	1.1	1.0	0	0	
Sankyo Engineering	0	0	0	0	0	
Santa Clara Plastics	5.8	15.0	37.6	37.9	37.2	
Sapi Equipements	3.0	2.0	0	0	0	
SCI Manufacturing	0.4	4.8	5.0	4.5	2.3	
Semifab	3.5	3.0	0	0	0	
Semitool	0	0	0	0	1.9	
Shimada	0	0	0	0	0	
Steag Microtech (formerly Pokorny)	0	0	0	2.8	8.4	
Submicron Systems Inc.	10.0	12.0	15.7	26.2	37.0	
Sugai	0	0	0	0	0	
S&K Products International	1.0	0	0	0	0	
Toho Kasei	0	0	0	0	0.7	
Toyoko Chemical	0	0	0	0	1.6	
Tokyo Electron	0	0	0	0	4.7	
Universal Plastics	4.5	5.5	6.0	7.0	0	
Verteq	1.1	1.7	1.0	0.8	15.2	
Total North America	36.3	62.9	70.6	90.2	149.6	42.5

Source: Dataquest (June 1995)

Table 4-11
Each Company's Revenue from Shipments of Auto Wet (Immersion) Stations to the Japanese Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Auto Wet Stations	267.8	290.6	285.7	285.4	518.5	18.0
CFM Technology	0	0	0.7	1.2	1.1	
Dainippon Screen	41.3	28.0	66.8	27.5	46.1	
Dalton Corporation	1.7	1.2	0	0	0	
Dan Science Company Ltd.	4.2	5.8	2.5	0.9	2.6	
Dexon	0	0	0	0	0	
ETS Company Ltd.	7.6	10.4	10.0	8.3	6.9	
Enya	5.6	10.7	2.5	1.3	2.4	
Fuji Electric	2.0	0.7	1.2	0	0	
Kaijo Denki	27.3	13.5	8.3	3.5	18.5	
Kuwano Electric	5.6	7.1	1.6	1.9	3.9	
Maruwa	5.9	5.9	2.0	2.7	4.1	
Musashi	3.9	3.1	1.1	2.3	2.6	
Pure-Aire	0	0	0	0	0	
Sankyo Engineering	25.0	23.8	12.2	16.3	34.0	
Santa Clara Plastics	0	0	0	0	0	
Sapi Equipements	0	0	0	0	0	
SCI Manufacturing	0	0	0	0	0	
Semifab	0	0	0	0	0	
Semitool	0	0	0	0	0	
Shimada	13.9	13.4	6.3	3.6	7.1	
Steag Microtech (formerly Pokorny)	0	0	0	0	0	
Submicron Systems Inc.	0	0	0	0	0	
Sugai	28.0	23.4	17.8	15.3	37.6	
S&K Products International	0	0	0	0	0	
Toho Kasei	3.4	5.2	9.5	11.2	10.0	
Toyoko Chemical	3.8	0.9	0	0	1.9	
Tokyo Electron	0	5.6	7.5	4.8	7.0	
Universal Plastics	0	0	0	0	0	
Verteq	0	0	0	0	0	
Total Japan	179.2	158.7	150.0	100.8	185.8	0.9

Source: Dataquest (June 1995)

Table 4-12
Each Company's Revenue from Shipments of Auto Wet (Immersion) Stations to the European Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Auto Wet Stations	267.8	290.6	285.7	285.4	518.5	18.0
CFM Technology	0	2.5	2.0	3.8	2.4	
Dainippon Screen	0.7	8.9	4.2	3.8	7.3	
Dalton Corporation	0	0	0	0	0	
Dan Science Company Ltd.	0	0	0	0	0	
Dexon	0	0	0	0	0	
ETS Company Ltd.	0	0	0	0	0	
Enya	0	0	0	0	0	
Fuji Electric	0	0	0	0	0	
Kaijo Denki	3.6	0	0	0	1.5	
Kuwano Electric	0	0	0	0	0	
Maruwa	0	0	0	0	0	
Musashi	0	0	0	0	0	
Pure-Aire	0	0	0	0	0	
Sankyo Engineering	6.9	2.4	1.1	0.5	0	
Santa Clara Plastics	1.4	2.0	3.1	5.6	6.5	
Sapi Equipements	0	0	2.0	1.5	1.5	
SCI Manufacturing	0	0	0	0	0	
Semifab	0	0	0	0	0	
Semitool	0	0	0	0	0	
Shimada	0	0	0	0	0	
Steag Microtech (formerly Pokorny)	6.2	6.6	5.2	10.2	3.3	
Submicron Systems Inc.	0	0	6.7	4.0	9.4	
Sugai	0	0	0	0	0	
S&K Products International	2.0	0	0	0	0	
Toho Kasei	4.6	0	0	0	0.6	
Toyoko Chemical	0	0	0	0	0	
Tokyo Electron	0	0	0	0	1.8	
Universal Plastics	0	0	0	0	0	
Verteq	0.6	0.6	0	0	0	
Total Europe	26.0	23.0	24.3	29.4	34.3	7.2

Source: Dataquest (June 1995)

Table 4-13
Each Company's Revenue from Shipments of Auto Wet (Immersion) Stations to Asia/Pacific-ROW (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Auto Wet Stations	267.8	290.6	285.7	285.4	518.5	18.0
CFM Technology	0	0	0	0	2.3	
Dainippon Screen	1.4	12.0	4.9	18.2	62.6	
Dalton Corporation	0	0	0	0	0	
Dan Science Company Ltd.	8.5	8.4	2.5	3.2	2.2	
Dexon	0	0	0	0	0	
ETS Company Ltd.	0	0	0	0	0	
Enya	0	0	0	0	0	
Fuji Electric	0	0.9	0	0	0	
Kaijo Denki	0	9.7	8.8	14.1	10.6	
Kuwano Electric	2.0	0	0	0	0	
Maruwa	0	2.2	0	0	0.9	
Musashi	1.9	1.0	0.5	0	0	
Pure-Aire	0.1	0.1	0	0	0	
Sankyo Engineering	1.7	1.2	6.1	0	24.2	
Santa Clara Plastics	2.0	2.5	3.0	2.3	2.6	
Sapi Equipements	0	0	0	0	0	
SCI Manufacturing	0	0	0	0	0	
Semifab	0	0	0	0	0	
Semitool	0	0	0	0	0	
Shimada	2.4	0	0	0	0	
Steag Microtech (formerly Pokorny)	0	0	0	1.0	0	
Submicron Systems Inc.	0	0	0	5.2	0	
Sugai	6.3	8.0	14.2	16.2	33.1	
S&K Products International	0	0	0	0	0	
Toho Kasei	0	0	0.8	1.4	1.3	
Toyoko Chemical	0	0	0	0	0	
Tokyo Electron	0	0	0	2.4	9.0	
Universal Plastics	0	0	0	1.0	0	
Verteq	0	0	0	0	0	
Total Asia/Pacific-ROW	26.3	46.0	40.8	65.0	148.8	54.2

Source: Dataquest (June 1995)

Table 4-14
Each Company's Revenue from Shipments of Auto Wet (Immersion) Stations to the Worldwide Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Auto Wet Stations	267.8	290.6	285.7	285.4	518.5	18.0
CFM Technology	2.1	4.8	5.9	12.3	12.0	
Dainippon Screen	43.4	57.7	75.9	51.7	142.8	
Dalton Corporation	1.7	1.2	0	0	0	
Dan Science Company Ltd.	12.7	14.2	5.0	4.1	4.8	
Dexon	0.5	0	0	0	0	
ETS Company Ltd.	7.6	10.4	10.0	8.3	6.9	
Enya	7.0	10.7	3.6	1.3	2.4	
Fuji Electric	2.0	1.6	1.2	0	0	
Kaijo Denki	30.9	29.9	17.1	19.1	38.2	
Kuwano Electric	9.6	7.1	1.6	1.9	3.9	
Maruwa	5.9	8.1	2.0	2.7	5.0	
Musashi	5.8	4.1	1.6	2.3	2.6	
Pure-Aire	1.1	1.2	1.0	0	0	
Sankyo Engineering	33.6	27.4	19.4	16.8	58.2	
Santa Clara Plastics	9.2	19.5	43.7	45.8	46.3	
Sapi Equipements	3.0	2.0	2.0	1.5	1.5	
SCI Manufacturing	0.4	4.8	5.0	4.5	2.3	
Semifab	3.5	3.0	0	0	0	
Semitool	0	0	0	0	1.9	
Shimada	16.3	13.4	6.3	3.6	7.1	
Steag Microtech (formerly Pokorny)	6.2	6.6	5.2	14.0	11.7	
Submicron Systems Inc.	10.0	12.0	22.4	35.4	46.4	
Sugai	34.3	31.4	32.0	31.5	70.7	
S&K Products International	3.0	0	0	0	0	
Toho Kasei	8.0	5.2	10.3	12.6	12.6	
Toyoko Chemical	3.8	0.9	0	0	3.5	
Tokyo Electron	0	5.6	7.5	7.2	22.5	
Universal Plastics	4.5	5.5	6.0	8.0	0	
Verteq	1.7	2.3	1.0	0.8	15.2	
Total Worldwide	267.8	290.6	285.7	285.4	518.5	18.0

Source: Dataquest (June 1995)

Table 4-15
Each Company's Revenue from Shipments of Spray Processors to the North American Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Spray Processors	NS	NS	NS	NS	67.1	NM
Dainippon Screen	NS	NS	NS	NS	0.6	
FSI International	NS	NS	NS	NS	17.6	
Semitool	NS	NS	NS	NS	15.3	
Total North America	NS	NS	NS	NS	33.5	NM

NM = Not meaningful
NS = Not surveyed
Source: Dataquest (June 1995)

Table 4-16
Each Company's Revenue from Shipments of Spray Processors to the Japanese Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Spray Processors	NS	NS	NS	NS	67.1	NM
Dainippon Screen	NS	NS	NS	NS	9.7	
FSI International	NS	NS	NS	NS	3.2	
Semitool	NS	NS	NS	NS	4.9	
Total Japan	NS	NS	NS	NS	17.8	NM

NM = Not meaningful
NS = Not surveyed
Source: Dataquest (June 1995)

Table 4-17
Each Company's Revenue from Shipments of Spray Processors to the European Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Spray Processors	NS	NS	NS	NS	67.1	NM
Dainippon Screen	NS	NS	NS	NS	0.2	
FSI International	NS	NS	NS	NS	4.0	
Semitool	NS	NS	NS	NS	6.2	
Total Europe	NS	NS	NS	NS	10.4	NM

NM = Not meaningful
NS = Not surveyed
Source: Dataquest (June 1995)

Table 4-18
Each Company's Revenue from Shipments of Spray Processors to Asia/Pacific-ROW (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Spray Processors	NS	NS	NS	NS	67.1	NM
Dainippon Screen	NS	NS	NS	NS	0.4	
FSI International	NS	NS	NS	NS	4.2	
Semitool	NS	NS	NS	NS	0.8	
Total Asia/Pacific-ROW	NS	NS	NS	NS	5.4	NM

NM = Not meaningful
NS = Not surveyed
Source: Dataquest (June 1995)

Table 4-19
Each Company's Revenue from Shipments of Spray Processors to the Worldwide Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Spray Processors	NS	NS	NS	NS	67.1	NM
Dainippon Screen	NS	NS	NS	NS	10.9	
FSI International	NS	NS	NS	NS	29.0	
Semitool	NS	NS	NS	NS	27.2	
Total Worldwide	NS	NS	NS	NS	67.1	NM

NM = Not meaningful
NS = Not surveyed
Source: Dataquest (June 1995)

Table 4-20
Each Company's Revenue from Shipments of Vapor Phase Clean Equipment to the North American Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Vapor Phase Clean Market	NS	NS	2.4	5.6	9.8	NM
Dainippon Screen	NS	NS	0	0	0	
FSI International	NS	NS	0.9	1.7	3.0	
Musashi	NS	NS	0	0	0	
Semitool	NS	NS	0	0	1.0	
Total North America	NS	NS	0.9	1.7	4.0	NM

NM = Not meaningful
NS = Not surveyed
Source: Dataquest (June 1995)

Table 4-21
Each Company's Revenue from Shipments of Vapor Phase Clean Equipment to the Japanese Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Vapor Phase Clean Market	NS	NS	2.4	5.6	9.8	NM
Dainippon Screen	NS	NS	0	0	0.4	
FSI International	NS	NS	0	1.7	0.9	
Musashi	NS	NS	0	0	0.9	
Semitool	NS	NS	0	0	0	
Total Japan	NS	NS	0	1.7	2.2	NM

Source: Dataquest (June 1995)

Table 4-22
Each Company's Revenue from Shipments of Vapor Phase Clean Equipment to the European Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Vapor Phase Clean Market	NS	NS	2.4	5.6	9.8	NM
Dainippon Screen	NS	NS	0	0	0	
FSI International	NS	NS	0.6	0	0.9	
Musashi	NS	NS	0	0	0	
Semitool	NS	NS	0	0	0	
Total Europe	NS	NS	0.6	0	0.9	NM

NM = Not meaningful
NS = Not surveyed
Source: Dataquest (June 1995)

Table 4-23
Each Company's Revenue from Shipments of Vapor Phase Clean Equipment to Asia/Pacific-ROW (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Vapor Phase Clean Market	NS	NS	2.4	5.6	9.8	NM
Dainippon Screen	NS	NS	0	0	0	
FSI International	NS	NS	0.9	2.2	2.7	
Musashi	NS	NS	0	0	0	
Semitool	NS	NS	0	0	0	
Total Asia/Pacific-ROW	NS	NS	0.9	2.2	2.7	NM

NM = Not meaningful
NS = Not surveyed
Source: Dataquest (June 1995)

Table 4-24
Each Company's Revenue from Shipments of Vapor Phase Clean Equipment to the Worldwide Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Vapor Phase Clean Market	NS	NS	2.4	5.6	9.8	NM
Dainippon Screen	NS	NS	0	0	0.4	
FSI International	NS	NS	2.4	5.6	7.5	
Musashi	NS	NS	0	0	0.9	
Semitool	NS	NS	0	0	1.0	
Total Worldwide	NS	NS	2.4	5.6	9.8	NM

NM = Not meaningful
NS = Not surveyed
Source: Dataquest (June 1995)

Table 4-25
Each Company's Revenue from Shipments of Post-CMP Clean Equipment to the North American Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Post-CMP Clean Market	NS	0.4	2.4	8.9	26.4	NM
Dainippon Screen	NS	0	0	0	3.2	
FSI International	NS	0	0	0.4	0	
IPEC/Westech Systems	NS	0.4	1.6	0.8	1.3	
OnTrack Systems	NS	0	0	4.1	11.9	
Verteq	NS	0	0	0	0.7	
Total North America	NS	0.4	1.6	5.3	17.1	NM

NM = Not meaningful
NS = Not surveyed
Source: Dataquest (June 1995)

Table 4-26
Each Company's Revenue from Shipments of Post-CMP Clean Equipment to the Japanese Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Post-CMP Clean Market	NS	0.4	2.4	8.9	26.4	NM
Dainippon Screen	NS	0	0	0	2.8	
FSI International	NS	0	0	0	0	
IPEC/Westech Systems	NS	0	0	0.8	0	
OnTrack Systems	NS	0	0	0	0	
Verteq	NS	0	0	0	0	
Total Japan	NS	0	0	0.8	2.8	NM

NM = Not meaningful
NS = Not surveyed
Source: Dataquest (June 1995)

Table 4-27
Each Company's Revenue from Shipments of Post-CMP Clean Equipment to the European Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Post-CMP Clean Market	NS	0.4	2.4	8.9	26.4	NM
Dainippon Screen	NS	0	0	0	1.1	
FSI International	NS	0	0	0	0	
IPEC/Westech Systems	NS	0	0.8	2.0	1.0	
OnTrack Systems	NS	0	0	0.4	2.6	
Verteq	NS	0	0	0	0	
Total Europe	NS	0	0.8	2.4	4.7	NM

NM = Not meaningful
NS = Not surveyed
Source: Dataquest (June 1995)

Table 4-28
Each Company's Revenue from Shipments of Post-CMP Clean Equipment to Asia/Pacific-ROW (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Post-CMP Clean Market	NS	0.4	2.4	8.9	26.4	NM
Dainippon Screen	NS	0	0	0	0	
FSI International	NS	0	0	0	0	
IPEC/Westech Systems	NS	0	0	0.4	1.0	
OnTrack Systems	NS	0	0	0	0.8	
Verteq	NS	0	0	0	0	
Total Asia/Pacific-ROW	NS	0	0	0.4	1.8	NM

NM = Not meaningful
NS = Not surveyed
Source: Dataquest (June 1995)

Table 4-29
Each Company's Revenue from Shipments of Post-CMP Clean Equipment to the Worldwide Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Post-CMP Clean Market	NS	0.4	2.4	8.9	26.4	NM
Dainippon Screen	NS	0	0	0	7.1	
FSI International	NS	0	0	0.4	0	
IPEC/Westech Systems	NS	0.4	2.4	4.0	3.3	
OnTrack Systems	NS	0	0	4.5	15.3	
Verteq	NS	0	0	0	0.7	
Total Worldwide	NS	0.4	2.4	8.9	26.4	NM

NM = Not meaningful
NS = Not surveyed
Source: Dataquest (June 1995)

Table 4-30
Each Company's Revenue from Shipments of Dry Strip Equipment to the North American Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Dry Strip Market	117.7	119.1	122.5	138.1	202.4	14.5
Alcan Tech	0	4.0	4.3	4.9	1.0	
Branson/IPC	6.0	0	0	0	0	
Chlorine Engineers	0	0	0	0	0	
Fusion Semiconductor Systems	1.5	0.8	2.5	3.0	5.9	
Gasonics	6.8	14.9	13.6	18.9	31.0	
Hitachi	0	0	0	0	0	
Japan Storage Battery	0	0	0	0	0	
LFE	1.0	1.1	0	0	0	
m.FSI	0	0	0	0	0	
Machine Technology	0	0	0	0	0	
Matrix	6.0	4.1	4.2	5.0	7.2	
Mattson Technologies	0	1.5	0.8	1.2	6.7	
MC Electronics	0	0	1.1	1.2	2.4	
Plasma Systems	1.1	1.2	0.8	0.6	0	
Ramco	0	2.1	1.1	0	0	
Samco	0.1	0.2	0.3	0.2	0.2	
Shinko Seiki	0	0	0	0	0	
Sumitomo Metals	0	0	0	0	0	
Tegal	2.0	1.6	0.8	0.6	1.0	
Tokyo Ohka Kogyo	0.6	0.7	0	0	0	
Ulvac	0	0	0	0	0	
Total North America	25.1	32.2	29.5	35.6	55.4	21.9

Source: Dataquest (June 1995)

Table 4-31
Each Company's Revenue from Shipments of Dry Strip Equipment to the Japanese Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Dry Strip Market	117.7	119.1	122.5	138.1	202.4	14.5
Alcan Tech	9.7	12.7	8.9	9.0	17.9	
Branson/IPC	1.0	0	0	0	0	
Chlorine Engineers	2.7	0	0	0	0	
Fusion Semiconductor Systems	0	0	0	0	0	
Gasonics	1.0	1.0	0	0	0	
Hitachi	2.7	4.5	3.6	6.3	4.9	
Japan Storage Battery	0	0	0.2	0.2	0	
LFE	0	0	0	0	0	
m.FSI	0	1.7	0.9	0	0	
Machine Technology	0	0	0	0	0	
Matrix	1.0	0.3	0	0.9	1.4	
Mattson Technologies	0	0	0.5	1.7	7.0	
MC Electronics	0	0	12.1	11.2	15.8	
Plasma Systems	21.0	16.7	4.1	12.1	10.7	
Ramco	16.0	5.6	12.1	0	0	
Samco	0.8	0.9	0.6	0.3	0.3	
Shinko Seiki	0	1.1	0.4	1.8	1.2	
Sumitomo Metals	0	2.1	4.5	1.7	2.2	
Tegal	0	0.7	0.2	0	0	
Tokyo Ohka Kogyo	17.3	12.5	8.9	3.8	3.5	
Ulvac	2.3	2.3	1.9	3.1	4.1	
Total Japan	75.5	62.1	58.9	52.1	69.0	-2.2

Source: Dataquest (June 1995)

Table 4-32
Each Company's Revenue from Shipments of Dry Strip Equipment to the European Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Dry Strip Market	117.7	119.1	122.5	138.1	202.4	14.5
Alcan Tech	2.0	0.9	0.9	1.1	0	
Branson/IPC	4.5	0	0	0	0	
Chlorine Engineers	0	0	0	0	0	
Fusion Semiconductor Systems	0	0.5	1.1	3.0	3.6	
Gasonics	0.4	2.0	1.7	11.8	11.8	
Hitachi	0	0	0	0	0	
Japan Storage Battery	0	0	0	0	0	
LFE	0	0	0	0	0	
m.FSI	0	0	0	0	0	
Machine Technology	0.2	0	0	0	0	
Matrix	1.5	2.4	1.8	2.5	2.6	
Mattson Technologies	0	0	0.5	0.3	1.5	
MC Electronics	0	0	0.6	1.3	1.4	
Plasma Systems	0	0	0	0	0	
Ramco	0	1.6	0.6	0	0	
Samco	0	0	0	0	0	
Shinko Seiki	0	0	0	0	0	
Sumitomo Metals	0	0	0	0	0	
Tegal	0.5	0.8	0	0	0	
Tokyo Ohka Kogyo	0.2	1.0	0	0	2.4	
Ulvac	0	0	0	0	0	
Total Europe	9.3	9.2	7.2	20.0	23.3	25.8

Source: Dataquest (June 1995)

Table 4-33
Each Company's Revenue from Shipments of Dry Strip Equipment to Asia/Pacific-ROW (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Dry Strip Market	117.7	119.1	122.5	138.1	202.4	14.5
Alcan Tech	0	1.6	1.6	1.8	6.9	
Branson/IPC	3.0	0	0	0	0	
Chlorine Engineers	0	0	0	0	0	
Fusion Semiconductor Systems	0	0.6	0	0.2	3.4	
Gasonics	0	5.0	9.1	7.8	8.8	
Hitachi	0	1.1	1.2	0	0	
Japan Storage Battery	0	0	0	0	0	
LFE	0.4	0.4	0	0	0	
m.FSI	0	0	0	0	0	
Machine Technology	0	0	0	0	0	
Matrix	0.5	0.7	1.0	0.6	1.5	
Mattson Technologies	0	0	0	0	2.5	
MC Electronics	0	0	1.1	5.4	9.8	
Plasma Systems	2.8	3.3	11.2	14.4	21.3	
Ramco	0	1.0	1.1	0	0	
Samco	0	0	0	0	0	
Shinko Seiki	0	0	0	0	0	
Sumitomo Metals	0	0	0	0	0	
Tegal	0.5	0.4	0.6	0.2	0.5	
Tokyo Ohka Kogyo	0.6	1.5	0	0	0	
Ulvac	0	0	0	0	0	
Total Asia/Pacific-ROW	7.8	15.6	26.9	30.4	54.7	62.7

Source: Dataquest (June 1995)

Table 4-34
Each Company's Revenue from Shipments of Dry Strip Equipment to the Worldwide Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Dry Strip Market	117.7	119.1	122.5	138.1	202.4	14.5
Alcan Tech	11.7	19.2	15.7	16.8	25.8	
Branson/IPC	14.5	0	0	0	0	
Chlorine Engineers	2.7	0	0	0	0	
Fusion Semiconductor Systems	1.5	1.9	3.6	6.2	12.9	
Gasonics	8.2	22.9	24.4	38.5	51.6	
Hitachi	2.7	5.6	4.8	6.3	4.9	
Japan Storage Battery	0	0	0.2	0.2	0	
LFE	1.4	1.5	0	0	0	
m.FSI	0	1.7	0.9	0	0	
Machine Technology	0.2	0	0	0	0	
Matrix	9.0	7.5	7.0	9.0	12.7	
Mattson Technologies	0	1.5	1.8	3.2	17.7	
MC Electronics	0	0	14.9	19.1	29.4	
Plasma Systems	24.9	21.2	16.1	27.1	32.0	
Ramco	16.0	10.3	14.9	0	0	
Samco	0.9	1.1	0.9	0.5	0.5	
Shinko Seiki	0	1.1	0.4	1.8	1.2	
Sumitomo Metals	0	2.1	4.5	1.7	2.2	
Tegal	3.0	3.5	1.6	0.8	1.5	
Tokyo Ohka Kogyo	18.7	15.7	8.9	3.8	5.9	
Ulvac	2.3	2.3	1.9	3.1	4.1	
Total Worldwide	117.7	119.1	122.5	138.1	202.4	14.5

Source: Dataquest (June 1995)

Table 4-35
Each Company's Revenue from Shipments of Dry Etch* Equipment to the North American Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Dry Etch Market	690.4	717.4	681.5	1,096.0	1,554.5	22.5
Alcan Technology	0	0	0	0	0	
Anelva	0	0	0	0	0.4	
Applied Materials	78.0	60.0	80.4	101.5	133.1	
Branson/IPC	2.0	0	0	0	0	
Drytek	13.0	15.0	12.6	3.6	0	
Elionix	0	0	0	0	0	
E.T. Electrotech	4.0	4.8	2.4	8.0	4.2	
Gasonics	0	3.5	2.5	2.3	3.0	
Hitachi	7.0	3.3	6.8	9.0	16.2	
Kokusai	0	0	0	0	0	
Lam Research	48.0	63.0	81.1	156.9	230.8	
Matsushita Electric Ind.	0	0	0	0	0	
Matrix	0	2.1	1.5	1.4	2.2	
Materials Research	0.8	2.6	0	0	0	
PMT	0	0	0	1.9	3.6	
Plasma Systems	0	0	0	0	0	
Plasma Technology	2.5	2.7	1.6	1.8	0	
Plasma-Therm	10.0	0.7	4.5	1.0	0	
Samco	0	0	0	0	0	
Shibaura	0	0	0.8	1.7	1.4	
Sumitomo Metals	0.7	0	0	0	0	
Tegal	13.0	11.0	15.1	22.1	21.2	
Tokyo Electron	0	0	0	0	0	
Tokuda	0.5	0	0	0	0	
Tokyo Ohka	0.3	0	0	0	0	
Ulvac	0	0	0	0	0	
Varian/TEL	4.7	4.4	2.0	12.2	4.9	
Total North America	184.5	173.1	211.3	323.4	421.0	22.9

*Dry Etch includes ECR Etch.

Source: Dataquest (June 1995)

Table 4-36
Each Company's Revenue from Shipments of Dry Etch* Equipment to the Japanese Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Dry Etch Market	690.4	717.4	681.5	1,096.0	1,554.5	22.5
Alcan Technology	2.5	5.6	3.8	2.2	3.1	
Anelva	27.3	19.3	17.7	14.4	24.9	
Applied Materials	52.0	47.0	43.2	60.2	74.9	
Branson/IPC	0	0	0	0	0	
Drytek	3.0	3.0	1.8	0	0	
Elionix	1.2	0.7	0.4	0	0	
E.T. Electrotech	2.5	0	0	0	0	
Gasonics	0	0	0	0	0	
Hitachi	79.5	95.1	67.8	95.1	108.5	
Kokusai	1.1	0	1.3	0.6	0	
Lam Research	24.2	21.1	22.3	34.1	66.0	
Matsushita Electric Ind.	0	0	3.1	0	2.3	
Matrix	0	0	0	0.3	0.6	
Materials Research	3.9	5.2	0	0	0	
PMT	0	0	0	2.8	2.9	
Plasma Systems	1.7	2.0	0.2	1.8	3.9	
Plasma Technology	0	0	0	1.2	0	
Plasma-Therm	5.0	11.0	0	0	0	
Samco	2.8	3.8	4.7	1.9	3.1	
Shibaura	0	26.9	12.8	33.6	22.5	
Sumitomo Metals	15.0	15.4	13.2	20.1	16.1	
Tegal	5.0	7.0	4.1	8.4	10.3	
Tokyo Electron	96.8	86.0	76.4	114.3	192.4	
Tokuda	22.3	0	0	0	0	
Tokyo Ohka	13.5	14.0	5.5	4.7	6.0	
Ulvac	6.6	6.2	2.0	3.2	2.7	
Varian/TEL	0	0	0	0	0	
Total Japan	365.9	369.3	280.3	398.9	540.2	10.2

*Dry Etch includes ECR Etch.
Source: Dataquest (June 1995)

Table 4-37
Each Company's Revenue from Shipments of Dry Etch* Equipment to the European Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Dry Etch Market	690.4	717.4	681.5	1,096.0	1,554.5	22.5
Alcan Technology	0	0	0	0	0	
Anelva	0	0	0	0	0.3	
Applied Materials	35.0	28.0	39.4	60.3	79.1	
Branson/IPC	1.0	0	0	0	0	
Drytek	4.0	5.0	1.8	0.9	0	
Elionix	0	0	0	0	0	
E.T. Electrotech	10.0	4.8	3.4	4.3	8.8	
Gasonics	0	1.5	0.5	0.8	0.6	
Hitachi	5.0	4.5	8.5	6.3	7.1	
Kokusai	0	0	0	0	0	
Lam Research	17.0	12.0	31.3	64.3	92.9	
Matsushita Electric Ind.	0	0	0	0	0	
Matrix	0	0	0	0.5	0.7	
Materials Research	0	1.8	0	0	0	
PMT	0	0	0	0	0	
Plasma Systems	0	0	0	0	0	
Plasma Technology	3.0	3.6	2.2	1.6	0	
Plasma-Therm	2.0	2.1	2.0	0	0	
Samco	0	0	0	0	0	
Shibaura	0	0	0.8	1.0	0.7	
Sumitomo Metals	0	0	0	0	3.2	
Tegal	11.0	8.0	8.1	5.3	8.5	
Tokyo Electron	0	0	0	0	0	
Tokuda	0.7	0	0	0	0	
Tokyo Ohka	0	0	0	0	0	
Ulvac	0	0	0	0	0	
Varian/TEL	6.9	6.5	5.0	8.2	6.7	
Total Europe	95.6	77.8	103.0	153.5	208.6	21.5

*Dry Etch includes ECR Etch.

Source: Dataquest (June 1995)

Table 4-38
Each Company's Revenue from Shipments of Dry Etch* Equipment to Asia/Pacific-ROW (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Dry Etch Market	690.4	717.4	681.5	1,096.0	1,554.5	22.5
Alcan Technology	0	0	0	0	0	
Anelva	2.1	2.0	1.9	0.8	1.3	
Applied Materials	10.0	19.0	24.0	95.2	129.0	
Branson/IPC	0.5	0	0	0	0	
Drytek	2.0	2.0	0.9	0	0	
Elionix	0	0	0	0	0	
E.T. Electrotech	1.0	2.4	0.8	0	0	
Gasonics	0	0	0	0	0.6	
Hitachi	0	12.3	12.0	18.0	25.8	
Kokusai	0	0	0	0	0	
Lam Research	20.0	31.0	29.2	66.5	121.0	
Matsushita Electric Ind.	0	0	0	0	0	
Matrix	0	0.2	0	0.7	1.2	
Materials Research	0	0	0	0	0	
PMT	0	0	0	0	3.4	
Plasma Systems	0	0	0	0	0	
Plasma Technology	0	0	0	1.0	0	
Plasma-Therm	1.0	0	0	0	0	
Samco	0	0	0	0	0	
Shibaura	0	0	0.4	0	0	
Sumitomo Metals	0	0	0	0	2.9	
Tegal	2.0	3.0	5.8	6.9	12.1	
Tokyo Electron	2.4	24.0	11.9	31.1	87.4	
Tokuda	0.6	0	0	0	0	
Tokyo Ohka	2.8	1.3	0	0	0	
Ulvac	0	0	0	0	0	
Varian/TEL	0	0	0	0	0	
Total Asia/Pacific-ROW	44.4	97.2	86.9	220.2	384.7	71.6

*Dry Etch includes ECR Etch.
Source: Dataquest (June 1995)

Table 4-39
Each Company's Revenue from Shipments of Dry Etch* Equipment to the Worldwide Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Dry Etch Market	690.4	717.4	681.5	1,096.0	1,554.5	22.5
Alcan Technology	2.5	5.6	3.8	2.2	3.1	
Anelva	29.4	21.3	19.6	15.2	26.9	
Applied Materials	175.0	154.0	187.0	317.2	416.1	
Branson/IPC	3.5	0	0	0	0	
Drytek	22.0	25.0	17.1	4.5	0	
Elionix	1.2	0.7	0.4	0	0	
E.T. Electrotech	17.5	12.0	6.6	12.3	13.0	
Gasonics	0	5.0	3.0	3.1	4.2	
Hitachi	91.5	115.2	95.1	128.4	157.6	
Kokusai	1.1	0	1.3	0.6	0	
Lam Research	109.2	127.1	163.9	321.8	510.7	
Matsushita Electric Ind.	0	0	3.1	0	2.3	
Matrix	0	2.3	1.5	2.9	4.7	
Materials Research	4.7	9.6	0	0	0	
PMT	0	0	0	4.7	9.9	
Plasma Systems	1.7	2.0	0.2	1.8	3.9	
Plasma Technology	5.5	6.3	3.8	5.6	0	
Plasma-Therm	18.0	13.8	6.5	1.0	0	
Samco	2.8	3.8	4.7	1.9	3.1	
Shibaura	0	26.9	14.8	36.3	24.6	
Sumitomo Metals	15.7	15.4	13.2	20.1	22.2	
Tegal	31.0	29.0	33.1	42.7	52.1	
Tokyo Electron	99.2	110.0	88.3	145.4	279.8	
Tokuda	24.1	0	0	0	0	
Tokyo Ohka	16.6	15.3	5.5	4.7	6.0	
Ulvac	6.6	6.2	2.0	3.2	2.7	
Varian/TEL	11.6	10.9	7.0	20.4	11.6	
Total Worldwide	690.4	717.4	681.5	1,096.0	1,554.5	22.5

*Dry Etch includes ECR Etch.
Source: Dataquest (June 1995)

Table 4-40
Each Company's Revenue from Shipments of Chemical Mechanical Polishing Equipment to the World (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1991-1994
World CMP Market	NS	10.8	19.7	43.6	64.8	81.7
North American Market						
Cybeq Systems	NS	0	2	2.9	3.7	
Ebara Corporation	NS	0	0	0	0	
Fujikoshi	NS	0	0	0	0	
Pressi	NS	0	0	0	0	
Speedfam	NS	0	0	0	3	
Strasbaugh	NS	2.6	2.9	4.6	5.8	
IPEC/Westech Systems	NS	5.8	10.8	22.2	28.1	
Total North America	NS	8.4	15.7	29.7	40.6	69.1
Japanese Market						
Cybeq Systems	NS	0	0.5	1.6	2.3	
Ebara Corporation	NS	0	0	0	4.7	
Fujikoshi	NS	0	0	0.3	0.7	
Pressi	NS	0	0	0	0	
Speedfam	NS	0	0	2	0.8	
Strasbaugh	NS	0	0	1.1	1.4	
IPEC/Westech Systems	NS	0	0.7	2.6	3.9	
Total Japan	NS	0	1.2	7.6	13.8	NM
European Market						
Cybeq Systems	NS	0	0	0	1.5	
Ebara Corporation	NS	0	0	0	0	
Fujikoshi	NS	0	0	0	0	
Pressi	NS	0.2	0.3	0.5	1.2	
Speedfam	NS	0	0	0	0	
Strasbaugh	NS	0	0	0	0	
IPEC/Westech Systems	NS	1.9	2.5	4.3	6.1	
Total Europe	NS	2.1	2.8	4.8	8.8	61.2
Asia/Pacific-ROW						
Cybeq Systems	NS	0	0	0	0	
Ebara Corporation	NS	0	0	0	0	
Fujikoshi	NS	0	0	0	0	
Pressi	NS	0	0	0	0	
Speedfam	NS	0	0	0	0	
Strasbaugh	NS	0	0	0	0	
IPEC/Westech Systems	NS	0.3	0	1.5	1.6	
Total Asia/Pacific-ROW	NS	0.3	0	1.5	1.6	74.7

(Continued)

Table 4-40 (Continued)
Each Company's Revenue from Shipments of Chemical Mechanical Polishing Equipment to the World (End-User Revenue in Millions of U.S. Dollars)

	1990[1]	1991	1992	1993	1994	CAGR (%) 1991-1994
Worldwide Market						
Cybeq Systems	NS	0	2.5	4.5	7.5	
Ebara Corporation	NS	0	0	0	4.7	
Fujikoshi	NS	0	0	0.3	0.7	
Pressi	NS	0.2	0.3	0.5	1.2	
Speedfam	NS	0	0	2	3.8	
Strasbaugh	NS	2.6	2.9	5.7	7.2	
IPEC/Westech Systems	NS	8	14	30.6	39.7	
Total Worldwide	NS	10.8	19.7	43.6	64.8	81.7

NS = Not surveyed
Source: Dataquest (June 1995)

Table 4-41
Each Company's Revenue from Shipments of Chemical Vapor Deposition Equipment to the North American Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World CVD Market	715.5	742.5	650.3	868.5	1,348.9	17.2
Tube CVD						
Horizontal Tube LPCVD						
Advanced Crystal Sciences	0	0	0.6	1.0	1.1	
ASM International	2.5	2.0	1.8	0.9	0	
Bruce Technologies	0	0	2.2	3.8	4.8	
BTU International	4.0	2.5	0	0	0	
Centrotherm	2.8	1.6	0.8	0.8	0	
ETS Company	0	0	0	0	0	
General Signal Thinfilm	2.0	0	0	0	0	
Kokusai Electric	0	0	0	0	0	
Koyo Lindberg	0	0	0	0	0	
Process Technology	2.5	1.2	1.1	1.5	0.7	
Silicon Valley Group	6.0	4.5	5.2	2.9	4.7	
Solitec	4.0	0	0	0	0	
Tokyo Electron Ltd.	0	0	0	0	0	
Tystar	0.2	0	0.6	0.6	0.4	
Ulvac	0	0	0	0	0	
Ulvac/BTU	0	0	0	0	0	
Varian/TEL	0	0	0	0	0	
Wellman Furnaces	0	0	0	0	0	
Yamato Semico. Ltd.	0	0	0	0	0	
Total Horizontal LPCVD	24.0	11.8	12.3	11.5	11.7	-16.4
Vertical Tube LPCVD						
ASM International	1.2	2.0	2.9	4.1	4.6	
Bruce Technologies	0	0	0	0.5	5.1	
BTU International	2.0	3.5	0	0	0	
Denko	0	0	0	0	0	
Disco	0	0	0	0	0	
General Signal Thinfilm	4.0	3.0	0	0	0	
Kokusai Electric	2.5	5.5	4.9	13.4	14.5	
Koyo Lindberg	0	0	0	0	0	
Semitherm	1.5	1.5	0.5	2.5	3.2	
Shinko Electric	0	0	0	0	0	
Silicon Valley Group	8.0	7.6	8.2	6.6	19.9	
Tempress	0	0	0.9	0.9	0	
Toyoko Chemical	0	0	0	0	0.6	

(Continued)

Table 4-41 (Continued)
Each Company's Revenue from Shipments of Chemical Vapor Deposition Equipment to the North American Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Tokyo Electron Ltd.	0	0	0	0	0	
Ulvac	0	0	0	0	0	
Varian/TEL	2.0	5.3	3.1	9.5	24.6	
Yamato Semico. Ltd.	0	0	0	0	0	
Total Vertical LPCVD	21.2	28.4	20.5	37.5	72.5	36.0
Horizontal Tube PECVD						
ASM International	16.0	10.0	7.8	7.8	7.2	
Pacific Western	1.5	1.0	1.0	0.6	0	
Total Horizontal Tube PECVD	17.5	11.0	8.8	8.4	7.2	-19.9
Total North America Tube CVD	62.7	51.2	41.6	57.4	91.4	9.9
Nontube CVD Reactors						
APCVD Reactors						
Alcan/Canon/Quester	0	2.7	6.3	2.0	4.9	
Amaya	0	0	0	0	0	
Applied Materials	0	0	0	0	0	
General Signal Thinfilm	0.5	0.5	0	0	0	
Koyo Lindberg	0	0	0	0	0	
Toshiba Machine	0	0	0	0	0	
Watkins-Johnson	10.0	13.2	20.2	26.8	29.4	
Yamato Semico. Ltd.	0	0	0	0	0	
Total APCVD Reactors	10.5	16.4	26.5	28.8	34.3	34.4
Dedicated LPCVD Reactors						
Anelva	0	0	0	0	0	
Applied Materials	12.0	12.0	27.3	38.2	56.5	
BCT Spectrum	0	2.0	0	0	0	
BTU/Ulvac	1.6	0	0	0	0	
Enya	0	0	0	0	0	
Genus	14.0	6.8	5.2	4.2	1.8	
Kokusai Electric	0	0	0	0	0	
LAM Research	1.3	0	5.7	1.3	0	
Materials Research Corporation	0	0	1.6	0	0	
Novellus	1.0	5.7	4.5	11.9	24.0	
Silicon Valley Group	0.6	0	0	0	0	
Spectrum CVD	2.0	0	0	0	0	
Tokyo Electron Ltd.	0	0	0	0	0	
Ulvac	0	1.5	1.4	1.6	0	
Total Dedicated LPCVD Reactors	32.5	28.0	45.7	57.2	82.3	26.1

(Continued)

Table 4-41 (Continued)
Each Company's Revenue from Shipments of Chemical Vapor Deposition Equipment to the North American Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Dedicated PECVD Reactors						
Applied Materials	68.2	77.0	85.0	81.5	102.5	
ASM International	0	0	0	0	0	
Enya	0	0	0	0	0	
E.T. Electrotech	3.5	3.4	2.1	1.4	0	
Japan Production	0	0	0	0	0	
Novellus	42.0	23.0	20.5	28.8	59.4	
Oxford Instruments	0	0	0	0.7	0	
Plasma & Materials Technology	0	0	0	1.5	0	
Plasma-Therm	2.0	1.2	0.8	0	0	
Samco	0	0	0	0	0	
Total Dedicated PECVD Reactors	115.7	104.6	108.4	113.9	161.9	8.8
HDP CVD						
Anelva	0	0	0	0	0	
Fuji Electric	0	0	0	0	0	
LAM Research	0	0	0	2.9	6.3	
Oxford Instruments	0.6	0.5	0.4	0	0	
Sumitomo Metals	2.5	2.7	0	0	0	
Total HDPCVD	3.1	3.2	0.4	2.9	6.3	19.4
Total North America Nontube CVD	161.8	152.2	181.0	202.8	284.8	15.2
Total North America CVD	224.5	203.4	222.6	260.2	376.2	13.8

Source: Dataquest (June 1995)

Table 4-42
Each Company's Revenue from Shipments of Chemical Vapor Deposition Equipment to the Japanese Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World CVD Market	715.5	742.5	650.3	868.5	1,348.9	17.2
Tube CVD						
Horizontal Tube LPCVD						
Advanced Crystal Sciences	0	0	0	0	0	
ASM International	1.5	0.9	0	0	0	
Bruce Technologies	0	0	0	0	0	
BTU International	0	0	0	0	0	
Centrotherm	0	0	0	0	0	
ETS Company	0	0	0	0.2	0	
General Signal Thinfilm	0	0	0	0	0	
Kokusai Electric	2.5	0	0	1.2	0.4	
Koyo Lindberg	1.0	0	0.8	1.3	1.6	
Process Technology	0	0	0	0	0	
Silicon Valley Group	0	0	0	0	0	
Solitec	0	0	0	0	0	
Tokyo Electron Ltd.	3.6	7.1	5.1	1.6	2.0	
Tystar	0	0	0	0	0	
Ulvac	0	2.3	2.5	1.8	1.6	
Ulvac/BTU	6.2	0	0	0	0	
Varian/TEL	0	0	0	0	0	
Wellman Furnaces	0	0	0	0	0	
Yamato Semico. Ltd.	0.3	0.3	0	0	0	
Total Horizontal LPCVD	15.1	10.6	8.4	6.1	5.6	-22.0
Vertical Tube LPCVD						
ASM International	13.9	14.1	8.0	6.5	7.0	
Bruce Technologies	0	0	0	0	0	
BTU International	0	0	0	0	0	
Denko	3.8	0	0	0	0	
Disco	0	2.7	0.9	0	0	
General Signal Thinfilm	0	0	0	0	0	
Kokusai Electric	39.2	32.3	29.3	32.8	42.6	
Koyo Lindberg	2.1	1.9	1.3	0.8	1.1	
Semitherm	0	0	0	0	0	
Shinko Electric	0	4.0	1.9	2.3	1.9	
Silicon Valley Group	0	0	0	0	0	
Tempress	0	0	0	0	0	
Toyoko Chemical	4.1	5.0	1.3	1.2	2.0	

(Continued)

Table 4-42 (Continued)
Each Company's Revenue from Shipments of Chemical Vapor Deposition Equipment to the Japanese Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Tokyo Electron Ltd.	34.0	45.0	34.3	41.5	75.1	
Ulvac	0	5.6	5.8	7.3	9.0	
Varian/TEL	0	0	0	0	0	
Yamato Semico. Ltd.	0.4	0	0	0	0	
Total Vertical LPCVD	97.5	110.6	82.8	92.4	138.7	9.2
Horizontal Tube PECVD						
ASM International	23.6	19.0	10.2	7.8	8.4	
Pacific Western	0	0	0	0	0	
Total Horizontal Tube PECVD	23.6	19.0	10.2	7.8	8.4	-22.8
Total Japan Tube CVD	136.2	140.2	101.4	106.3	152.7	2.9
Nontube CVD Reactors						
APCVD Reactors						
Alcan/Canon/Quester	15.0	21.4	19.0	19.8	25.9	
Amaya	15.3	12.3	6.3	5.4	3.9	
Applied Materials	3.0	0	0	0	0	
General Signal Thinfilm	0	0	0	0	0	
Koyo Lindberg	0.8	0.6	0	0.5	0	
Toshiba Machine	3.2	3.2	2.1	1.2	0.4	
Watkins-Johnson	20.0	15.4	7.9	10.1	26.9	
Yamato Semico. Ltd.	0.2	0	0	0	0	
Total APCVD Reactors	57.5	52.9	35.3	37.0	57.1	-0.2
Dedicated LPCVD Reactors						
Anelva	1.4	0	0	0	0.9	
Applied Materials	8.0	17.0	22.0	25.7	40.3	
BCT Spectrum	0	0	0	0	0	
BTU/Ulvac	0	0	0	0	0	
Enya	3.5	0	0	0	0	
Genus	17.2	10.0	3.7	3.8	5.9	
Kokusai Electric	3.1	0	0	0	0	
LAM Research	1.4	0	0	0	0	
Materials Research Corporation	0	0	1.2	0	1.7	
Novellus	0	0	1.1	4.9	13.3	
Silicon Valley Group	0	0	0	0	0	
Spectrum CVD	0.6	0	0	0	0	
Tokyo Electron Ltd.	4.9	2.7	0	1.5	12.7	
Ulvac	4.5	7.9	8.0	7.2	6.4	
Total Dedicated LPCVD Reactors	44.6	37.6	36.0	43.1	81.2	16.2

(Continued)

Table 4-42 (Continued)
Each Company's Revenue from Shipments of Chemical Vapor Deposition Equipment to the Japanese Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Dedicated PECVD Reactors						
Applied Materials	71.7	63.4	41.0	58.2	73.2	
ASM International	0	0	0	1.6	6.4	
Enya	3.8	1.6	0.8	0	0	
E.T. Electrotech	4.5	7.6	3.6	2.2	4.2	
Japan Production	8.0	5.6	3.2	2.2	3.1	
Novellus	11.0	26.0	16.7	17.9	38.4	
Oxford Instruments	0	0	0	0.4	0	
Plasma & Materials Technology	0	0	0	0	0	
Plasma-Therm	0.5	0	0	0	0	
Samco	2.3	4.3	5.4	3.1	2.8	
Total Dedicated PECVD Reactors	101.8	108.5	70.7	85.6	128.1	5.9
HDP CVD						
Anelva	0.4	3.8	0	0	0	
Fuji Electric	0	0	4.0	2.2	0	
LAM Research	0	0	0	0	0	
Oxford Instruments	0	0	0	0.4	0	
Sumitomo Metals	2.9	0	0	5.2	0	
Total HDPCVD	3.3	3.8	4.0	7.8	0	-100.0
Total Japan Nontube CVD	207.2	202.8	146.0	173.5	266.4	6.5
Total Japan CVD	343.4	343.0	247.4	279.8	419.1	5.1

Source: Dataquest (June 1995)

Table 4-43
Each Company's Revenue from Shipments of Chemical Vapor Deposition Equipment to the European Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World CVD Market	715.5	742.5	650.3	868.5	1,348.9	17.2
Tube CVD						
Horizontal Tube LPCVD						
Advanced Crystal Sciences	0	0	0.1	0	0	
ASM International	5.0	3.5	2.5	0.8	0	
Bruce Technologies	0	0	0.7	2.0	4.3	
BTU International	2.0	1.5	0	0	0	
Centrotherm	2.0	1.5	0.8	0.8	0	
ETS Company	0	0	0	0	0	
General Signal Thinfilm	1.0	0	0	0	0	
Kokusai Electric	2.0	0	0	0	0	
Koyo Lindberg	0	0	0	0	0	
Process Technology	0.5	0.2	0	0	0.1	
Silicon Valley Group	2.0	1.6	1.6	2.7	3.5	
Solitec	0	0	0	0	0	
Tokyo Electron Ltd.	0	0	0	0	0	
Tystar	0	0	0	0	0	
Ulvac	0	0	0	0	0	
Ulvac/BTU	0	0	0	0	0	
Varian/TEL	2.1	1.9	0.6	0	0	
Wellman Furnaces	0	0	0	0	0	
Yamato Semico. Ltd.	0	0	0	0	0	
Total Horizontal LPCVD	16.6	10.2	6.3	6.3	7.9	-16.9
Vertical Tube LPCVD						
ASM International	1.8	3.5	5.9	10.2	23.5	
Bruce Technologies	0	0	0	0	0	
BTU International	1.5	1.0	0	0	0	
Denko	0	0	0	0	0	
Disco	0	0	0	0	0	
General Signal Thinfilm	0	0	0	0	0	
Kokusai Electric	0	2.2	2.1	6.0	3.4	
Koyo Lindberg	0	0	0	0	0	
Semitherm	0	0	0	0	0	
Shinko Electric	0	0	0	0	0	
Silicon Valley Group	1.6	2.7	2.4	6.3	11.3	
Tempress	0	0	0.5	1.0	0	
Toyoko Chemical	0.7	0	0	0	0	

(Continued)

Table 4-43 (Continued)
Each Company's Revenue from Shipments of Chemical Vapor Deposition Equipment to the European Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Tokyo Electron Ltd.	0	0	0	0	0	
Ulvac	0	0	0	0	0	
Varian/TEL	0.7	2.4	2.5	5.5	7.6	
Yamato Semico. Ltd.	0	0	0	0	0	
Total Vertical LPCVD	6.3	11.8	13.4	29.0	45.8	64.2
Horizontal Tube PECVD						
ASM International	5.0	4.0	5.7	6.6	9.8	
Pacific Western	1.0	0	0	0	0	
Total Horizontal Tube PECVD	6.0	4.0	5.7	6.6	9.8	13.0
Total Europe Tube CVD	28.9	26.0	25.4	41.9	63.5	21.8
Nontube CVD Reactors						
APCVD Reactors						
Alcan/Canon/Quester	0	0	0	0	2.3	
Amaya	0	0	0	0	0	
Applied Materials	1.0	0	0	0	0	
General Signal Thinfilm	0.3	0	0	0	0	
Koyo Lindberg	0	0	0	0	0	
Toshiba Machine	0	0	0	0	0	
Watkins-Johnson	8.0	4.9	3.4	13.7	15.9	
Yamato Semico. Ltd.	0	0	0	0	0	
Total APCVD Reactors	9.3	4.9	3.4	13.7	18.2	18.3
Dedicated LPCVD Reactors						
Anelva	0	0	0	0	0	
Applied Materials	5.0	2.0	7.4	10.6	14.8	
BCT Spectrum	0	0	0	0	0	
BTU/Ulvac	0	0	0	0	0	
Enya	0	0	0	0	0	
Genus	5.2	4.8	6.0	6.0	8.4	
Kokusai Electric	0	0	0	0	0	
LAM Research	0	0	1.6	1.3	2.0	
Materials Research Corporation	0	0	1.3	0	3.8	
Novellus	0	0	0	1.1	2.8	
Silicon Valley Group	0.7	0	0	0	0	
Spectrum CVD	0.6	0	0	0	0	
Tokyo Electron Ltd.	0	0	0	0	0	
Ulvac	0	0	0	0.8	0	
Total Dedicated LPCVD Reactors	11.5	6.8	16.3	19.8	31.8	29.0

(Continued)

Table 4-43 (Continued)
Each Company's Revenue from Shipments of Chemical Vapor Deposition Equipment to the European Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Dedicated PECVD Reactors						
Applied Materials	24.5	29.0	26.6	51.2	58.6	
ASM International	0	0	0	0	1.6	
Enya	0	0	0	0	0	
E.T. Electrotech	8.0	8.0	6.3	3.4	7.0	
Japan Production	0	0	0	0	0	
Novellus	6.0	9.0	4.7	10.9	19.4	
Oxford Instruments	0	0	0	1.0	0	
Plasma & Materials Technology	0	0	0	0	0	
Plasma-Therm	0.5	0	0	0	0	
Samco	0	0	0	0	0	
Total Dedicated PECVD Reactors	39.0	46.0	37.6	66.5	86.6	22.1
HDP CVD						
Anelva	0	0	0	0	0	
Fuji Electric	0	0	0	0	0	
LAM Research	0	0	0	1.3	1.6	
Oxford Instruments	1.9	1.0	0.4	0.7	0	
Sumitomo Metals	0	0	0	0	0	
Total HDPCVD	1.9	1.0	0.4	2.0	1.6	-4.2
Total Europe Nontube CVD	61.7	58.7	57.7	102.0	138.2	22.3
Total Europe CVD	90.6	84.7	83.1	143.9	201.7	22.2

Source: Dataquest (June 1995)

Table 4-44
Each Company's Revenue from Shipments of Chemical Vapor Deposition Equipment to Asia/Pacific-ROW (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World CVD Market	715.5	742.5	650.3	868.5	1,348.9	17.2
Tube CVD						
Horizontal Tube LPCVD						
Advanced Crystal Sciences	0	0	0	0	0	
ASM International	1.0	1.5	1.0	0.4	0	
Bruce Technologies	0	0	0	0	0	
BTU International	1.2	2.0	0	0	0	
Centrotherm	0	0	0	0	0	
ETS Company	0	0	0	0	0	
General Signal Thinfilm	0	0	0	0	0	
Kokusai Electric	0	1.6	0	0	0	
Koyo Lindberg	0	0	0	0	0	
Process Technology	0	0	0	0	0	
Silicon Valley Group	2.0	1.2	1.0	0.3	0.3	
Solitec	1.0	0	0	0	0	
Tokyo Electron Ltd.	3.3	0	0	1.5	0	
Tystar	0.2	0.3	0	0	0	
Ulvac	0	0	0	0	0	
Ulvac/BTU	0	0	0	0	0	
Varian/TEL	0	0	0	0	0	
Wellman Furnaces	0	0	0	0	0	
Yamato Semico. Ltd.	0	0	0	0	0	
Total Horizontal LPCVD	8.7	6.6	2.0	2.2	0.3	-56.9
Vertical Tube LPCVD						
ASM International	0.6	3.0	2.2	1.8	0	
Bruce Technologies	0	0	0	0	0	
BTU International	1.5	0	0	0	0	
Denko	0	0	0	0	0	
Disco	0	0	0	0	0	
General Signal Thinfilm	0	0	0	0	0	
Kokusai Electric	13.4	22.0	18.2	37.6	65.9	
Koyo Lindberg	0	0	0	0	0	
Semitherm	0	0	0	0	0	
Shinko Electric	0	2.2	0	0	0.6	
Silicon Valley Group	1.6	1.9	1.6	0.9	0.6	
Tempress	0	0	0	0	0	
Toyoko Chemical	0	0	0	0	1.3	

(Continued)

Table 4-44 (Continued)
Each Company's Revenue from Shipments of Chemical Vapor Deposition Equipment to Asia/Pacific-ROW (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Tokyo Electron Ltd.	0	8.0	16.2	31.6	69.4	
Ulvac	0	0	0	0	0	
Varian/TEL	0	0	0	0	0	
Yamato Semico. Ltd.	0	0	0	0	0	
Total Vertical LPCVD	17.1	37.1	38.2	71.9	137.8	68.5
Horizontal Tube PECVD						
ASM International	5.0	7.0	4.7	3.0	0.6	
Pacific Western	0	0	0	0.6	0	
Total Horizontal Tube PECVD	5.0	7.0	4.7	3.6	0.6	-41.1
Total Asia/Pacific-ROW Tube CVD	30.8	50.7	44.9	77.7	138.7	45.7
Nontube CVD Reactors						
APCVD Reactors						
Alcan/Canon/Quester	0	2.7	3.2	8.3	31.6	
Amaya	0.7	0	0	0	0	
Applied Materials	1.0	0	0	0	0	
General Signal Thinfilm	0.5	0	0	0	0	
Koyo Lindberg	0	0	0	0	0	
Toshiba Machine	0	0	0	0	0	
Watkins-Johnson	3.0	15.0	13.5	15.6	50.2	
Yamato Semico. Ltd.	0	0	0	0	0	
Total APCVD Reactors	5.2	17.7	16.7	23.9	81.8	99.2
Dedicated LPCVD Reactors						
Anelva	0	0	0	0	0	
Applied Materials	1.0	1.0	4.2	14.2	22.8	
BCT Spectrum	0	0	0	0	0	
BTU/Ulvac	0	0	0	0	0	
Enya	0	0	0	0	0	
Genus	4.0	8.1	7.0	10.5	15.0	
Kokusai Electric	0	0	0	0	0	
LAM Research	0	1.9	0	1.4	0	
Materials Research Corporation	0	0	0	0	0	
Novellus	0	0	1.1	1.1	4.0	
Silicon Valley Group	0	0	0	0	0	
Spectrum CVD	0	0	0	0	0	
Tokyo Electron Ltd.	0	0	0	0	2.1	
Ulvac	0	0	0	0	0	
Total Dedicated LPCVD Reactors	5.0	11.0	12.3	27.2	43.9	72.1

(Continued)

Table 4-44 (Continued)
Each Company's Revenue from Shipments of Chemical Vapor Deposition Equipment to Asia/Pacific-ROW (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Dedicated PECVD Reactors						
Applied Materials	10.5	25.0	16.2	41.9	58.6	
ASM International	0	0	0	0	0	
Enya	0	0	0	0	0	
E.T. Electrotech	1.5	1.0	0.6	0.7	0	
Japan Production	0	0	0	0	0	
Novellus	4.0	6.0	6.5	12.9	28.9	
Oxford Instruments	0	0	0	0.3	0	
Plasma & Materials Technology	0	0	0	0	0	
Plasma-Therm	0	0	0	0	0	
Samco	0	0	0	0	0	
Total Dedicated PECVD Reactors	16.0	32.0	23.3	55.8	87.5	52.9
HDP CVD						
Anelva	0	0	0	0	0	
Fuji Electric	0	0	0	0	0	
LAM Research	0	0	0	0	0	
Oxford Instruments	0	0	0	0	0	
Sumitomo Metals	0	0	0	0	0	
Total HDPCVD	0	0	0	0	0	NM
Total Asia/Pacific-ROW Nontube CVD	26.2	60.7	52.3	106.9	213.2	68.9
Total Asia/Pacific-ROW CVD	57.0	111.4	97.2	184.6	351.9	57.6

Source: Dataquest (June 1995)

Table 4-45
Each Company's Revenue from Shipments of Chemical Vapor Deposition Equipment to the Worldwide Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World CVD Market	715.5	742.5	650.3	868.5	1,348.9	17.2
Tube CVD						
Horizontal Tube LPCVD						
Advanced Crystal Sciences	0	0	0.7	1.0	1.1	
ASM International	10.0	7.9	5.3	2.1	0	
Bruce Technologies	0	0	2.9	5.8	9.1	
BTU International	7.2	6.0	0	0	0	
Centrotherm	4.8	3.1	1.6	1.6	0	
ETS Company	0	0	0	0.2	0	
General Signal Thinfilm	3.0	0	0	0	0	
Kokusai Electric	4.5	1.6	0	1.2	0.4	
Koyo Lindberg	1.0	0	0.8	1.3	1.6	
Process Technology	3.0	1.4	1.1	1.5	0.8	
Silicon Valley Group	10.0	7.3	7.8	5.9	8.5	
Solitec	5.0	0	0	0	0	
Tokyo Electron Ltd.	6.9	7.1	5.1	3.1	2.0	
Tystar	0.4	0.3	0.6	0.6	0.4	
Ulvac	0	2.3	2.5	1.8	1.6	
Ulvac/BTU	6.2	0	0	0	0	
Varian/TEL	2.1	1.9	0.6	0	0	
Wellman Furnaces	0	0	0	0	0	
Yamato Semico. Ltd.	0.3	0.3	0	0	0	
Total Horizontal LPCVD	64.4	39.2	29.0	26.1	25.5	-20.7
Vertical Tube LPCVD						
ASM International	17.5	22.6	19.0	22.6	35.1	
Bruce Technologies	0	0	0	0.5	5.1	
BTU International	5.0	4.5	0	0	0	
Denko	3.8	0	0	0	0	
Disco	0	2.7	0.9	0	0	
General Signal Thinfilm	4.0	3.0	0	0	0	
Kokusai Electric	55.1	62.0	54.5	89.8	126.4	
Koyo Lindberg	2.1	1.9	1.3	0.8	1.1	
Semitherm	1.5	1.5	0.5	2.5	3.2	
Shinko Electric	0	6.2	1.9	2.3	2.5	
Silicon Valley Group	11.2	12.2	12.2	13.8	31.8	
Tempress	0	0	1.4	1.9	0	
Toyoko Chemical	4.8	5.0	1.3	1.2	3.9	

(Continued)

Table 4-45 (Continued)
Each Company's Revenue from Shipments of Chemical Vapor Deposition Equipment to the Worldwide Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Tokyo Electron Ltd.	34.0	53.0	50.5	73.1	144.5	
Ulvac	0	5.6	5.8	7.3	9.0	
Varian/TEL	2.7	7.7	5.6	15.0	32.2	
Yamato Semico. Ltd.	0.4	0	0	0	0	
Total Vertical LPCVD	142.1	187.9	154.9	230.8	394.8	29.1
Horizontal Tube PECVD						
ASM International	49.6	40.0	28.4	25.2	26.0	
Pacific Western	2.5	1.0	1.0	1.2	0	
Total Horizontal Tube PECVD	52.1	41.0	29.4	26.4	26.0	-16.0
Total Worldwide Tube CVD	258.6	268.1	213.3	283.3	446.3	14.6
Nontube CVD Reactors						
APCVD Reactors						
Alcan/Canon/Quester	15.0	26.8	28.5	30.1	64.7	
Amaya	16.0	12.3	6.3	5.4	3.9	
Applied Materials	5.0	0	0	0	0	
General Signal Thinfilm	1.3	0.5	0	0	0	
Koyo Lindberg	0.8	0.6	0	0.5	0	
Toshiba Machine	3.2	3.2	2.1	1.2	0.4	
Watkins-Johnson	41.0	48.5	45.0	66.2	122.4	
Yamato Semico. Ltd.	0.2	0	0	0	0	
Total APCVD Reactors	82.5	91.9	81.9	103.4	191.4	23.4
Dedicated LPCVD Reactors						
Anelva	1.4	0	0	0	0.9	
Applied Materials	26.0	32.0	60.9	88.7	134.4	
BCT Spectrum	0	2.0	0	0	0	
BTU/Ulvac	1.6	0	0	0	0	
Enya	3.5	0	0	0	0	
Genus	40.4	29.7	21.9	24.5	31.1	
Kokusai Electric	3.1	0	0	0	0	
LAM Research	2.7	1.9	7.3	4.0	2.0	
Materials Research Corporation	0	0	4.1	0	5.5	
Novellus	1.0	5.7	6.7	19.0	44.1	
Silicon Valley Group	1.3	0	0	0	0	
Spectrum CVD	3.2	0	0	0	0	
Tokyo Electron Ltd.	4.9	2.7	0	1.5	14.8	
Ulvac	4.5	9.4	9.4	9.6	6.4	
Total Dedicated LPCVD Reactors	93.6	83.4	110.3	147.3	239.2	26.4

(Continued)

Table 4-45 (Continued)
Each Company's Revenue from Shipments of Chemical Vapor Deposition Equipment to the Worldwide Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Dedicated PECVD Reactors						
Applied Materials	174.9	194.4	168.8	232.8	292.9	
ASM International	0	0	0	1.6	8.0	
Enya	3.8	1.6	0.8	0	0	
E.T. Electrotech	17.5	20.0	12.6	7.7	11.2	
Japan Production	8.0	5.6	3.2	2.2	3.1	
Novellus	63.0	64.0	48.4	70.5	146.1	
Oxford Instruments	0	0	0	2.4	0	
Plasma & Materials Technology	0	0	0	1.5	0	
Plasma-Therm	3.0	1.2	0.8	0	0	
Samco	2.3	4.3	5.4	3.1	2.8	
Total Dedicated PECVD Reactors	272.5	291.1	240.0	321.8	464.1	14.2
HDP CVD						
Anelva	0.4	3.8	0	0	0	
Fuji Electric	0	0	4.0	2.2	0	
LAM Research	0	0	0	4.2	7.9	
Oxford Instruments	2.5	1.5	0.8	1.1	0	
Sumitomo Metals	5.4	2.7	0	5.2	0	
Total HDPCVD	8.3	8.0	4.8	12.7	7.9	-1.2
Total Worldwide Non-Tube CVD	456.9	474.4	437.0	585.2	902.6	18.6
Total Worldwide CVD	715.5	742.5	650.3	868.5	1,348.9	17.2

Source: Dataquest (June 1995)

Table 4-46
Each Company's Revenue from Shipments of All Segments of Chemical Vapor Deposition to the World (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World CVD Market	715.5	742.5	650.3	868.5	1,348.9	17.2
Advanced Crystal Sciences	0	0	0.7	1	1.1	
Alcan/Canon/Quester	15	26.8	28.5	30.1	64.7	
Amaya	16	12.3	6.3	5.4	3.9	
Anelva	1.8	3.8	0	0	0.9	
Applied Materials	205.9	226.4	229.7	321.5	427.3	
ASM International	77.1	70.5	52.7	51.5	69.1	
BCT Spectrum	0	2	0	0	0	
Bruce Technologies	0	0	2.9	6.3	14.2	
BTU International	12.2	10.5	0	0	0	
BTU/Ulvac	1.6	0	0	0	0	
Centrotherm	4.8	3.1	1.6	1.6	0	
Denko	3.8	0	0	0	0	
Disco	0	2.7	0.9	0	0	
E.T. Electrotech	17.5	20	12.6	7.7	11.2	
Enya	7.3	1.6	0.8	0	0	
ETE Company Ltd.	0	0	0	0.2	0	
Focus Semiconductor	0	0	0	0	0	
Fuji Electric	0	0	4	2.2	0	
General Signal Thinfilm	8.3	3.5	0	0	0	
Genus	40.4	29.7	21.9	24.5	31.1	
Helmut Seier	0	0	0	0	0	
Hitachi	0	0	0	0	0	
Japan Production	8	5.6	3.2	2.2	3.1	
Kokusai Electric	62.7	63.6	54.5	91	126.8	
Koyo Lindberg	3.9	2.5	2.1	2.6	2.7	
LAM Research	2.7	1.9	7.3	8.2	9.9	
Materials Research Corporation	0	0	4.1	0	5.5	
Novellus	64	69.7	55.1	89.5	190.2	
Pacific Western	2.5	1	1	1.2	0	
PMT	0	0	0	1.5	0	
Plasma Technology	2.5	1.5	0.8	3.5	0	
Plasma-Therm	3	1.2	0.8	0	0	
Process Technology	3	1.4	1.1	1.5	0.8	
Samco	2.3	4.3	5.4	3.1	2.8	
Semitherm	1.5	1.5	0.5	2.5	3.2	
Shinko Electric	0	6.2	1.9	2.3	2.5	

(Continued)

Table 4-46 (Continued)
Each Company's Revenue from Shipments of All Segments of Chemical Vapor Deposition to the World (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Silicon Valley Group	22.5	19.5	20	19.7	40.3	
Solitec	5	0	0	0	0	
Spectrum CVD	3.2	0	0	0	0	
Sumitomo Metals	5.4	2.7	0	5.2	0	
Tempress	0	0	1.4	1.9	0	
Tokyo Electron Ltd.	45.8	62.8	55.6	77.7	161.3	
Toshiba Machine	3.2	3.2	2.1	1.2	0.4	
Toyoko Chemical	4.8	5	1.3	1.2	3.9	
Tystar	0.4	0.3	0.6	0.6	0.4	
Ulvac	4.5	17.3	17.7	18.7	17	
Ulvac/BTU	6.2	0	0	0	0	
Varian	0	0	0	0	0	
Varian/TEL	4.8	9.6	6.2	15	32.2	
Watkins-Johnson	41	48.5	45	66.2	122.4	
Wellman	0	0	0	0	0	
Yamato Semico	0.9	0.3	0	0	0	
Total Worldwide CVD Market	715.5	742.5	650.3	868.5	1,348.9	17.2

Source: Dataquest (June 1995)

Table 4-47
Each Company's Revenue from Shipments of Sputter Equipment to the North American Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Sputter Market	359.2	425.2	446.4	584.2	1,025.1	30.0
Advanced Film Tech.	0	0	0	0	0	
Anelva	17.8	20.8	23.7	34.2	33.4	
Applied Materials	6.5	13.6	41.6	94.7	196.7	
Balzers	2	0	0	0	0	
CHA Industries	0.4	0.4	0.2	0	1.1	
CPA	1	2	1	0	0	
CVC Products	5	4.5	4	5.3	6.4	
E.T. Electrotech	3	3	1.2	0	5.3	
Innotec	0.3	0.2	0	0	0	
Ion Tech	0.1	0.2	0.1	0	0	
Kurt J. Lesker	1	0.2	0.4	2	1.7	
Leybold-Heraeus	2	1	0	0	0	
Materials Research Co	25	30	55.6	38.2	53.4	
Novellus	0	1.8	2.4	4.8	7.2	
Shibaura	0	0	0	0	0	
Shinko Seiki	0	0	0	0	0	
Sputtered Films	1	2	2.3	5.9	7	
Temescal	0.1	0	0	0	0	
Tokuda	0	0	0	0	0	
Ulvac	12.6	2.2	2.5	2.3	3.9	
Varian	36	25.5	16.4	32.3	29.7	
Others	1.3	1.4	1	2	2.5	
Total North America	115.1	108.8	152.4	221.7	348.3	18.4

Source: Dataquest (June 1995)

Table 4-48
Each Company's Revenue from Shipments of Sputter Equipment to the Japanese Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Sputter Market	359.2	425.2	446.4	584.2	1,025.1	30.0
Advanced Film Tech.	0.7	0.8	0	0	0	
Anelva	64.5	80	52.2	41.4	72.8	
Applied Materials	6.5	19.5	36.4	74.8	147.3	
Balzers	0	0	0	0	0	
CHA Industries	0	0	0	0	0	
CPA	0	0	0	0	0	
CVC Products	0	0.5	0	1	0.5	
E.T. Electrotech	1	0	0	0	8.8	
Innotec	0	0	0	0	0	
Ion Tech	0	0	0	0	0	
Kurt J. Lesker	0	0	0	0	0	
Leybold-Heraeus	0	0	0	0	0	
Materials Research Co	27	34	10.3	29.8	29.7	
Novellus	0	0	0	0	0	
Shibaura	0	2.6	4.4	0	0	
Shinko Seiki	0	0.4	1.4	0.9	2.5	
Sputtered Films	0	0	0	0	0	
Temescal	0	0	0	0	0	
Tokuda	5.8	0	0	0	0	
Ulvac	46	43.1	35	45	70.7	
Varian	26	28.2	8.9	7	16.5	
Others	0	0	0	0	0	
Total Japan	177.5	209.1	148.6	199.9	348.8	18.4

Source: Dataquest (June 1995)

Table 4-49
Each Company's Revenue from Shipments of Sputter Equipment to the European Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Sputter Market	359.2	425.2	446.4	584.2	1,025.1	30.0
Advanced Film Tech.	0	0	0	0	0	
Anelva	5	3.7	0	2.7	19.3	
Applied Materials	2	1.8	21.6	29.9	55.5	
Balzers	5	0	0	0	0	
CHA Industries	0	0	0	0	0	
CPA	0	0	0	0	0	
CVC Products	1.5	0.5	0.5	0.6	0.8	
E.T. Electrotech	8	8	6	9.1	14.4	
Innotec	0	0	0	0	0	
Ion Tech	0	0	0	0	0	
Kurt J. Lesker	0	0.8	0.4	0.4	0.8	
Leybold-Heraeus	5	2.6	0	0	0	
Materials Research Co	7	8.5	16.5	22.2	25.2	
Novellus	0	0	0	0	0	
Shibaura	0	0	0	0	0	
Shinko Seiki	0	0	0	0	0	
Sputtered Films	0	0	0	0	0	
Temescal	0	0	0	0	0	
Tokuda	0	0	0	0	0	
Ulvac	0	0	0	0	0	
Varian	10	12.7	12.9	6.2	1.6	
Others	0	0	0	0	0	
Total Europe	43.5	38.6	57.9	71.1	117.6	18.4

Source: Dataquest (June 1995)

Table 4-50
Each Company's Revenue from Shipments of Sputter Equipment to Asia/Pacific-ROW (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Sputter Market	359.2	425.2	446.4	584.2	1,025.1	30.0
Advanced Film Tech.	0	0	0	0	0	
Anelva	3.5	10	5.9	0	9.2	
Applied Materials	0	17.4	25.2	49.9	104.9	
Balzers	0	0	0	0	0	
CHA Industries	0	0.3	0	0.2	0.6	
CPA	0	0	0	0	0	
CVC Products	1	1.5	1.5	0	0	
E.T. Electrotech	1.5	1	0	0.8	0	
Innotec	0.5	0.5	0.4	0	0	
Ion Tech	0	0	0	0	0	
Kurt J. Lesker	0	0	0	0	0.2	
Leybold-Heraeus	0.8	0.8	0	0	0	
Materials Research Co	3.6	12	20.5	6.3	4	
Novellus	0	0	0	0	0	
Shibaura	0	0	0	0	0	
Shinko Seiki	0	0	0	0	0	
Sputtered Films	0	0.3	0.4	0	0	
Temescal	0	0	0	0	0	
Tokuda	0	0	0	0	0	
Ulvac	0	0	0	0	0	
Varian	12	24.5	33.6	33.3	90	
Others	0.2	0.4	0	1	1.5	
Total Asia/Pacific-ROW	23.1	68.7	87.5	91.5	210.4	18.4

Source: Dataquest (June 1995)

Table 4-51
Each Company's Revenue from Shipments of Sputter Equipment to the Worldwide Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Sputter Market	359.2	425.2	446.4	584.2	1,025.1	30.0
Advanced Film Tech.	0.7	0.8	0	0	0	
Anelva	90.8	114.5	81.8	78.3	134.7	
Applied Materials	15	52.3	124.8	249.3	504.4	
Balzers	7	0	0	0	0	
CHA Industries	0.4	0.7	0.2	0.2	1.7	
CPA	1	2	1	0	0	
CVC Products	7.5	7	6	6.9	7.7	
E.T. Electrotech	13.5	12	7.2	9.9	28.5	
Innotec	0.8	0.7	0.4	0	0	
Ion Tech	0.1	0.2	0.1	0	0	
Kurt J. Lesker	1	1	0.8	2.4	2.7	
Leybold-Heraeus	7.8	4.4	0	0	0	
Materials Research Co	62.6	84.5	102.9	96.5	112.3	
Novellus	0	1.8	2.4	4.8	7.2	
Shibaura	0	2.6	4.4	0	0	
Shinko Seiki	0	0.4	1.4	0.9	2.5	
Sputtered Films	1	2.3	2.7	5.9	7	
Temescal	0.1	0	0	0	0	
Tokuda	5.8	0	0	0	0	
Ulvac	58.6	45.3	37.5	47.3	74.6	
Varian	84	90.9	71.8	78.8	137.8	
Others	1.5	1.8	1	3	4	
Total Worldwide	359.2	425.2	446.4	584.2	1,025.1	18.4

Source: Dataquest (June 1995)

Table 4-52
Each Company's Revenue from Shipments of Silicon Epitaxy Equipment to Each Region (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Total Epitaxy Market	68.2	89.0	84.0	82.6	100.2	2.4
North America						
Applied Materials	12.5	7.0	5.5	6.5	8.4	
ASM Epitaxy	12.6	15.0	19.2	20.0	22.1	
Concept Systems Design	0	0.4	0	0.4	3.5	
Kokusai Electric	0	0	0	0	0	
Lam Research	7.9	0	0	0	0	
LPE	0	0	0	0	0	
Moore	1.8	2.8	2.1	4.7	3.6	
Rapro	0.9	0	0	0	0	
Toshiba Machine	0	0	0	0	0	
Total North America	35.7	25.2	26.8	31.6	37.6	-0.1
Japan						
Applied Materials	8.5	20.0	14.9	8.8	11.0	
ASM Epitaxy	3.0	7.2	7.2	6.0	7.5	
Concept Systems Design	0	0	1.6	0.8	0	
Kokusai Electric	2.2	5.9	11.1	4.6	0.9	
Lam Research	0	0	0	0	0	
LPE	0	0	0	0	0	
Moore	0	0.5	2.0	0.7	0.4	
Rapro	0	0	0	0	0	
Toshiba Machine	4.5	12.5	9.5	4.5	7.2	
Total Japan	18.2	46.1	46.3	25.4	27.0	5.2
Europe						
Applied Materials	3.1	3.0	0.9	5.3	7.3	
ASM Epitaxy	3.6	5.5	3.6	10.2	8.5	
Concept Systems Design	0	0	0	2.0	2.7	
Kokusai Electric	0	0	0	0	0	
Lam Research	0	0	0	0	0	
LPE	4.0	2.5	2.0	3.0	4.0	
Moore	1.2	0	0.4	0.4	6.0	
Rapro	0	0	0	0	0	
Toshiba Machine	0	0	0	0	0	
Total Europe	11.9	11.0	6.9	20.9	28.5	15.9

(Continued)

Table 4-52 (Continued)
Each Company's Revenue from Shipments of Silicon Epitaxy Equipment to Each Region (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Asia/Pacific-ROW						
Applied Materials	0.9	2.0	1.7	1.3	1.4	
ASM Epitaxy	0	2.2	1.2	2.4	2.4	
Concept Systems Design	0	0	0	0	2.3	
Kokusai Electric	0	0	0	0	0	
Lam Research	0	0	0	0	0	
LPE	1.5	2.5	1.1	1.0	1.0	
Moore	0	0	0	0	0	
Rapro	0	0	0	0	0	
Toshiba Machine	0	0	0	0	0	
Total Asia/Pacific-ROW	2.4	6.7	4.0	4.7	7.1	-6.3
Worldwide						
Applied Materials	25.0	32.0	23.0	21.9	28.1	
ASM Epitaxy	19.2	29.9	31.2	38.6	40.5	
Concept Systems Design	0	0.4	1.6	3.2	8.5	
Kokusai Electric	2.2	5.9	11.1	4.6	0.9	
Lam Research	7.9	0	0	0	0	
LPE	5.5	5.0	3.1	4.0	5.0	
Moore	3.0	3.3	4.5	5.8	10.0	
Rapro	0.9	0	0	0	0	
Toshiba Machine	4.5	12.5	9.5	4.5	7.2	
Total Worldwide	68.2	89.0	84.0	82.6	100.2	14.6

Source: Dataquest (June 1995)

Table 4-53
Each Company's Revenue from Shipments of Diffusion Furnace Equipment to the North American Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Diffusion Market	324.7	326.4	246.2	342.3	491.8	10.9
Horizontal Tube						
Advanced Crystal Sciences	0	0	0	0.1	0	
ASM International	3.5	2.5	1.6	0.5	0	
Bruce Technologies	0	0	5.4	7.4	11.6	
BTU International	10.0	6.0	0	0	0	
Centrotherm	1.9	1.2	1.3	0.7	0	
ETE Company	0	0	0	0	0	
Gasonics	6.0	7.5	3.7	0.8	0	
GSTC	3.0	1.0	0	0	0	
Kokusai Electric	0	0	0	0	0	
Koyo Lindberg	0	0	0	0	0	
Pacific Western	0.6	0.4	0.6	0	0	
Silicon Valley Group	24.0	13.4	15.6	6.7	8.4	
Tokyo Electron Ltd.	0	0	0	0	0	
Tystar	0.3	0.5	0.2	0.2	0.2	
Ulvac	0	0	0	0	0	
Ulvac/BTU	0	0	0	0	0	
Varian/TEL	0	3.0	0	0	0	
Wellman Furnaces	0	0	0	0	0	
Yamato Semico. Ltd.	0	0	0	0	0	
Total North America Horizontal Tube	49.3	35.5	28.4	16.4	20.2	-20.0
Vertical Tube						
ASM International	2.0	4.0	3.2	4.6	2.4	
Bruce Technologies	0	0	0	0.5	11.1	
BTU International	3.0	5.0	0	0	0	
Denko	0	0	0	0	0	
Disco	0	0	0	0	0	
GSTC	5.0	2.0	0	0	0	
Koyo Lindberg	0	0	0	0	0	
Kokusai Electric	1.7	7.0	6.3	28.9	23.6	
Semitherm	4.0	3.0	0.9	4.9	4.4	
Shinko Electric	0	0	0	0	0	
Silicon Valley Group	10.0	11.8	12.7	15.4	36.0	
Tempress	0	0	0.3	0.7	0	
Tokyo Electron Ltd.	0	0	0	0	0	
Ulvac	0	0	0	0	0	

(Continued)

Table 4-53 (Continued)
Each Company's Revenue from Shipments of Diffusion Furnace Equipment to the North American Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Ulvac/BTU	0	0	0	0	0	
Varian/TEL	2.1	4.8	4.3	18.0	32.7	
Total North America Vertical Tube	27.8	37.6	27.7	73.0	110.2	41.1
Total North America Diffusion	77.1	73.1	56.1	89.4	130.4	14.0

Source: Dataquest (June 1995)

Table 4-54
Each Company's Revenue from Shipments of Diffusion Furnace Equipment to the Japanese Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Diffusion Market	324.7	326.4	246.2	342.3	491.8	10.9
Horizontal Tube						
Advanced Crystal Sciences	0	0	0	0	0	
ASM International	2.6	2.2	1.1	0.2	0	
Bruce Technologies	0	0	0	0	0	
BTU International	0	0	0	0	0	
Centrotherm	0	0	0	0	0	
ETE Company	0	0	0.1	0.6	0	
Gasonics	1.0	0	0.7	0	0.8	
GSTC	0	0	0	0	0	
Kokusai Electric	4.8	5.6	5.3	3.7	5.3	
Koyo Lindberg	4.5	5.9	8.2	3.4	6.4	
Pacific Western	0	0	0	0	0	
Silicon Valley Group	0	0	0	0	0	
Tokyo Electron Ltd.	38.0	22.3	10.8	13.9	6.1	
Tystar	0	0	0	0	0	
Ulvac	0	12.6	10.1	11.0	3.9	
Ulvac/BTU	13.2	0	0	0	0	
Varian/TEL	0	0	0	0	0	
Wellman Furnaces	0	0	0	0	0	
Yamato Semico. Ltd.	0.6	0.8	0.3	0	0	
Total Japan Horizontal Tube	64.7	49.4	36.6	32.8	22.5	-23.2
Vertical Tube						
ASM International	2.8	1.0	0.7	1.2	0.4	
Bruce Technologies	0	0	0	0	0	
BTU International	0	0	0	0	0	
Denko	6.9	0	0	0	0	
Disco	5.8	10.0	5.4	2.2	0	
GSTC	0	0	0	0	0	
Koyo Lindberg	7.6	6.7	9.2	6.5	8.3	
Kokusai Electric	34.3	31.7	22.1	24.1	27.9	
Semitherm	0	0	0	0	0	
Shinko Electric	0	7.4	3.6	4.0	2.7	
Silicon Valley Group	0	0	0	0	0	
Tempress	0	0	0	0	0	
Tokyo Electron Ltd.	48.0	48.3	47.7	41.6	95.3	
Ulvac	0	4.2	4.4	3.8	5.9	

(Continued)

Table 4-54 (Continued)
Each Company's Revenue from Shipments of Diffusion Furnace Equipment to the Japanese Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Ulvac/BTU	3.3	0	0	0	0	
Varian/TEL	0	0	0	0	0	
Total Japan Vertical Tube	108.7	109.3	93.1	83.4	140.5	6.6
Total Japan Diffusion	173.4	158.7	129.7	116.2	163.0	-1.5

Source: Dataquest (June 1995)

Table 4-55
Each Company's Revenue from Shipments of Diffusion Furnace Equipment to the European Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Diffusion Market	324.7	326.4	246.2	342.3	491.8	10.9
Horizontal Tube						
Advanced Crystal Sciences	0	0	0	0	0	
ASM International	8.0	5.0	3.3	1.4	0	
Bruce Technologies	0	0	1.8	5.8	9.2	
BTU International	5.0	3.0	0	0	0	
Centrotherm	5.0	4.0	2.0	2.8	0	
ETE Company	0	0	0	0	0	
Gasonics	0	0	0	0	0	
GSTC	1.0	0	0	0	0	
Kokusai Electric	0	0	0	0	0	
Koyo Lindberg	0	0	0	0	0	
Pacific Western	0	0	0	0.3	0	
Silicon Valley Group	10.0	4.8	4.7	6.1	9.5	
Tokyo Electron Ltd.	0	0	0	0	0	
Tystar	0	0	0	0	0	
Ulvac	0	0	0	0	0	
Ulvac/BTU	0	0	0	0	0	
Varian/TEL	4.2	2.7	2.0	0	0	
Wellman Furnaces	0.2	0.5	0	0	0	
Yamato Semico. Ltd.	0	0	0	0	0	
Total Europe Horizontal Tube	33.4	20.0	13.8	16.4	18.7	-13.5
Vertical Tube						
ASM International	3.0	3.0	3.5	5.5	7.7	
Bruce Technologies	0	0	0	0	0	
BTU International	1.5	1.0	0	0	0	
Denko	0	0	0	0	0	
Disco	0	0	0	0	0	
GSTC	0	0	0	0	0	
Koyo Lindberg	0	0	0	0	0	
Kokusai Electric	0	3.8	0	22.1	8.0	
Semitherm	0	0	0	0	0.6	
Shinko Electric	0	0	0	0	0	
Silicon Valley Group	3.2	4.2	3.8	14.1	32.9	
Tempress	0	0	0.7	0.3	0	
Tokyo Electron Ltd.	0	0	0	0	0	
Ulvac	0	0	0	0	0	

(Continued)

Table 4-55 (Continued)
Each Company's Revenue from Shipments of Diffusion Furnace Equipment to the European Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Ulvac/BTU	0	0	0	0	0	
Varian/TEL	0	3.3	0.8	9.5	7.2	
Total Europe Vertical Tube	7.7	15.3	8.8	51.5	56.4	64.5
Total Europe Diffusion	41.1	35.3	22.6	67.9	75.1	16.3

Source: Dataquest (June 1995)

Table 4-56
Each Company's Revenue from Shipments of Diffusion Furnace Equipment to Asia/Pacific-ROW (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Diffusion Market	324.7	326.4	246.2	342.3	491.8	10.9
Horizontal Tube						
Advanced Crystal Sciences	0	0	0	0	0	
ASM International	1.5	2.0	2.2	1.0	0	
Bruce Technologies	0	0	0	0	0	
BTU International	3.0	4.0	0	0	0	
Centrotherm	1.5	1.5	0	0	0	
ETE Company	0	0	0	0	0	
Gasonics	1.0	1.2	0	0	0	
GSTC	0	0	0	0	0	
Kokusai Electric	0	0	0	0	0	
Koyo Lindberg	0	0	0	0	0	
Pacific Western	0	0	0	1.2	0	
Silicon Valley Group	4.0	3.4	3.0	1.1	1.7	
Tokyo Electron Ltd.	6.2	14.7	0.9	3.2	0	
Tystar	0.2	0	0	0	0	
Ulvac	0	0	0	0	0	
Ulvac/BTU	0	0	0	0	0	
Varian/TEL	0	0	0	0	0	
Wellman Furnaces	0	0	0	0	0	
Yamato Semico. Ltd.	0	0	0	0	0	
Total Asia/Pacific-ROW Horizontal Tube	17.4	26.8	6.1	6.5	1.7	-44.1
Vertical Tube						
ASM International	1.0	2.0	1.0	0.7	0	
Bruce Technologies	0	0	0	0	0	
BTU International	1.5	0	0	0	0	
Denko	0	0	0	0	0	
Disco	0	0	0	0	0	
GSTC	0	0	0	0	0	
Koyo Lindberg	0	0	0	0	2.1	
Kokusai Electric	10.1	20.0	15.0	31.4	59.1	
Semitherm	0	0	0	0	0	
Shinko Electric	0	0	0	0	2.7	
Silicon Valley Group	3.0	3.1	2.5	2.6	0.7	
Tempress	0	0	0	0	0	
Tokyo Electron Ltd.	0	7.4	13.2	27.6	57.0	
Ulvac	0	0	0	0	0	

(Continued)

Table 4-56 (Continued)
Each Company's Revenue from Shipments of Diffusion Furnace Equipment to Asia/Pacific-ROW (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Ulvac/BTU	0	0	0	0	0	
Varian/TEL	0	0	0	0	0	
Total Asia/Pacific-ROW Vertical Tube	15.6	32.5	31.7	62.3	121.6	67.1
Total Asia/Pacific-ROW Diffusion	33.0	59.3	37.8	68.8	123.3	39.0

Source: Dataquest (June 1995)

Table 4-57
Each Company's Revenue from Shipments of Diffusion Furnace Equipment to the Worldwide Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Diffusion Market	324.7	326.4	246.2	342.3	491.8	10.9
Horizontal Tube						
Advanced Crystal Sciences	0	0	0	0.1	0	
ASM International	15.6	11.7	8.2	3.1	0	
Bruce Technologies	0	0	7.2	13.2	20.8	
BTU International	18.0	13.0	0	0	0	
Centrotherm	8.4	6.7	3.3	3.5	0	
ETE Company	0	0	0.1	0.6	0	
Gasonics	8.0	8.7	4.4	0.8	0.8	
GSTC	4.0	1.0	0	0	0	
Kokusai Electric	4.8	5.6	5.3	3.7	5.3	
Koyo Lindberg	4.5	5.9	8.2	3.4	6.4	
Pacific Western	0.6	0.4	0.6	1.5	0	
Silicon Valley Group	38.0	21.6	23.3	13.9	19.6	
Tokyo Electron Ltd.	44.2	37.0	11.7	17.1	6.1	
Tystar	0.5	0.5	0.2	0.2	0.2	
Ulvac	0	12.6	10.1	11.0	3.9	
Ulvac/BTU	13.2	0	0	0	0	
Varian/TEL	4.2	5.7	2.0	0	0	
Wellman Furnaces	0.2	0.5	0	0	0	
Yamato Semico. Ltd.	0.6	0.8	0.3	0	0	
Total Worldwide Horizontal Tube	164.8	131.7	84.9	72.1	63.1	-21.3
Vertical Tube						
ASM International	8.8	10.0	8.4	12.0	10.5	
Bruce Technologies	0	0	0	0.5	11.1	
BTU International	6.0	6.0	0	0	0	
Denko	6.9	0	0	0	0	
Disco	5.8	10.0	5.4	2.2	0	
GSTC	5.0	2.0	0	0	0	
Koyo Lindberg	7.6	6.7	9.2	6.5	10.4	
Kokusai Electric	46.1	62.5	43.4	106.5	118.6	
Semitherm	4.0	3.0	0.9	4.9	5.0	
Shinko Electric	0	7.4	3.6	4.0	5.4	
Silicon Valley Group	16.2	19.1	19.0	32.1	69.6	
Tempress	0	0	1.0	1.0	0	
Tokyo Electron Ltd.	48.0	55.7	60.9	69.2	152.3	
Ulvac	0	4.2	4.4	3.8	5.9	

(Continued)

Table 4-57 (Continued)
Each Company's Revenue from Shipments of Diffusion Furnace Equipment to the Worldwide Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Ulvac/BTU	3.3	0	0	0	0	
Varian/TEL	2.1	8.1	5.1	27.5	39.9	
Total Worldwide Vertical Tube	159.8	194.7	161.3	270.2	428.7	28.0
Total Worldwide Diffusion	324.6	326.4	246.2	342.3	491.8	10.9

Source: Dataquest (June 1995)

Table 4-58
Each Company's Revenue from Shipments of Rapid Thermal Processing Equipment to Each Region (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World RTP Market	33.1	45.8	36.3	45.2	79.7	24.6
North America						
AET Thermal	0	0	0	0.6	0.7	
AG Associates	9.2	11.9	8.0	11.3	20.4	
AST Electronik	0	0	1.4	4.0	10.4	
Dainippon Screen	0	0	0	0	0	
High Temperature Eng.	0.3	0.5	0.6	0.9	1.4	
Jipelec	0.7	0	0	0	0	
Kokusai	0	0	0	0	0	
Koyo Lindberg	0	0	0	0	0	
Nanosil	0.4	0.3	0	0	0	
Peak Systems	3.3	4.0	4.5	1.9	0	
Process Products	0.7	0.7	0	0	0	
Samco	0	0	0	0	0	
Sitesa Addax	0	0	0	0	0	
Total North America	14.6	17.4	14.5	18.7	32.9	22.5
Japan						
AET Thermal	0	0	0	0.2	0	
AG Associates	4.0	9.3	2.5	3.8	5.0	
AST Electronik	0	0	1.0	1.3	2.3	
Dainippon Screen	2.3	3.5	2.8	4.6	17.1	
High Temperature Eng.	0	0.2	0.4	0	0.3	
Jipelec	0	0	0	0	0	
Kokusai	0	0.6	0.6	0	0	
Koyo Lindberg	0.7	0.3	0.5	1.4	0.7	
Nanosil	0.1	0	0	0	0	
Peak Systems	2.1	2.0	3.0	0.9	0	
Process Products	0	0	0	0	0	
Samco	0	0	0.9	0.9	1.5	
Sitesa Addax	0	0	0	0	0	
Total Japan	9.2	15.9	11.7	13.1	26.9	30.8
Europe						
AET Thermal	0	0.6	0.9	0	0.1	
AG Associates	0.8	3.2	2.0	4.9	3.0	
AST Electronik	3.4	4.1	2.3	2.7	4.3	
Dainippon Screen	0	0	0	0	0	
High Temperature Eng.	0	0	0	0.3	0.7	
Jipelec	0	1.0	1.3	0.9	0.9	

(Continued)

Table 4-58 (Continued)
Each Company's Revenue from Shipments of Rapid Thermal Processing Equipment to Each Region (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
Kokusai	0	0	0	0	0	
Koyo Lindberg	0	0	0	0	0	
Nanosil	0	0	0	0	0	
Peak Systems	0.9	1.0	1.0	0.3	0	
Process Products	0.4	0.4	0	0	0	
Samco	0	0	0	0	0	
Sitesa Addax	1.0	0	0	0	0	
Total Europe	6.5	10.3	7.5	9.1	9.0	8.5
Asia/Pacific-ROW						
AET Thermal	0	0.1	0	0.3	0.3	
AG Associates	0.6	0	1.0	1.7	8.0	
AST Electronik	0	0	0	1.3	1.7	
Dainippon Screen	0	0	0	0	0	
High Temperature Eng.	0	0.1	0	0	0	
Jipelec	0	0	0	0.6	0.9	
Koyo Lindberg	0	0	0	0	0	
Nanosil	0	0	0	0	0	
Peak Systems	2.1	1.6	1.6	0.4	0	
Process Products	0.1	0.4	0	0	0	
Samco	0	0	0	0	0	
Sitesa Addax	0	0	0	0	0	
Total Asia/Pacific-ROW	2.8	2.2	2.6	4.3	10.9	40.5
Worldwide						
AET Thermal	0	0.7	0.9	1.1	1.1	
AG Associates	14.6	24.4	13.5	21.7	36.4	
AST Electronik	3.4	4.1	4.7	9.3	18.7	
Dainippon Screen	2.3	3.5	2.8	4.6	17.1	
High Temperature Eng.	0.3	0.8	1.0	1.2	2.4	
Jipelec	0.7	1.0	1.3	1.5	1.8	
Kokusai	0	0.6	0.6	0	0	
Koyo Lindberg	0.7	0.3	0.5	1.4	0.7	
Nanosil	0.5	0.3	0	0	0	
Peak Systems	8.4	8.6	10.1	3.5	0	
Process Products	1.2	1.5	0	0	0	
Samco	0	0	0.9	0.9	1.5	
Sitesa Addax	1.0	0	0	0	0	
Total Worldwide	33.1	45.8	36.3	45.2	79.7	24.6

Source: Dataquest (June 1995)

Table 4-59
Each Company's Revenue from Shipments of Ion Implantation Equipment to the North American Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Implanter Market	369.8	353.4	262.9	359.1	654.2	15.3
Medium Current						
Eaton	5.7	4.4	0.7	8.4	17.8	
Nissin	1.9	2.8	0	0	3.9	
Sumitomo/Eaton Nova	0	0	0	0	0	
TEL/Varian	0	0	0	0	0	
Ulvac	0	0	0	0	0	
Varian	9.6	9.1	9.6	18.1	36.8	
Total Medium Current	17.2	16.3	10.3	26.5	58.5	35.8
High Current						
Applied Materials	24.2	12.0	15.0	25.5	40.9	
Eaton	19.5	18.5	15.3	16.7	48.7	
Hitachi	0	0	0	0	0	
Nissin	1.7	0	0	0	0	
Sumitomo/Eaton Nova	0	0	0	0	0	
TEL/Varian	0	0	0	0	0	
Varian	13.0	8.1	14.6	14.9	23.0	
Total High Current	58.4	38.6	44.9	57.1	112.6	17.8
High Voltage						
Eaton	0	0	7.2	2.0	0	
Genus	2.6	2.9	0	0	0	
National Electrostatics	0	0	0	0	0	
Nissin	0	0	0	0	0	
Sumitomo/Eaton Nova	0	0	0	0	0	
Total High Voltage	2.6	2.9	7.2	3.0	0	-100.0
Total North America	78.2	57.8	62.4	86.6	171.1	21.6

Source: Dataquest (June 1995)

Table 4-60
Each Company's Revenue from Shipments of Ion Implantation Equipment to the Japanese Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Implanter Market	369.8	353.4	262.9	359.1	654.2	15.3
Medium Current						
Eaton	0	0	0	0	0	
Nissin	30.4	18.4	18.4	14.1	24.4	
Sumitomo/Eaton Nova	0	0	0	0	0	
TEL/Varian	20.4	11.7	17.0	12.1	33.9	
Ulvac	6.9	11.1	5.5	12.9	23.5	
Varian	12.0	18.4	7.9	6.8	11.6	
Total Medium Current	69.7	59.6	48.8	45.9	93.4	7.6
High Current						
Applied Materials	12.1	12.7	15.0	24.2	33.0	
Eaton	0	0	0	0	0	
Hitachi	11.2	10.2	4.9	2.7	0	
Nissin	7.5	11.2	0	5.9	0	
Sumitomo/Eaton Nova	51.6	45.7	18.6	47.0	86.4	
TEL/Varian	33.3	30.7	23.6	15.2	12.6	
Varian	20.4	19.2	8.2	0	1.9	
Total High Current	136.1	129.7	70.3	95.0	133.9	-0.4
High Voltage						
Eaton	0	0	0	0	0	
Genus	4.2	8.4	5.8	2.9	5.8	
National Electrostatics	0	0	0	0	0	
Nissin	3.0	0	2.7	2.7	0	
Sumitomo/Eaton Nova	0	0	0	0	4.0	
Total High Voltage	4.2	11.4	5.8	5.6	9.8	23.6
Total Japan	210.0	200.7	124.9	146.5	237.1	3.1

Source: Dataquest (June 1995)

Table 4-61
Each Company's Revenue from Shipments of Ion Implantation Equipment to the European Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Implanter Market	369.8	353.4	262.9	359.1	654.2	15.3
Medium Current						
Eaton	2.6	3.7	2.7	9.5	14.7	
Nissin	4.1	1.8	0	0	0	
Sumitomo/Eaton Nova	0	0	0	0	0	
TEL/Varian	0	0	0	0	0	
Ulvac	0	0	0	0	0	
Varian	1.2	8.2	5.0	6.0	23.4	
Total Medium Current	7.9	13.7	7.7	15.5	38.1	48.2
High Current						
Applied Materials	9.7	9.2	7.5	12.4	28.0	
Eaton	11.9	10.5	9.8	11.2	22.8	
Hitachi	0	0	0	0	0	
Nissin	0	0	0	0	0	
Sumitomo/Eaton Nova	0	0	0	0	0	
TEL/Varian	0	0	0	0	0	
Varian	5.5	6.8	9.2	13.2	19.4	
Total High Current	27.1	26.5	26.5	36.8	70.2	26.9
High Voltage						
Eaton	0	3.3	0	0	0	
Genus	0	0	2.7	2.9	3.0	
National Electrostatics	0	0	0	0	0	
Nissin	0	0	0	0	0	
Sumitomo/Eaton Nova	0	0	0	0	0	
Total High Voltage	0	3.3	2.7	2.9	3.0	NM
Total Europe	35.0	43.5	36.9	55.2	111.3	33.5

NM = Not meaningful
Source: Dataquest (June 1995)

Table 4-62
Each Company's Revenue from Shipments of Ion Implantation Equipment to Asia/Pacific-ROW (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Implanter Market	369.8	353.4	262.9	359.1	654.2	15.3
Medium Current						
Eaton	9.2	4.5	7.6	3.2	0	
Nissin	1.1	5.0	1.0	3.7	7.6	
Sumitomo/Eaton Nova	0	0	0	0	0	
TEL/Varian	0	0	0	0	0	
Ulvac	0	0	0	0	0	
Varian	8.4	8.4	8.0	13.1	36.1	
Total Medium Current	18.7	17.9	16.6	20.0	43.7	23.6
High Current						
Applied Materials	0	0	0	0	2.9	
Eaton	18.7	11.6	11.5	20.9	32.8	
Hitachi	0	10.2	0	0	0	
Nissin	0	0	0	0	0	
Sumitomo/Eaton Nova	0	0	0	0	0	
TEL/Varian	0	0	0	0	0	
Varian	9.2	11.7	10.6	23.3	38.8	
Total High Current	27.9	33.5	22.1	44.2	74.5	27.8
High Voltage						
Eaton	0	0	0	0	0	
Genus	0	0	6.6	6.6	16.5	
National Electrostatics	0	0	0	0	0	
Nissin	0	0	0	0	0	
Sumitomo/Eaton Nova	0	0	0	0	0	
Total High Voltage	0	0	0	6.6	16.5	NM
Total Asia/Pacific-ROW	46.6	51.4	38.7	70.8	134.7	30.4

NM = Not meaningful
Source: Dataquest (June 1995)

Table 4-63
Each Company's Revenue from Shipments of Ion Implantation Equipment to the Worldwide Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Implanter Market	369.8	353.4	262.9	359.1	654.2	15.3
Medium Current						
Eaton	17.5	12.6	11.0	21.1	32.5	
Nissin	37.5	28.0	19.4	17.8	35.9	
Sumitomo/Eaton Nova	0	0	0	0	0	
TEL/Varian	20.4	11.7	17.0	12.1	33.9	
Ulvac	6.9	11.1	5.5	12.9	23.5	
Varian	31.2	44.1	30.5	44.0	107.9	
Total Medium Current	113.5	107.5	83.4	107.9	233.7	19.8
High Current						
Applied Materials	46.0	33.9	37.5	62.1	104.8	
Eaton	50.1	40.6	36.6	48.8	104.3	
Hitachi	11.2	20.4	4.9	2.7	0	
Nissin	9.2	11.2	0	5.9	0	
Sumitomo/Eaton Nova	51.6	45.7	18.6	47.0	86.4	
TEL/Varian	33.3	30.7	23.6	15.2	12.6	
Varian	48.1	45.8	42.6	51.4	83.1	
Total High Current	249.5	228.3	163.8	233.1	391.2	11.9
High Voltage						
Eaton	0	3.3	7.2	3.0	0	
Genus	6.8	11.3	8.5	12.4	25.3	
National Electrostatics	0	0	0	0	0	
Nissin	0	3.0	0	2.7	0	
Sumitomo/Eaton Nova	0	0	0	0	4.0	
Total High Voltage	6.8	17.6	15.7	18.1	29.3	44.1
Total Worldwide	369.8	353.4	262.9	359.1	654.2	15.3

Source: Dataquest (June 1995)

Table 4-64
Each Company's Revenue from Shipments of Optical CD Metrology and CD SEM Equipment to the North American Market
(End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Optical CD Metrology and CD SEM Market	146.3	151.3	118.3	125.6	241.6	13.4
Optical Critical Dimension						
Biorad	4.0	3.0	1.2	3.5	7.8	
Hitachi	0.3	0	0	0	0	
IVS Inc.	6.0	4.8	1.2	1.2	3.4	
KLA Instruments	3.4	2.8	4.6	5.0	9.8	
Leica	1.5	0.6	0	0	0	
Leica Lasertechnik	0.3	0	0	0	0	
Micro-Controle	0	0	0	0	0	
Nano-Master	0	0.8	0.8	0	0	
Nanometrics	1.4	0.9	0.8	0.8	0	
Nikon	0	0	0	0	0	
Optical Specialties	0.3	1.0	1.1	2.6	2.6	
Ryokosha	0	0	0	0	0	
SiScan Systems	2.0	2.2	0.9	0.2	0	
Toyko Aircraft Systems	0.4	0.4	0	0	0	
Other CD Companies	1.2	0.8	0.7	0	0	
Total Optical CD Metrology[1]	20.8	17.3	11.3	13.3	23.6	3.2
CD SEM						
ABT Corporation	0	0	0	0	0	
Amray	1.1	2.8	1.8	0.9	0	
Amgstrom Measurements	0	2.2	0	0	0	
Biorad	6.9	4.9	0	0	0	
Hitachi	13.9	8.0	15.8	12.6	18.1	
Holon	0	0	0	0	0	
IVS Inc. (Angstom)	0	0	0	1.6	1.2	
JEOL	0	0	0	0	0	
Jenoptik	0	0	0	0	0	
KLA Instruments	0	0	0	0	2.5	
Metrologix	0	0	2.2	2.5	0	
Nanometrics	0.5	0	0.3	0	0.9	
Nikon	0	0	0	0	0	
Opal	0.8	0	5.6	9.5	15.4	
Topcon	0	0	0	0	0	
Total CD SEM	23.2	17.9	25.7	27.1	38.1	13.2
Total North America Optical CD Metrology and CD SEM	44.0	35.2	37.0	40.4	61.7	8.8

[1]The category of Optical CD Metrology includes dedicated overlay tools, in addition to joint linewidth/overlay measurement systems.
Source: Dataquest (June 1995)

Table 4-65
Each Company's Revenue from Shipments of Optical CD Metrology and CD SEM Equipment to the Japanese Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Optical CD Metrology and CD SEM Market	146.3	151.3	118.3	125.6	241.6	13.4
Optical Critical Dimension						
Biorad	0	0	0	0	0	
Hitachi	5.1	3.6	1.4	2.4	3.1	
IVS Inc.	0	0	0.2	0.3	0.2	
KLA Instruments	3.3	3.4	2.8	6.6	9.3	
Leica	0	0	0.3	0	0	
Leica Lasertechnik	0	0	0	0	0	
Micro-Controle	0	0	0	0	0	
Nano-Master	0	0	0	0	0	
Nanometrics	0	0.9	1.0	1.0	0	
Nikon	3.8	6.9	0.5	0.3	0.9	
Optical Specialties	0.9	3.9	3.8	1.9	4.2	
Ryokosha	1.0	0.7	0.3	0.3	0	
SiScan Systems	0	0	0	0	0	
Toyko Aircraft Systems	3.3	2.9	2.8	2.0	3.7	
Other CD Companies	1.2	1.3	0.5	0	0	
Total Optical CD Metrology[1]	18.6	23.6	13.6	14.8	21.4	3.6
CD SEM						
ABT Corporation	5.2	0	0	0	0	
Amray	0	0	0	0.6	0	
Amgstrom Measurements	0	0	0	0	0	
Biorad	0	0	0	0	0	
Hitachi	38.8	45.6	20.8	23.7	59.9	
Holon	8.9	8.0	5.0	6.3	6.3	
IVS Inc. (Angstom)	0	0	0	0	0	
JEOL	0	0	1.4	0.7	1.6	
Jenoptik	0	0	0	0	0	
KLA Instruments	0	0	0	0	0	
Metrologix	0	0	0	0.9	0	
Nanometrics	0	0	0	0	0	
Nikon	0	0	0	0.8	1.8	
Opal	1.6	1.6	3.8	1.0	2.1	
Topcon	0	2.1	4.3	1.4	4.7	
Total CD SEM	54.5	57.3	35.3	35.4	76.4	8.8
Total Japan Optical CD Metrology and CD SEM	73.1	80.9	48.9	50.2	97.8	7.5

[1]The category of Optical CD Metrology includes dedicated overlay tools, in addition to joint linewidth/overlay measurement systems.
Source: Dataquest (June 1995)

Table 4-66
Each Company's Revenue from Shipments of Optical CD Metrology and CD SEM Equipment to the European Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Optical CD Metrology and CD SEM Market	146.3	151.3	118.3	125.6	241.6	13.4
Optical Critical Dimension						
Biorad	2.2	1.7	0.8	1.6	2.5	
Hitachi	0	0.6	0	0	0	
IVS Inc.	0.8	1.6	0.7	0.9	0.5	
KLA Instruments	0.8	1.2	1.3	3.6	4.9	
Leica	5.0	0.5	0.3	0.4	0	
Leica Lasertechnik	0.7	0	0	0	0	
Micro-Controle	4.4	0	0	0	0	
Nano-Master	0	5.2	6.3	0	0	
Nanometrics	0.4	0	0	0	0	
Nikon	0	0	0	0	0	
Optical Specialties	0	0	0.1	0.7	0.1	
Ryokosha	0	0	0	0	0	
SiScan Systems	0	0	0	0	0	
Toyko Aircraft Systems	0	0	0	0	0	
Other CD Companies	0.8	0.5	0.2	0	0	
Total Optical CD Metrology[1]	15.1	11.3	9.7	7.2	8.0	-14.7
CD SEM						
ABT Corporation	0	0	0	0	0	
Amray	0.6	0.6	1.2	0	0	
Amgstrom Measurements	0	0	0	0	0	
Biorad	0	0	0	0	0	
Hitachi	6.2	4.0	3.2	0.7	2.0	
Holon	0	0	0	0	0	
IVS Inc. (Angstom)	0	0	0	0.8	0	
JEOL	0	0	0	0	0	
Jenoptik	0	0	0	0	0.7	
KLA Instruments	0	0	0	0	2.2	
Metrologix	0	0	0	0	0	
Nanometrics	0	0	0	0	0	
Nikon	0	0	0	0	0	
Opal	0	0.8	0	2.1	4.2	
Topcon	0	0	0	0	0	
Total CD SEM	6.8	5.4	4.4	3.6	9.1	7.6
Total Europe Optical CD Metrology and CD SEM	21.9	16.7	14.1	10.8	17.1	-6.0

[1]The category of Optical CD Metrology includes dedicated overlay tools, in addition to joint linewidth/overlay measurement systems.
Source: Dataquest (June 1995)

Table 4-67
Each Company's Revenue from Shipments of Optical CD Metrology and CD SEM Equipment to Asia/Pacific-ROW (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Optical CD Metrology and CD SEM Market	146.3	151.3	118.3	125.6	241.6	13.4
Optical Critical Dimension						
Biorad	0	0.9	0.4	1.3	1.9	
Hitachi	0	0	0	0	0	
IVS Inc.	1.2	1.2	0.2	0.6	1.0	
KLA Instruments	1.1	1.9	2.5	2.8	6.2	
Leica	0	0.7	0.2	0.5	0	
Leica Lasertechnik	0	0	0	0	0	
Micro-Controle	0	0	0	0	0	
Nano-Master	0	0	0	0	0	
Nanometrics	0	0	0	0	0	
Nikon	0	0	0	0	0	
Optical Specialties	0.7	0.8	1.4	1.2	3.1	
Ryokosha	0	0	0	0	0	
SiScan Systems	0	0	0	0	0	
Toyko Aircraft Systems	0	0	0	0	0	
Other CD Companies	1.2	1.0	0.6	0	0	
Total Optical CD Metrology[1]	4.2	6.5	5.3	6.4	12.2	30.6
CD SEM						
ABT Corporation	0	0	0	0	0	
Amray	0	0	0	0	0	
Amgstrom Measurements	0	0	0	0	0	
Biorad	0	0	0	0	0	
Hitachi	3.1	12.0	13.0	13.5	37.5	
Holon	0	0	0	0	7.9	
IVS Inc. (Angstom)	0	0	0	0	0	
JEOL	0	0	0	0	2.3	
Jenoptik	0	0	0	0	0	
KLA Instruments	0	0	0	0	0	
Metrologix	0	0	0	1.0	0	
Nanometrics	0	0	0	0	0	
Nikon	0	0	0	0	0	
Opal	0	0	0	2.1	5.1	
Topcon	0	0	0	0	0	
Total CD SEM	3.1	12.0	13.0	16.6	52.8	103.2
Total Asia/Pacific-ROW Optical CD Metrology and CD SEM	7.3	18.5	18.3	23.0	65.0	72.7

[1]The category of Optical CD Metrology includes dedicated overlay tools, in addition to joint linewidth/overlay measurement systems.
Source: Dataquest (June 1995)

Table 4-68
Each Company's Revenue from Shipments of Optical CD Metrology and CD SEM Equipment to the Worldwide Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Optical CD Metrology and CD SEM Market	146.3	151.3	118.3	125.6	241.6	13.4
Optical Critical Dimension						
Biorad	6.2	5.6	2.4	6.4	12.2	
Hitachi	5.4	4.2	1.4	2.4	3.1	
IVS Inc.	8.0	7.6	2.3	3.0	5.1	
KLA Instruments	8.6	9.3	11.2	18.0	30.2	
Leica	6.5	1.8	0.8	0.9	0	
Leica Lasertechnik	1.0	0	0	0	0	
Micro-Controle	4.4	0	0	0	0	
Nano-Master	0	6.0	7.1	0	0	
Nanometrics	1.8	1.8	1.8	1.8	0	
Nikon	3.8	6.9	0.5	0.3	0.9	
Optical Specialties	1.9	5.7	6.4	6.4	10.0	
Ryokosha	1.0	0.7	0.3	0.3	0	
SiScan Systems	2.0	2.2	0.9	0.2	0	
Toyko Aircraft Systems	3.7	3.3	2.8	2.0	3.7	
Other CD Companies	4.4	3.6	2.0	0	0	
Total Optical CD Metrology[1]	58.7	58.7	39.9	41.7	65.2	2.7
CD SEM						
ABT Corporation	5.2	0	0	0	0	
Amray	1.7	3.4	3.0	1.5	0	
Amgstrom Measurements	0	2.2	0	0	0	
Biorad	6.9	4.9	0	0	0	
Hitachi	62.0	69.6	52.8	50.5	117.5	
Holon	8.9	8.0	5.0	6.3	14.2	
IVS Inc. (Angstom)	0	0	0	2.4	1.2	
JEOL	0	0	1.4	0.7	3.9	
Jenoptik	0	0	0	0	0.7	
KLA Instruments	0	0	0	0	4.7	
Metrologix	0	0	2.2	4.4	0	
Nanometrics	0.5	0	0.3	0	0.9	
Nikon	0	0	0	0.8	1.8	
Opal	2.4	2.4	9.4	14.7	26.8	
Topcon	0	2.1	4.3	1.4	4.7	
Total CD SEM	87.6	92.6	78.4	82.7	176.4	19.1
Total Worldwide Optical CD Metrology and CD SEM	146.3	151.3	118.3	124.4	241.6	13.4

[1]The category of Optical CD Metrology includes dedicated overlay tools, in addition to joint linewidth/overlay measurement systems.
Source: Dataquest (June 1995)

Table 4-69
Each Company's Revenue from Shipments of Patterned Wafer Inspection and Review to the North American Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Inspection and Review Market	135.9	134.5	136.1	180.7	350.1	26.7
Canon	0	0	0	0	0	
Hitachi[1]	3.3	3.2	0	0.8	0	
Inspex	6.0	5.7	7.1	5.1	6.0	
Insystems	7.4	6.5	0	0	0	
JEOL	0	0	0	0	0	
KLA Instruments[2]	14.9	11.0	23.1	22.6	50.9	
Lasertec	0	0	0	0	0	
Leica[3]	0.8	1.4	2.8	6.2	15.0	
Micro-Controle	0	0	0	0	0	
Nano-Master	0	0	0	0	0	
Nidek	0.8	1.7	1.1	1.8	2.0	
Nikon	2.1	3.4	3.0	5.4	6.1	
Optical Specialties	0.1	0.1	4.4	3.0	0.3	
Orbot	0	0	0	0	0	
Tencor Instruments	4.6	4.2	5.0	7.2	20.6	
Topcon	0	0	0	0	0	
Toray	0	0	0	0	0	
Ultrapointe	0	0	0	0.3	4.0	
Carl Zeiss	0.7	0.7	0.5	0.7	0.7	
Other Companies	0.9	0.8	0.6	0	0	
Total North America Inspection and Review	41.6	38.7	47.6	53.1	105.6	26.2

[1]Hitachi figures include both patterned wafer inspection and review.
[2]KLA Instruments figures do not include review stations.
[3]Leica figures do not include microscope review stations.
Source: Dataquest (June 1995)

Table 4-70
Each Company's Revenue from Shipments of Patterned Wafer Inspection and Review to the Japanese Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Inspection and Review Market	135.9	134.5	136.1	180.7	350.1	26.7
Canon	3.8	4.0	2.5	2.0	1.8	
Hitachi[1]	16.1	24.2	10.6	20.0	29.1	
Inspex	0	1.0	1.1	0.9	1.0	
Insystems	7.0	3.9	0	0	0	
JEOL	0	1.7	0.6	1.4	2.4	
KLA Instruments[2]	16.1	9.9	16.8	30.9	62.1	
Lasertec	0	0	0	0.5	1.2	
Leica[3]	0	0	0.3	1.1	6.4	
Micro-Controle	0	0	0	0	0	
Nano-Master	0	0	0	0	0	
Nidek	5.7	5.2	3.7	2.6	4.5	
Nikon	7.1	6.7	2.8	3.8	3.0	
Optical Specialties	0	0	0	0.7	2.0	
Orbot	0	0	0	0	0	
Tencor Instruments	3.3	3.7	1.8	4.0	9.9	
Topcon	0	0	0.6	0.7	0	
Toray	0	0	2.3	1.6	4.9	
Ultrapointe	0	0	0	0.3	0	
Carl Zeiss	0	0	0	0	0	
Other Companies	0.5	0.9	0.8	0	0	
Total Japan Inspection and Review	59.6	61.2	43.9	70.5	128.3	21.1

[1]Hitachi figures include both patterned wafer inspection and review.
[2]KLA Instruments figures do not include review stations.
[3]Leica figures do not include microscope review stations.
Source: Dataquest (June 1995)

Table 4-71
Each Company's Revenue from Shipments of Patterned Wafer Inspection and Review to the European Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Inspection and Review Market	135.9	134.5	136.1	180.7	350.1	26.7
Canon	0	0	0	0	0	
Hitachi[1]	1.1	0.6	0	0.7	0	
Inspex	2.1	1.9	3.5	2.1	2.0	
Insystems	1.2	2.6	0	0	0	
JEOL	0	0	0	0	0	
KLA Instruments[2]	4.7	3.3	5.7	12.6	19.5	
Lasertec	0	0	0	0	0	
Leica[3]	5.2	2.5	2.2	2.0	4.8	
Micro-Controle	5.0	0	0	0	0	
Nano-Master	0	5.4	5.4	0	0	
Nidek	0.2	0.2	0.3	0.2	0.2	
Nikon	1.2	0.7	1.2	0.8	0.4	
Optical Specialties	0	0	0	0	0	
Orbot	0	0	0	0	2.9	
Tencor Instruments	2.5	2.8	3.1	4.4	5.8	
Topcon	0	0	0	0	0	
Toray	0	0	0	0	0	
Ultrapointe	0	0	0	0.3	0.6	
Carl Zeiss	0.7	0.7	0.5	0.5	0.5	
Other Companies	0.1	0.1	0.1	0	0	
Total Europe Inspection and Review	24.0	20.8	22.0	23.6	36.7	11.2

[1]Hitachi figures include both patterned wafer inspection and review.
[2]KLA Instruments figures do not include review stations.
[3]Leica figures do not include microscope review stations.
Source: Dataquest (June 1995)

Table 4-72
Each Company's Revenue from Shipments of Patterned Wafer Inspection and Review to Asia/Pacific-ROW (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Inspection and Review Market	135.9	134.5	136.1	180.7	350.1	26.7
Canon	0.4	0.4	0	0	0	
Hitachi[1]	0.6	0.9	0	0	0	
Inspex	4.7	4.5	4.4	10.7	13.1	
Insystems	1.2	0	0	0	0	
JEOL	0	0	0	0	0	
KLA Instruments[2]	1.3	2.2	14.4	18.7	49.8	
Lasertec	0	0	0	0	0	
Leica[3]	0.8	1.0	0.7	0.4	2.5	
Micro-Controle	0	0	0	0	0	
Nano-Master	0	0	0	0	0	
Nidek	0	0	0	0	2.8	
Nikon	0.3	2.9	1.1	1.6	3.7	
Optical Specialties	0.2	0	0	0	0	
Orbot	0	0	0	0	0	
Tencor Instruments	0.8	1.4	1.8	2.1	7.3	
Topcon	0	0	0	0	0	
Toray	0	0	0	0	0	
Ultrapointe	0	0	0	0	0.3	
Carl Zeiss	0	0	0	0	0	
Other Companies	0.4	0.5	0.2	0	0	
Total Asia/Pacific-ROW Inspection and Review	10.7	13.8	22.6	33.5	79.5	65.1

[1]Hitachi figures include both patterned wafer inspection and review.
[2]KLA Instruments figures do not include review stations.
[3]Leica figures do not include microscope review stations.
Source: Dataquest (June 1995)

Table 4-73
Each Company's Revenue from Shipments of Patterned Wafer Inspection and Review to the Worldwide Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Inspection and Review Market	135.9	134.5	136.1	180.7	350.1	26.7
Canon	4.2	4.4	2.5	2.0	1.8	
Hitachi[1]	21.1	28.9	10.6	21.5	29.1	
Inspex	12.8	13.1	16.1	18.8	22.1	
Insystems	16.8	13.0	0	0	0	
JEOL	0	1.7	0.6	1.4	2.4	
KLA Instruments[2]	37.0	26.4	60.0	84.8	182.3	
Lasertec	0	0	0	0.5	1.2	
Leica[3]	6.8	4.9	6.0	9.7	28.7	
Micro-Controle	5.0	0	0	0	0	
Nano-Master	0	5.4	5.4	0	0	
Nidek	6.7	7.1	5.1	4.6	9.5	
Nikon	10.7	13.7	8.1	11.6	13.2	
Optical Specialties	0.3	0.1	4.4	3.7	2.3	
Orbot	0	0	0	0	2.9	
Tencor Instruments	11.2	12.1	11.7	17.7	43.6	
Topcon	0	0	0.6	0.7	0	
Toray	0	0	2.3	1.6	4.9	
Ultrapointe	0	0	0	0.9	4.9	
Carl Zeiss	1.4	1.4	1.0	1.2	1.2	
Other Companies	1.9	2.3	1.7	0	0	
Total Worldwide Inspection and Review	135.9	134.5	136.1	180.7	350.1	26.7

[1]Hitachi figures include both patterned wafer inspection and review.
[2]KLA Instruments figures do not include review stations.
[3]Leica figures do not include microscope review stations.
Source: Dataquest (June 1995)

Table 4-74
Each Company's Revenue from Shipments of Thin Film Measurement Equipment to the North American Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Thin Film Measurement Market	NS	42.6	57.8	71.6	97.9	NM
Dainippon Screen	NS	0.1	0	0	0	
Leica	NS	0.7	0.5	1.0	0.9	
Nanometrics	NS	2.9	2.7	2.8	2.1	
Rudolph Research	NS	2.5	3.4	4.6	9.0	
Tencor Instruments	NS	7.1	15.2	22.4	21.8	
Therma-Wave	NS	0.3	1.9	1.5	5.5	
Other Companies	NS	0	0.2	0.5	0.5	
Total North America	NS	13.6	23.9	32.8	39.8	NM

NM = Not meaningful
NS = Not surveyed
Note: All Tencor Instruments figures reflect acquisition of Prometrix.
Source: Dataquest (June 1995)

Table 4-75
Each Company's Revenue from Shipments of Thin Film Measurement Equipment to the Japanese Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Thin Film Measurement Market	NS	42.6	57.8	71.6	97.9	NM
Dainippon Screen	NS	5.2	10.4	5.8	5.2	
Leica	NS	0	0	0	0	
Nanometrics	NS	6.1	3.2	2.8	2.2	
Rudolph Research	NS	1.1	1.8	2.9	6.2	
Tencor Instruments	NS	4.1	3.1	3.0	10.1	
Therma-Wave	NS	0	0	1.0	0	
Other Companies	NS	0.2	1.7	0.9	1.0	
Total Japan	NS	16.7	20.2	16.4	24.7	NM

NM = Not meaningful
NS = Not surveyed
Note: All Tencor Instruments figures reflect acquisition of Prometrix.
Source: Dataquest (June 1995)

Table 4-76
Each Company's Revenue from Shipments of Thin Film Measurement Equipment to the European Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Thin Film Measurement Market	NS	42.6	57.8	71.6	97.9	NM
Dainippon Screen	NS	0.3	0	0.6	0.5	
Leica	NS	0.6	0.8	0.5	0.2	
Nanometrics	NS	0.4	0.3	1.1	0.4	
Rudolph Research	NS	0.2	1.4	1.4	1.4	
Tencor Instruments	NS	2.5	6.6	7.2	5.5	
Therma-Wave	NS	0	0	0.4	1.9	
Other Companies	NS	2.4	0.4	0.2	0.4	
Total Europe	NS	6.4	9.5	11.4	10.3	NM

NM = Not meaningful
NS = Not surveyed
Note: All Tencor Instruments figures reflect acquisition of Prometrix.
Source: Dataquest (June 1995)

Table 4-77
Each Company's Revenue from Shipments of Thin Film Measurement Equipment to Asia/Pacific-ROW (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Thin Film Measurement Marke	NS	42.6	57.8	71.6	97.9	NM
Dainippon Screen	NS	1.4	0.2	0.3	0	
Leica	NS	0.5	0.6	0.4	0.3	
Nanometrics	NS	1.1	2.0	3.7	2.8	
Rudolph Research	NS	1.6	1.2	1.5	4.0	
Tencor Instruments	NS	0.9	0	3.9	9.9	
Therma-Wave	NS	0	0	1.0	5.9	
Other Companies	NS	0.4	0.2	0.2	0.2	
Total Asia/Pacific-ROW	NS	5.9	4.2	11.0	23.1	NM

NM = Not meaningful
NS = Not surveyed
Note: All Tencor Instruments figures reflect acquisition of Prometrix.
Source: Dataquest (June 1995)

Table 4-78
Each Company's Revenue from Shipments of Thin Film Measurement Equipment to the Worldwide Market (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	CAGR (%) 1990-1994
World Thin Film Measurement Marke	NS	42.6	57.8	71.6	97.9	NM
Dainippon Screen	NS	7.0	10.6	6.7	5.7	
Leica	NS	1.8	1.9	1.9	1.4	
Nanometrics	NS	10.5	8.2	10.4	7.5	
Rudolph Research	NS	5.4	7.8	10.4	20.6	
Tencor Instruments	NS	14.6	24.9	36.5	47.3	
Therma-Wave	NS	0.3	1.9	3.9	13.3	
Other Companies	NS	3.0	2.5	1.8	2.1	
Total Worldwide	NS	42.6	57.8	71.6	97.9	NM

NM = Not meaningful
NS = Not surveyed
Note: All Tencor Instruments figures reflect acquisition of Prometrix.
Source: Dataquest (June 1995)

Chapter 5
Wafer Fab Equipment—Company Rankings

This section of the wafer fab equipment database presents the ranking of wafer fab equipment manufacturers by 1994 revenue. Table 5-1 presents a comparison of semiconductor wafer fab equipment company revenue and ranking for 1994 and 1993. For easier use of the information presented in this chapter, Table 5-2 presents an alphabetical listing of wafer fab equipment companies, along with their 1994 revenue and ranking. Finally, Tables 5-3 and 5-4 present 1994 wafer fab equipment company revenue and ranking with detailed equipment segment revenue identified.

Line 1 in each of these tables shows the total worldwide wafer fab equipment market. Individual company data shown in the tables represents 91 percent of the 1994 total wafer fab equipment market of about $10.75 billion. The companies listed here represent virtually all worldwide industry sales in the key front-end equipment categories of lithography (contact/proximity, projection aligners, steppers, maskmaking, direct-write, and X-ray), automatic photoresist processing equipment (Track), etch clean and polishing (automated wet stations, spray processors, vapor phase clean, post-CMP, other clean process, dry etch, dry strip, and chemical mechanical polishing), deposition (CVD, sputter, and silicon epitaxy), diffusion, rapid thermal processing, ion implantation, critical dimension measurement, and patterned wafer inspection and review equipment. The other 9 percent of the total worldwide wafer fab equipment market consists of equipment segments for which little or no detailed company data is available. Categories for which partial company detail is available include contact/proximity, other wet process, thin film measurement, and other process control. Categories for which no company detail is available include ion milling, other deposition (evaporation, MOCVD, and MBE), factory automation, and other equipment. Unavailable company sales for these categories are not included in the Chapter 5 tables.

The tables of Chapter 5 include only company sales of front-end equipment; they do not include company sales of assembly and test equipment. For instance, back-end equipment sales by ASM International are not included. Similarly, only KLA's CD/wafer inspection equipment sales are included; KLA's sales of mask inspection equipment (part of the "Other Process Control" equipment category) are not.

The revenue reported in the tables of Chapter 5 reflects calendar year activities and includes system sales, upgrades, and retrofits, but it does not include service and spare parts. In addition, no revenue is included from equipment sales for nonsemiconductor applications such as thin film head manufacturing or flat panel display manufacturing. Thus, the revenue reported here will differ from each company's sales as reported in its financial statements.

Some companies have experienced significant growth as a result of mergers and acquisitions. Similarly, other companies have experienced a number of divestitures and management buyouts during the past several years, which have reduced their presence in the wafer fab equipment industry. Please refer to Table 1-3 in chapter 1 for a summary of merger and acquisition activities in the wafer fab equipment industry.

Several companies (Eaton, Tokyo Electron, and Varian) are involved in wafer fab equipment joint-venture companies that provide the same equipment products as offered by one of the joint-venture partner companies. For the purposes of company ranking, the revenue of the joint-venture companies has been combined with the appropriate joint-venture partner. For example, the revenue of Tokyo Electron and the Varian/TEL joint venture has been combined in the tables of Chapter 5 because the track, diffusion, etch, and CVD products of Tokyo Electron are sold through the Varian/TEL joint venture. Similarly, Varian and TEL/Varian revenue are combined, as well as the revenue of Eaton and Sumitomo/Eaton Nova.

Table 5-1
Semiconductor Wafer Fab Equipment Companies: Comparison of 1994 and 1993 Ranking by Worldwide Sales* (End-User Revenue in Millions of U.S. Dollars)

	1994	1994 Rank	1993	1993 Rank	Percent Change
All Companies	10,754.8	-	6,876.1	-	56.4
Applied Materials	1,480.7	1	972.0	1	52.3
Tokyo Electron Ltd. & Varian/TEL	1,066.3	2	574.1	2	85.7
Nikon	1,027.1	3	503.2	3	104.1
Lam Research	520.6	4	330.0	4	57.8
Canon	502.2	5	317.4	5	58.2
Varian and TEL/Varian	375.3	6	201.5	10	86.3
Dainippon Screen	372.1	7	232.0	7	60.4
Hitachi	339.7	8	252.3	6	34.6
Kokusai and Bruce Technologies	297.7	9	226.4	8	31.5
Silicon Valley Group	290.5	10	218.2	9	33.1
ASM Lithography	272.8	11	169.9	11	60.6
KLA Instruments	255.5	12	135.7	12	88.3
Eaton and Sumitomo/Eaton Nova	227.2	13	122.0	13	86.2
Novellus Systems Inc.	197.4	14	94.3	19	109.3
Tencor Instruments	171.1	15	100.7	16	69.9
Anelva	170.1	16	106.1	14	60.3
Ulvac	131.7	17	100.0	17	31.7
Watkins-Johnson	122.4	18	66.2	20	84.9
ASM International	120.1	19	105.2	15	14.2
Materials Research Corporation	117.8	20	96.5	18	22.1
Alcan/Canon/Quester	93.6	21	49.1	21	90.6
FSI International	73.3	22	45.0	23	62.9
Sugai	71.9	23	32.6	31	120.6
Sankyo Engineering	62.1	24	25.3	37	145.5
Gasonics	56.6	25	42.4	25	33.5
Genus	56.4	26	36.9	26	52.8
Ultratech	56.4	27	31.7	32	77.9
Tegal	53.6	28	43.5	24	23.2
SubMicron Systems Inc.	53.4	29	35.4	28	50.8
E.T. Electrotech	52.7	30	29.9	33	76.3
Santa Clara Plastics	51.5	31	48.0	22	7.3
Etec	50.7	32	34.6	29	46.5
Semitherm and Semitool	48.6	33	22.4	39	117.0
IPEC/Westech Systems	43.0	34	34.6	30	24.3
Verteq	42.2	35	19.9	42	112.1
Leica	41.0	36	22.9	38	79.0

(Continued)

Table 5-1 (Continued)
Semiconductor Wafer Fab Equipment Companies: Comparison of 1994 and 1993 Ranking by Worldwide Sales* (End-User Revenue in Millions of U.S. Dollars)

	1994	1994 Rank	1993	1993 Rank	Percent Change
Nissin Electric	38.4	37	27.8	35	38.1
Kaijo Denki	38.2	38	19.5	43	95.9
AG Associates	36.4	39	21.7	41	67.7
Plasma Systems	35.9	40	28.9	34	24.2
MC Electronics	29.4	41	19.1	44	53.9
Fusion Semiconductor Systems	26.8	42	18.2	46	47.3
Opal	26.8	43	14.7	50	82.3
Shibaura Engineering Works	24.6	44	36.3	27	-32.2
Sumitomo Metals	24.4	45	27.0	36	-9.6
Semiconductor Systems	24.0	46	21.9	40	9.6
JEOL	23.3	47	9.3	65	150.5
Inspex	22.1	48	18.8	45	17.6
Rudolph Research	20.6	49	10.4	60	98.1
Koyo Lindberg	20.2	50	13.9	52	45.3
Convac	19.7	51	17.6	48	11.9
AST Electronic GMBH	18.7	52	9.3	64	101.1
Mattson Technologies	17.7	53	3.2	99	453.1
Matrix Integrated Systems	17.4	54	11.9	58	46.2
OnTrack Systems	15.3	55	4.5	89	240.0
Toho Kasei	15.1	56	17.4	49	-13.2
Holon	14.2	57	6.3	75	125.4
Maruwa	13.3	58	9.4	63	41.5
Therma-Wave	13.3	59	3.9	94	241.0
Tazmo	12.9	60	18.0	47	-28.3
Optical Specialties Inc.	12.3	61	10.1	61	21.8
Biorad	12.2	62	6.4	72	90.6
CFM Technology	12.0	63	12.3	56	-2.4
Tokyo Ohka Kogyo	11.9	64	8.5	68	40.0
Steag Microtech (formerly Pokorny)	11.7	65	14.0	51	-16.4
Yuasa	11.3	66	8.1	69	39.5
Moore Epitaxial Inc.	10.0	67	5.8	79	72.4
Plasma & Materials Technologies	9.9	68	6.2	77	59.7
Toshiba	9.6	69	5.7	81	68.4
Nidek	9.5	70	4.6	86	106.5
Toyoko Kagaku	9.3	71	2.2	109	322.7
Shimada	9.2	72	4.7	85	95.7
Jenoptik	9.0	73	7.5	70	20.0

(Continued)

Table 5-1 (Continued)
Semiconductor Wafer Fab Equipment Companies: Comparison of 1994 and 1993 Ranking by Worldwide Sales* (End-User Revenue in Millions of U.S. Dollars)

	1994	1994 Rank	1993	1993 Rank	Percent Change
ETS Company Ltd.	8.9	74	13.5	53	-34.1
Concept Systems Design	8.5	75	3.2	98	165.6
Nanometrics	8.4	76	12.2	57	-31.1
Samco	7.9	77	6.4	73	23.4
Shinko Electric	7.9	78	6.3	76	25.4
CVC Products	7.7	79	6.9	71	11.6
Cybeq	7.5	80	4.5	87	66.7
Strasbaugh	7.2	81	5.7	80	26.3
Sputtered Films	7.0	82	5.9	78	18.6
Dan Science Company Ltd.	6.9	83	8.9	67	-22.5
IVS Inc.	6.3	84	5.4	83	16.7
Sapi Equipements	5.2	85	2.5	104	108.0
LPE	5.0	86	4.0	93	25.0
Toray Industries	4.9	87	1.6	114	206.3
Ultrapointe	4.9	88	0.9	124	444.4
Ebara Corporation	4.7	89	0	-	NM
Topcon	4.7	90	4.3	92	9.3
Enya	4.4	91	3.6	95	22.2
Musashi	4.1	92	3.4	97	20.6
Denton Vacuum	4.0	93	3.0	100	33.3
Amaya	3.9	94	5.4	82	-27.8
Kuwano Electric	3.9	95	1.9	113	105.3
Speedfam	3.8	96	2.0	111	90.0
Shinko Seiki	3.7	97	2.7	103	37.0
Tokyo Aircraft Instruments	3.7	98	2.0	112	85.0
Japan Production Engineering	3.1	99	2.2	108	40.9
Orbot	2.9	100	0	-	NM
Kurt J. Lesker	2.7	101	2.4	105	12.5
High Temperature Engineering	2.4	102	1.2	119	100.0
Matsushita Electric	2.3	103	0	-	NM
SCI Manufacturing	2.3	104	4.5	90	-48.9
Jipelec	1.8	105	1.5	116	20.0
CHA Industries	1.7	106	0.2	131	750.0
Carl Zeiss	1.2	107	1.2	118	0
Lasertec Corporation	1.2	108	0.5	126	140.0
Pressi	1.2	109	0.5	127	140.0
Advanced Crystal Sciences Inc.	1.1	110	1.1	120	0

(Continued)

Table 5-1 (Continued)
Semiconductor Wafer Fab Equipment Companies: Comparison of 1994 and 1993 Ranking by Worldwide Sales* (End-User Revenue in Millions of U.S. Dollars)

	1994	1994 Rank	1993	1993 Rank	Percent Change
AET Thermal	1.1	111	1.1	121	0
Process Technology Ltd.	0.8	112	1.5	117	-46.7
Fujikoshi	0.7	113	0.3	128	133.3
Tystar	0.6	114	0.8	125	-25.0
Amray	0	-	1.5	115	-100.0
Centrotherm	0	-	5.1	84	-100.0
Disco	0	-	2.2	106	-100.0
Drytek	0	-	4.5	88	-100.0
Fuji Electric	0	-	2.2	107	-100.0
Japan Storage Battery	0	-	0.2	132	-100.0
Karl Suss	0	-	2.0	110	-100.0
m.FSI	0	-	11.7	59	-100.0
Machine Technology Inc.	0	-	13.2	54	-100.0
Metrologix	0	-	4.4	91	-100.0
Oxford Plasma Technology	0	-	9.1	66	-100.0
Pacific Western	0	-	2.7	102	-100.0
Peak Systems	0	-	3.5	96	-100.0
Plasma-Therm	0	-	1.0	123	-100.0
Poly-Flow Engineering	0	-	0.3	129	-100.0
Ryokosha	0	-	0.3	130	-100.0
S&K Products International	0	-	9.9	62	-100.0
Semifab	0	-	6.4	74	-100.0
SiScan Systems	0	-	0.2	133	-100.0
Solitec	0	-	1.1	122	-100.0
Tempress	0	-	2.9	101	-100.0
Universal Plastics	0	-	12.7	55	-100.0

NM = Not meaningful

*The company revenue reflected in Table 5-1 is based on the following major categories of front-end wafer fabrication equipment: Projection Aligners, Steppers, Maskmaking, Direct-Write, X-Ray Lithography, Automatic Photoresist Processing Equipment, Automated Wet Stations, Post-CMP Clean, Spray Processors, Vapor Phase Clean, Dry Etch, Dry Strip, Chemical Mechanical Polishing (CMP), CVD, Sputter, Silicon Epitaxy, Diffusion, Rapid Thermal Processing, Ion Implantation, Critical Dimension Measurement, and Patterned Wafer Inspection and Review. No revenue associated with service and spares, or nonsemiconductor applications, is included.

Source: Dataquest (June 1995)

Table 5-2
Semiconductor Wafer Fab Equipment Companies: Alphabetical Listing of 1994 Worldwide Sales* and Ranking (End-User Revenue in Millions of U.S. Dollars)

	1994	1994 Rank
All Companies	10,754.8	-
Advanced Crystal Sciences Inc.	1.1	110
AET Thermal	1.1	111
AG Associates	36.4	39
Alcan/Canon/Quester	93.6	21
Amaya	3.9	94
Anelva	170.1	16
Applied Materials	1,480.7	1
ASM International	120.1	19
ASM Lithography	272.8	11
AST Electronic GMBH	18.7	52
Biorad	12.2	62
Canon	502.2	5
Carl Zeiss	1.2	107
CFM Technology	12.0	63
CHA Industries	1.7	106
Concept Systems Design	8.5	75
Convac	19.7	51
CVC Products	7.7	79
Cybeq	7.5	80
Dainippon Screen	372.1	7
Dan Science Company Ltd.	6.9	83
Denton Vacuum	4.0	93
E.T. Electrotech	52.7	30
Eaton and Sumitomo/Eaton Nova	227.2	13
Ebara Corporation	4.7	89
Enya	4.4	91
Etec	50.7	32
ETS Company Ltd.	8.9	74
FSI International	73.3	22
Fujikoshi	0.7	113
Fusion Semiconductor Systems	26.8	42
Gasonics	56.6	25
Genus	56.4	26
High Temperature Engineering	2.4	102
Hitachi	339.7	8
Holon	14.2	57

(Continued)

Table 5-2 (Continued)
Semiconductor Wafer Fab Equipment Companies: Alphabetical Listing of 1994 Worldwide Sales* and Ranking (End-User Revenue in Millions of U.S. Dollars)

	1994	1994 Rank
Inspex	22.1	48
IPEC/Westech Systems	43.0	34
IVS Inc.	6.3	84
Japan Production Engineering	3.1	99
Jenoptik	9.0	73
JEOL	23.3	47
Jipelec	1.8	105
Kaijo Denki	38.2	38
KLA Instruments	255.5	12
Kokusai and Bruce Technologies	297.7	9
Koyo Lindberg	20.2	50
Kurt J. Lesker	2.7	101
Kuwano Electric	3.9	95
Lam Research	520.6	4
Lasertec Corporation	1.2	108
Leica	41.0	36
LPE	5.0	86
Maruwa	13.3	58
Matrix Integrated Systems	17.4	54
Matsushita Electric	2.3	103
Mattson Technologies	17.7	53
MC Electronics	29.4	41
Moore Epitaxial Inc.	10.0	67
Materials Research Corporation	117.8	20
Musashi	4.1	92
Nanometrics	8.4	76
Nidek	9.5	70
Nikon	1,027.1	3
Nissin Electric	38.4	37
Novellus Systems Inc.	197.4	14
OnTrack Systems	15.3	55
Opal	26.8	43
Optical Specialties Inc.	12.3	61
Orbot	2.9	100
Plasma & Materials Technologies	9.9	68
Plasma Systems	35.9	40
Pressi	1.2	109

(Continued)

Table 5-2 (Continued)
Semiconductor Wafer Fab Equipment Companies: Alphabetical Listing of 1994 Worldwide Sales* and Ranking (End-User Revenue in Millions of U.S. Dollars)

	1994	1994 Rank
Process Technology Ltd.	0.8	112
Rudolph Research	20.6	49
Samco	7.9	77
Sankyo Engineering	62.1	24
Santa Clara Plastics	51.5	31
Sapi Equipements	5.2	85
SCI Manufacturing	2.3	104
Semiconductor Systems	24.0	46
Semitherm and Semitool	48.6	33
Shibaura Engineering Works	24.6	44
Shimada	9.2	72
Shinko Electric	7.9	78
Shinko Seiki	3.7	97
Silicon Valley Group	290.5	10
Speedfam	3.8	96
Sputtered Films	7.0	82
Steag Microtech (formerly Pokorny)	11.7	65
Strasbaugh	7.2	81
SubMicron Systems Inc.	53.4	29
Sugai	71.9	23
Sumitomo Metals	24.4	45
Tazmo	12.9	60
Tegal	53.6	28
Tencor Instruments	171.1	15
Therma-Wave	13.3	59
Toho Kasei	15.1	56
Tokyo Aircraft Instruments	3.7	98
Tokyo Electron Ltd. & Varian/TEL	1,066.3	2
Tokyo Ohka Kogyo	11.9	64
Topcon	4.7	90
Toray Industries	4.9	87
Toshiba	9.6	69
Toyoko Kagaku	9.3	71
Tystar	0.6	114
Ultrapointe	4.9	88
Ultratech	56.4	27
Ulvac	131.7	17

(Continued)

Table 5-2 (Continued)
Semiconductor Wafer Fab Equipment Companies: Alphabetical Listing of 1994 Worldwide Sales* and Ranking (End-User Revenue in Millions of U.S. Dollars)

	1994	1994 Rank
Varian and TEL/Varian	375.3	6
Verteq	42.2	35
Watkins-Johnson	122.4	18
Yuasa	11.3	66

NM = Not meaningful

*The company revenue reflected in Table 5-2 is based on the following major categories of front-end wafer fabrication equipment: Projection Aligners, Steppers, Maskmaking, Direct-Write, X-Ray Lithography, Automatic Photoresist Processing Equipment, Automated Wet Stations, Post-CMP Clean, Spray Processors, Vapor Phase Clean, Dry Etch, Dry Strip, Chemical Mechanical Polishing (CMP), CVD, Sputter, Silicon Epitaxy, Diffusion, Rapid Thermal Processing, Ion Implantation, Critical Dimension Measurement, and Patterned Wafer Inspection and Review. No revenue associated with service and spares, or nonsemiconductor applications, is included.

Source: Dataquest (June 1995)

Table 5-3
Top 40 Semiconductor Wafer Fab Equipment Companies Ranked by 1994 Worldwide Sales with Equipment Segment Detail
(End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
World Fab Equipment Market	5,866.6	6,014.0	5,088.7	6,876.1	10,754.8	
Applied Materials						1
Low Density Etch	175.0	154.0	187.0	317.2	391.0	
High Density Etch	0	0	0	0	25.1	
APCVD	5.0	0	0	0	0	
LPCVD	26.0	32.0	60.9	88.7	134.4	
PECVD	174.9	194.4	168.8	232.8	292.9	
Sputtering	15.0	52.3	124.8	249.3	504.4	
Silicon Epitaxy	25.0	32.0	23.0	21.9	28.1	
Ion Implantation	46.0	33.9	37.5	62.1	104.8	
Total	466.9	498.6	602.0	972.0	1,480.7	
Tokyo Electron Ltd. and Varian/TEL						2
Tokyo Electron Ltd.						
Resist Processing Equipment	105.9	126.2	96.7	130.5	302.5	
Low Density Etch	99.2	110.0	88.3	145.4	279.8	
Automated Wet Stations	0	5.6	7.5	7.2	22.5	
LPCVD	45.8	62.8	55.6	77.7	161.3	
Diffusion	92.2	92.7	72.6	86.3	158.4	
Total - TEL	343.1	397.3	320.7	447.1	924.5	
Varian/TEL						
Resist Processing Equipment	13.8	24.0	30.0	64.1	58.1	
Low Density Etch	11.6	10.9	7.0	20.4	11.6	
LPCVD	4.8	9.6	6.2	15.0	32.2	
Diffusion	6.3	13.8	7.1	27.5	39.9	
Total - Varian/TEL	36.5	58.3	50.3	127.0	141.8	
Total - TEL and Varian/TEL	379.6	455.6	371.0	574.1	1,066.3	
Nikon						3
Steppers	518.4	538.2	291.1	490.5	1,011.2	
Critical Dimension	3.8	6.9	0.5	1.1	2.7	
Patterned Wafer Inspection and Review	10.7	13.7	8.1	11.6	13.2	
Total	532.9	558.8	299.7	503.2	1,027.1	

(Continued)

Table 5-3 (Continued)
Top 40 Semiconductor Wafer Fab Equipment Companies Ranked by 1994 Worldwide Sales with Equipment Segment Detail
(End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
LAM Research						4
Low Density Etch	109.2	127.1	150.7	254.6	346.9	
High Density Etch	0	0	13.2	67.2	163.8	
LPCVD	2.7	1.9	7.3	4.0	2.0	
PECVD	0	0	0	4.2	7.9	
Silicon Epitaxy	7.9	0	0	0	0	
Total	119.8	129.0	171.2	330.0	520.6	
Canon						5
Contact Proximity	10.5	11.9	NS	NS	NS	
Projection Aligners	56.4	56.2	36.6	35.1	17.1	
Steppers	202.2	181.2	137.6	267.7	468.6	
Resist Processing Equipment	8.4	12.3	15.1	12.6	14.7	
Patterned Wafer Inspection and Review	4.2	4.4	2.5	2.0	1.8	
Total	281.7	266.0	191.8	317.4	502.2	
Varian Associates and TEL/Varian						6
Varian						
Sputtering	84.0	90.9	71.8	78.8	137.8	
Other Deposition	3.7	0	NS	NS	NS	
Ion Implantation	79.3	89.9	73.1	95.4	191.0	
Total - Varian	167.0	180.8	144.9	174.2	328.8	
TEL/Varian						
Ion Implantation	53.7	42.4	40.6	27.3	46.5	
Total - Varian and TEL/Varian	220.7	223.2	185.5	201.5	375.3	
Dainippon Screen						7
Resist Processing Equipment	59.2	69.5	77.4	107.5	138.7	
Automated Wet Stations	43.4	57.7	75.9	51.7	142.8	
Spray Processors	NA	NA	NA	NA	10.9	
Vapor Phase Clean	NS	NS	0	0	0.4	
Post-CMP Clean	NS	0	0	0	7.1	
Other Clean Process	NA	NA	NA	NA	49.4	
Other Wet Process	22.3	37.1	12.8	61.5	NA	
Rapid Thermal Processing	2.3	3.5	2.8	4.6	17.1	
Thin Film Measurement	NS	7.0	10.6	6.7	5.7	
Total	127.2	174.8	179.5	232.0	372.1	

(Continued)

Table 5-3 (Continued)
Top 40 Semiconductor Wafer Fab Equipment Companies Ranked by 1994 Worldwide Sales with Equipment Segment Detail
(End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Hitachi						8
Direct Write	19.5	17.8	3.2	7.2	17.7	
Maskmaking	6.2	6.7	7.1	8.1	9.8	
Steppers	103.8	86.7	39.8	25.2	0	
Dry Strip	2.7	5.6	4.8	6.3	4.9	
Low Density Etch	4.5	1.5	1.2	0.7	0.5	
High Density Etch	87.0	113.7	93.9	127.7	157.1	
Ion Implantation	11.2	20.4	4.9	2.7	0	
Patterned Wafer Inspection and Review	21.1	28.9	10.6	21.5	29.1	
Critical Dimension	67.4	73.8	54.2	52.9	120.6	
Total	323.4	355.1	219.7	252.3	339.7	
Kokusai Electric and Bruce Technologies						9
LPCVD	62.7	63.6	57.4	97.3	141.0	
Diffusion	50.9	68.1	55.9	123.9	155.8	
Low Density Etch	1.1	0	1.3	0.6	0	
Silicon Epitaxy	2.2	5.9	11.1	4.6	0.9	
Rapid Thermal Processing	0	0.6	0.6	0	0	
Total	116.9	138.2	126.3	226.4	297.7	
Silicon Valley Group						10
Projection Aligners	37.0	22.2	11.6	22.1	27.1	
Steppers	30.6	30.4	23.2	29.4	29.4	
Resist Processing Equipment	44.0	38.0	44.8	89.6	93.3	
LPCVD	22.5	19.5	20.0	19.7	40.3	
XRay	0	0	0	11.4	11.2	
Diffusion	54.2	40.7	42.3	46.0	89.2	
Total	188.3	150.8	141.9	218.2	290.5	
ASM Lithography						11
Steppers	91.0	71.3	102.0	169.9	272.8	
KLA Instruments						12
Critical Dimension	8.6	9.3	11.2	18.0	34.9	
Patterned Wafer Inspection and Review	37.0	26.4	60.0	84.8	182.3	
Other Process Control	51.2	62.3	25.5	32.9	38.3	
Total	96.8	98.0	96.7	135.7	255.5	

(Continued)

Table 5-3 (Continued)
Top 40 Semiconductor Wafer Fab Equipment Companies Ranked by 1994 Worldwide Sales with Equipment Segment Detail
(End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Eaton and Sumitomo/Eaton Nova						13
Eaton						
Ion Implantation	67.6	56.5	54.8	72.9	136.8	
Resist Processing Equipment	4.7	4.2	2.6	2.1	0	
Total - Eaton	72.3	60.7	57.4	75.0	136.8	
Sumitomo Eaton/Nova						
Ion Implantation	51.6	45.7	18.6	47.0	90.4	
Total - Eaton and Sumitomo/Eaton Nova	123.9	106.4	76.0	122.0	227.2	
Novellus Systems Inc.						14
PECVD	63.0	64.0	48.4	70.5	146.1	
Sputtering	0	1.8	2.4	4.8	7.2	
LPCVD	1.0	5.7	6.7	19.0	44.1	
Total	64.0	71.5	57.5	94.3	197.4	
Tencor Instruments						15
Thin Film Measurement	NS	14.6	24.9	36.5	47.3	
Patterned Wafer Inspection and Review	11.2	12.1	11.7	17.7	43.6	
Other Process Control	54.0	44.8	40.1	46.5	80.2	
Total	65.2	71.5	76.7	100.7	171.1	
Anelva						16
Low Density Etch	23.8	16.3	9.0	13.4	21.7	
High Density Etch	5.6	5.0	10.6	1.8	5.2	
LPCVD	1.4	0	0	0	0.9	
PECVD	0.4	3.8	0	0	0	
Sputtering	90.8	114.5	81.8	78.3	134.7	
Other Deposition	10.3	12.8	6.2	12.6	7.6	
Total	132.3	152.4	107.6	106.1	170.1	
Ulvac						17
Dry Strip	2.3	2.3	1.9	3.1	4.1	
Low Density Etch	6.6	6.2	2.0	3.2	2.7	
LPCVD	4.5	17.3	17.7	18.7	17.0	

(Continued)

Table 5-3 (Continued)
Top 40 Semiconductor Wafer Fab Equipment Companies Ranked by 1994 Worldwide Sales with Equipment Segment Detail
(End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Diffusion	0	16.8	14.5	14.8	9.8	
Sputtering	58.6	45.3	37.5	47.3	74.6	
Other Deposition	21.5	18.7	NS	NS	NS	
Ion Implantation	6.9	11.1	5.5	12.9	23.5	
Total	100.4	117.7	79.1	100.0	131.7	
Watkins-Johnson						18
APCVD	41.0	48.5	45.0	66.2	122.4	
ASM International						19
Diffusion	24.4	21.7	16.6	15.1	10.5	
PECVD	49.6	40.0	28.4	26.8	34.0	
LPCVD	27.5	30.5	24.3	24.7	35.1	
Silicon Epitaxy	19.2	29.9	31.2	38.6	40.5	
Total	120.7	122.1	100.5	105.2	120.1	
Materials Research Corporation						20
Low Density Etch	4.7	9.6	0	0	0	
LPCVD	0	0	4.1	0	5.5	
Sputtering	62.6	84.5	102.9	96.5	112.3	
Total	67.3	94.1	107.0	96.5	117.8	
Alcan/Canon/Quester						21
Dry Strip	11.7	19.2	15.7	16.8	25.8	
Low Density Etch	2.5	5.6	3.8	2.2	3.1	
APCVD	15.0	26.8	28.5	30.1	64.7	
Total	29.2	51.6	48.0	49.1	93.6	
FSI International						22
Resist Processing Equipment	0	5.1	16.6	21.0	35.5	
Spray Processors	NA	NA	NA	NA	29.0	
Vapor Phase Clean	NS	NS	2.4	5.6	7.5	
Post-CMP Clean	NS	0	0	0.4	0	
Other Clean Process	NA	NA	NA	NA	1.3	
Other Wet Process	17.9	17.2	18.4	18.0	NA	
Total	17.9	22.3	37.4	45.0	73.3	

(Continued)

Table 5-3 (Continued)
Top 40 Semiconductor Wafer Fab Equipment Companies Ranked by 1994 Worldwide Sales with Equipment Segment Detail
(End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Sugai						23
Automated Wet Stations	34.3	31.4	32.0	31.5	70.7	
Other Clean Process	NA	NA	NA	NA	1.2	
Other Wet Process	1.4	1.2	1.6	1.1	NA	
Total	35.7	32.6	33.6	32.6	71.9	
Sankyo Engineering						24
Automated Wet Stations	33.6	27.4	19.4	16.8	58.2	
Other Clean Process	NA	NA	NA	NA	3.9	
Other Wet Process	5.5	5.3	1.7	8.5	NA	
Total	39.1	32.7	21.1	25.3	62.1	
Gasonics						25
Low Density Etch	0	5.0	3.0	3.1	4.2	
Dry Strip	8.2	22.9	24.4	38.5	51.6	
Diffusion	8.0	8.7	4.4	0.8	0.8	
Total	16.2	36.6	31.8	42.4	56.6	
Genus						26
LPCVD	40.4	29.7	21.9	24.5	31.1	
Ion Implantation	6.8	11.3	8.5	12.4	25.3	
Total	47.2	41.0	30.4	36.9	56.4	
Ultratech						27
Steppers	28.0	24.6	19.2	31.7	56.4	
Tegal						28
Dry Strip	3.0	3.5	1.6	0.8	1.5	
High Density Etch	0	0	0	9.8	14.0	
Low Density Etch	31.0	29.0	33.1	32.9	38.1	
Total	34.0	32.5	34.7	43.5	53.6	
SubMicron Systems Inc.						29
Automated Wet Stations	10.0	12.0	22.4	35.4	46.4	
Other Clean Process	NA	NA	NA	NA	7.0	
Total	10.0	12.0	22.4	35.4	53.4	

(Continued)

Table 5-3 (Continued)
Top 40 Semiconductor Wafer Fab Equipment Companies Ranked by 1994 Worldwide Sales with Equipment Segment Detail
(End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
E.T. Electrotech						30
PECVD	17.5	20.0	12.6	7.7	11.2	
Low Density Etch	17.5	12.0	6.6	12.3	13.0	
Sputtering	13.5	12.0	7.2	9.9	28.5	
Total	48.5	44.0	26.4	29.9	52.7	
Santa Clara Plastics						31
Automated Wet Stations	9.2	19.5	43.7	45.8	46.3	
Other Clean Process	NA	NA	NA	NA	5.2	
Other Wet Process	0.9	0.7	NS	2.2	NA	
Total	10.1	20.2	43.7	48.0	51.5	
Etec Systems						32
Direct Write	10.5	0	8.0	0	2.0	
Maskmaking	14.0	10.5	28.8	34.6	48.7	
Total	24.5	10.5	36.8	34.6	50.7	
Semitool and Semitherm						33
Automated Wet Stations	0	0	0	0	1.9	
Spray Processors	NA	NA	NA	NA	27.2	
Vapor Phase Clean	NS	NS	0	0	1.0	
Other Clean Process	NA	NA	NA	NA	10.3	
Other Wet Process	11.5	12.1	NS	15.0	NA	
Diffusion	4.0	3.0	0.9	4.9	5.0	
LPCVD	1.5	1.5	0.5	2.5	3.2	
Total	17.0	16.6	1.4	22.4	48.6	
IPEC/Westech						34
Other Clean Process	NA	NA	NA	NA	3.3	
Other Wet Process	0	0.4	2.4	4.0	NA	
Chemical Mechanical Polishing	NS	8.0	14.0	30.6	39.7	
Total	0	8.4	16.4	34.6	43	
Verteq						35
Automated Wet Stations	1.7	2.3	1.0	0.8	15.2	
Other Clean Process	NA	NA	NA	NA	27.0	
Other Wet Process	11.8	13.2	NS	19.1	NA	
Total	13.5	15.5	1.0	19.9	42.2	

(Continued)

Table 5-3 (Continued)
Top 40 Semiconductor Wafer Fab Equipment Companies Ranked by 1994 Worldwide Sales with Equipment Segment Detail
(End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Leica						36
Direct Write	10.8	5.6	5.9	5.4	8.0	
Maskmaking	2.5	4.5	5.7	5.0	2.9	
Critical Dimension	7.5	1.8	0.8	0.9	0	
Thin Film Measurement	NS	1.8	1.9	1.9	1.4	
Patterned Wafer Inspection and Review	6.8	4.9	6.0	9.7	28.7	
Total	27.6	18.6	20.3	22.9	41.0	
Nissin Electric						37
Ion Implantation	46.7	42.2	19.4	26.4	35.9	
Other Deposition	0	1.7	0	1.4	2.5	
Total	46.7	43.9	19.4	27.8	38.4	
Kaijo Denki						38
Automated Wet Stations	30.9	29.9	17.1	19.1	38.2	
Other Clean Process	NA	NA	NA	NA	0	
Other Wet Process	6.2	3.2	NS	0.4	NA	
Total	37.1	33.1	17.1	19.5	38.2	
AG Associates						39
Rapid Thermal Processing	14.6	24.4	13.5	21.7	36.4	
Plasma Systems						40
Dry Strip	24.9	21.2	16.1	27.1	32.0	
Low Density Etch	1.7	2.0	0.2	1.8	3.9	
Total	26.6	23.2	16.3	28.9	35.9	

NA = Not applicable

NS = Not surveyed. In Dataquest's 1992 Market Statistics program for wafer fabrication equipment, company activities in the categories of Contact/Proximity, Other Wet Process Equipment (Manual Wet Benches, Rinser/Dryers, Acid Processors, and Megasonics), and Other Deposition Equipment (Evaporation, MOCVD, and MBE) were not surveyed. Market coverage for Chemical Mechanical Polishing (CMP) and Thin Film Measurement started in 1991.

Source: Dataquest (June 1995)

Table 5-4
Semiconductor Wafer Fab Equipment Companies (Other than Top 40) by 1994 Sales Rank and Company Name (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
World Fab Equipment Market	5,866.6	6,014.0	5,088.7	6,876.1	10,754.8	
MC Electronics						41
Dry Strip	0	0	14.9	19.1	29.4	
Fusion Semiconductor Systems						42
Dry Strip	1.5	1.9	3.6	6.2	12.9	
Other Equipment	0	0	0	12.0	13.9	
Total	1.5	1.9	3.6	18.2	26.8	
Opal						43
Critical Dimension	2.4	2.4	9.4	14.7	26.8	
Shibaura Engineering Works						44
Low Density Etch	0	26.9	14.8	36.3	24.6	
Sputter	0	2.6	4.4	0	0	
Total	0	29.5	19.2	36.3	24.6	
Sumitomo Metals						45
Dry Strip	0	2.1	4.5	1.7	2.2	
High Density Etch	15.7	15.4	13.2	20.1	22.2	
ECR CVD	5.4	2.7	0	5.2	0	
Total	21.1	20.2	17.7	27.0	24.4	
Semiconductor Systems (Postmanagement Buyout)						46
Photoresist Processing	0	17.2	20.9	21.9	24.0	
JEOL						47
Direct Write	35.4	26.8	8.7	7.2	7.8	
Maskmaking	10.4	11.1	11.1	0	9.2	
Patterned Wafer Inspection and Review	0	1.7	0.6	1.4	2.4	
Critical Dimension	0	0	1.4	0.7	3.9	
Total	45.8	39.6	21.8	9.3	23.3	
Inspex						48
Patterned Wafer Inspection and Review	12.8	13.1	16.1	18.8	22.1	

(Continued)

Table 5-4 (Continued)
Semiconductor Wafer Fab Equipment Companies (Other than Top 40) by 1994 Sales Rank and Company Name (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Rudolph Research						49
Thin Film Measurement	NS	5.4	7.8	10.4	20.6	
Koyo Lindberg						50
APCVD	0.8	0.6	0	0.5	0	
LPCVD	3.1	1.9	2.1	2.1	2.7	
Diffusion	12.1	12.6	17.4	9.9	16.8	
Rapid Thermal Processing	0.7	0.3	0.5	1.4	0.7	
Total	16.7	15.4	20.0	13.9	20.2	
Convac						51
Resist Processing Equipment	15.4	15.0	16.6	17.6	19.7	
AST Electronic GMBH						52
Rapid Thermal Processing	3.4	4.1	4.7	9.3	18.7	
Mattson Technologies						53
Dry Strip	0	1.5	1.8	3.2	17.7	
Matrix Integrated Systems						54
Dry Strip	9.0	7.5	7.0	9.0	12.7	
Low Density Etch	0	2.3	1.5	2.9	4.7	
Total	9.0	9.8	8.5	11.9	17.4	
OnTrack Systems						55
Other Clean Process	NA	NA	NA	NA	15.3	
Other Wet Process	0	0	0	4.5	NA	
Total	0	0	0	4.5	15.3	
Toho Kasei						56
Automated Wet Stations	8.0	5.2	10.3	12.6	12.6	
Other Clean Process	NA	NA	NA	NA	2.5	
Other Wet Process	2.9	1.9	1.0	4.8	NA	
Total	10.9	7.1	11.3	17.4	15.1	
Holon						57
Critical Dimension	8.9	8.0	5.0	6.3	14.2	

(Continued)

Table 5-4 (Continued)
Semiconductor Wafer Fab Equipment Companies (Other than Top 40) by 1994 Sales Rank and Company Name (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Maruwa						58
Automated Wet Stations	5.9	8.1	2.0	2.7	5.0	
Other Clean Process	NA	NA	NA	NA	8.3	
Other Wet Process	6.4	6.9	4.3	6.7	NA	
Total	12.3	15.0	6.3	9.4	13.3	
Therma-Wave						59
Thin Film Measurement	NS	0.3	1.9	3.9	13.3	
Tazmo						60
Resist Processing Equipment	17.5	15.2	10.0	18.0	12.9	
Optical Specialties Inc.						61
Critical Dimension	1.9	5.7	6.4	6.4	10.0	
Patterned Wafer Inspection and Review	0.3	0.1	4.4	3.7	2.3	
Total	2.2	5.8	10.8	10.1	12.3	
Biorad						62
Critical Dimension	13.1	10.5	2.4	6.4	12.2	
CFM Technology						63
Automated Wet Stations	2.1	4.8	5.9	12.3	12.0	
Other Clean Process	NA	NA	NA	NA	0	
Other Wet Process	0	0	NS	NS	NA	
Total	2.1	4.8	5.9	12.3	12.0	
Tokyo Ohka Kogyo						64
Dry Strip	18.7	15.7	8.9	3.8	5.9	
Low Density Etch	16.6	15.3	5.5	4.7	6.0	
Total	35.3	31.0	14.4	8.5	11.9	
Steag Microtech (formerly Pokorny)						65
Automated Wet Stations	NA	NA	NA	NA	11.7	
Yuasa						66
Resist Processing Equipment	7.3	5.9	2.4	8.1	11.3	

(Continued)

Table 5-4 (Continued)
Semiconductor Wafer Fab Equipment Companies (Other than Top 40) by 1994 Sales Rank and Company Name (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Moore Epitaxial Inc.						67
Silicon Epitaxy	3.0	3.3	4.5	5.8	10.0	
Plasma & Materials Technologies						68
High Density Etch	0	0	0	4.7	9.9	
Total PECVD	0	0	0	1.5	0	
Total	0	0	0	6.2	9.9	
Toshiba						69
Maskmaking	0	0	0	0	2.0	
APCVD	3.2	3.2	2.1	1.2	0.4	
Silicon Epitaxy	4.5	12.5	9.5	4.5	7.2	
Total	7.7	15.7	11.6	5.7	9.6	
Nidek						70
Patterned Wafer Inspection and Review	6.7	7.1	5.1	4.6	9.5	
Toyoko Kagaku						71
Automated Wet Stations	3.8	0.9	0	0	3.5	
Other Clean Process	NA	NA	NA	NA	1.9	
Other Wet Process	1.3	0	0.8	1.0	NA	
LPCVD	4.8	5.0	1.3	1.2	3.9	
Total	9.9	5.9	2.1	2.2	9.3	
Shimada						72
Automated Wet Stations	16.3	13.4	6.3	3.6	7.1	
Other Clean Process	NA	NA	NA	NA	2.1	
Other Wet Process	5.8	8.9	2.4	1.1	NA	
Total	22.1	22.3	8.7	4.7	9.2	
Jenoptik						73
Direct Write	0	0	0	3.2	3.3	
Maskmaking	0	0	0	4.3	5.0	
Critical Dimension	0	0	0	0	0.7	
Total	0	0	0	7.5	9.0	

(Continued)

Table 5-4 (Continued)
Semiconductor Wafer Fab Equipment Companies (Other than Top 40) by 1994 Sales Rank and Company Name (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
ETS Company Inc.						74
Automated Wet Stations	7.6	10.4	10.0	8.3	6.9	
Other Clean Process	NA	NA	NA	NA	2.0	
Other Wet Process	2.1	0.5	0	1.9	NA	
Other Deposition	0	0	0	2.5	0	
Horizontal LPCVD	0	0	0	0.2	0	
Horizontal Diffusion	0	0	0.1	0.6	0	
Total	9.7	10.9	10.1	13.5	8.9	
Concept Systems Design						75
Silicon Epitaxy	0	0.4	1.6	3.2	8.5	
Nanometrics						76
Critical Dimension	2.3	1.8	2.1	1.8	0.9	
Thin Film Measurement	NS	10.5	8.2	10.4	7.5	
Total	2.3	12.3	10.3	12.2	8.4	
Samco						77
Dry Strip	0.9	1.1	0.9	0.5	0.5	
Low Density Etch	2.8	3.8	4.7	1.9	3.1	
PECVD	2.3	4.3	5.4	3.1	2.8	
Other Deposition	0.8	0.9	NS	NS	NS	
Rapid Thermal Processing	0	0	0.9	0.9	1.5	
Total	6.8	10.1	11.9	6.4	7.9	
Shinko Electric						78
LPCVD	0	6.2	1.9	2.3	2.5	
Diffusion	0	7.4	3.6	4.0	5.4	
Total	0	13.6	5.5	6.3	7.9	
CVC Products						79
Sputtering	7.5	7.0	6.0	6.9	7.7	
Other Deposition	2.7	2.7	NS	NS	NS	
Total	10.2	9.7	6.0	6.9	7.7	
Cybeq						80
Chemical Mechanical Polishing	NS	0	2.5	4.5	7.5	

(Continued)

Table 5-4 (Continued)
Semiconductor Wafer Fab Equipment Companies (Other than Top 40) by 1994 Sales Rank and Company Name (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Strasbaugh						81
Chemical Mechanical Polishing	NS	2.6	2.9	5.7	7.2	
Sputtered Films						82
Sputtering	1.0	2.3	2.7	5.9	7.0	
Dan Science Company Ltd.						83
Automated Wet Stations	12.7	14.2	5.0	4.1	4.8	
Other Clean Process	NA	NA	NA	NA	2.1	
Other Wet Process	5.5	4.9	0	4.8	NA	
Total	18.2	19.1	5.0	8.9	6.9	
IVS Inc.						84
Critical Dimension	8.0	7.6	2.3	5.4	6.3	
Sapi Equipements						85
Automated Wet Stations	3.0	2.0	2.0	1.5	1.5	
Other Clean Process	NA	NA	NA	NA	3.7	
Other Wet Process	1.8	1.5	NS	1.0	NA	
Total	4.8	3.5	2.0	2.5	5.2	
LPE						86
Silicon Epitaxy	5.5	5.0	3.1	4.0	5.0	
Toray Instruments						87
Patterned Wafer Inspection and Review	0	0	2.3	1.6	4.9	
Ultrapointe						88
Patterned Wafer Inspection and Review	0	0	0	0.9	4.9	
Ebara Corporation						89
Chemical Mechanical Polishing	NS	0	0	0	4.7	
Topcon						90
Critical Dimension	0	2.1	4.3	1.4	4.7	
Patterned Wafer Inspection and Review	0	0	0.6	0.7	0	
Other Process Control	0	6.5	4.0	2.2	0	
Total	0	8.6	8.9	4.3	4.7	

(Continued)

Table 5-4 (Continued)
Semiconductor Wafer Fab Equipment Companies (Other than Top 40) by 1994 Sales Rank and Company Name (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Enya						91
Automated Wet Stations	7.0	10.7	3.6	1.3	2.4	
Other Clean Process	NA	NA	NA	NA	2.0	
Other Wet Process	4.7	3.1	0.9	2.3	NA	
LPCVD	3.5	0	0	0	0	
PECVD	3.8	1.6	0.8	0	0	
Total	19.0	15.4	5.3	3.6	4.4	
Musashi						92
Automated Wet Stations	5.8	4.1	1.6	2.3	2.6	
Other Clean Process	NA	NA	NA	NA	1.5	
Other Wet Process	0.9	1.4	0.7	1.1	NA	
Total	6.7	5.5	2.3	3.4	4.1	
Denton Vacuum						93
Sputtering	1.5	1.8	1.0	3.0	4.0	
Other Deposition	3.0	3.2	NS	NS	NS	
Total	4.5	5.0	1.0	3.0	4.0	
Amaya						94
APCVD	16.0	12.3	6.3	5.4	3.9	
Kuwano Electric						95
Automated Wet Stations	9.6	7.1	1.6	1.9	3.9	
Other Clean Process	NA	NA	NA	NA	0	
Other Wet Process	0	0	NS	NS	NA	
Total	9.6	7.1	1.6	1.9	3.9	
Speedfam						96
Chemical Mechanical Polishing	NS	0	0	2.0	3.8	
Shinko Seiki						97
Dry Strip	0	1.1	0.4	1.8	1.2	
Sputter	0	0.4	1.4	0.9	2.5	
Total	0	1.5	1.8	2.7	3.7	

(Continued)

Table 5-4 (Continued)
Semiconductor Wafer Fab Equipment Companies (Other than Top 40) by 1994 Sales Rank and Company Name (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Tokyo Aircraft Instruments						98
Critical Dimension	3.7	3.3	2.8	2.0	3.7	
Japan Production Engineering						99
PECVD	8.0	5.6	3.2	2.2	3.1	
Orbot						100
Patterned Wafer Inspection and Review	0	0	0	0	2.9	
Kurt J. Lesker						101
Sputtering	1.0	1.0	0.8	2.4	2.7	
Other Deposition	0.6	0.8	NS	NS	NS	
Total	1.6	1.8	0.8	2.4	2.7	
High Temperature Engineering						102
RTP	0.3	0.8	1.0	1.2	2.4	
Matsushita Electric						103
Low Density Etch	0	0	3.1	0	2.3	
SCI Manufacturing						104
Automated Wet Stations	0.4	4.8	5.0	4.5	2.3	
Other Clean Process	NA	NA	NA	NA	0	
Other Wet Process	0	0	NS	NS	NA	
Total	0.4	4.8	5.0	4.5	2.3	
Jipelec						105
RTP	0.7	1.0	1.3	1.5	1.8	
CHA Industries						106
Sputtering	0.4	0.7	0.2	0.2	1.7	
Other Deposition	4.0	3.7	NS	NS	NS	
Total	4.4	4.4	0.2	0.2	1.7	
Carl Zeiss						107
Patterned Wafer Inspection and Review	1.4	1.4	1.0	1.2	1.2	

(Continued)

Table 5-4 (Continued)
Semiconductor Wafer Fab Equipment Companies (Other than Top 40) by 1994 Sales Rank and Company Name (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Lasertec Corporation						108
Patterned Wafer Inspection and Review	0	0	0	0.5	1.2	
Pressi						109
Chemical Mechanical Polishing	NS	0.2	0.3	0.5	1.2	
Advanced Crystal Sciences Inc.						110
LPCVD	0	0	0.7	1.0	1.1	
Diffusion	0	0	0	0.1	0	
Total	0	0	0.7	1.1	1.1	
ATE Thermal						111
RTP	0	0.7	0.9	1.1	1.1	
Process Technology Ltd.						112
LPCVD	3.0	1.4	1.1	1.5	0.8	
Fujikoshi						113
Chemical Mechanical Polishing	NS	0	0	0.3	0.7	
Tystar						114
LPCVD	0.4	0.3	0.6	0.6	0.4	
Diffusion	0.5	0.5	0.2	0.2	0.2	
Total	0.9	0.8	0.8	0.8	0.6	
ABT Corporation						-
Critical Dimension	5.2	0	0	0	0	
Advanced Film Technology Inc.						-
Sputter	0.7	0.8	0	0	0	
Advantage Production Technology						-
Other Wet Process	0	3.4	NS	NS	NA	
Aixtron						-
Other Deposition	13.9	15.0	NS	NS	NS	

(Continued)

Table 5-4 (Continued)
Semiconductor Wafer Fab Equipment Companies (Other than Top 40) by 1994 Sales Rank and Company Name (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Alameda Instruments						-
Other Wet Process	1.2	1.6	NS	NS	NA	
Amray						-
Critical Dimension	1.7	3.4	3.0	1.5	0	
Angstrom Measurements						-
Critical Dimension	0	2.2	0	0	0	
Ateq						-
Maskmaking	14.0	15.0	0	0	0	
Athens						-
Other Wet Process	4.2	1.2	NS	NS	NA	
Balzers						-
Sputtering	7.0	0	0	0	0	
Other Deposition	6.5	0	NS	NS	NS	
Total	13.5	0	0	0	0	
BCT Spectrum						-
LPCVD	0	2.0	0	0	0	
Branson/IPC						-
Dry Strip	14.5	0	0	0	0	
Low Density Etch	3.5	0	0	0	0	
Total	18.0	0	0	0	0	
BTU International						-
LPCVD	12.2	10.5	0	0	0	
Diffusion	24.0	19.0	0	0	0	
Total	36.2	29.5	0	0	0	
BTU/Ulvac						-
LPCVD	1.6	0	0	0	0	

(Continued)

Table 5-4 (Continued)
Semiconductor Wafer Fab Equipment Companies (Other than Top 40) by 1994 Sales Rank and Company Name (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Centrotherm						-
Diffusion	8.4	6.7	3.3	3.5	0	
LPCVD	4.8	3.1	1.6	1.6	0	
Total	13.2	9.8	4.9	5.1	0	
Chlorine Engineering						-
Dry Strip	2.7	0	0	0	0	
CPA (Postmanagement Buyout)						-
Sputter	1.0	2.0	1.0	0	0	
CVD Equipment						-
Other Deposition	0.7	0.7	0	0	0	
CVT						-
Other Deposition	2.2	1.0	NS	NS	NS	
Daido Sanso						-
Other Deposition	0	1.8	NS	NS	NS	
Dalton Corporation						-
Automated Wet Stations	1.7	1.2	0	0	0	
Other Wet Process	0.9	0.7	NS	NS	NA	
Total	2.6	1.9	0	0	0	
Denko						-
LPCVD	3.8	0	0	0	0	
Diffusion	6.9	0	0	0	0	
Total	10.7	0	0	0	0	
Dexon						-
Automated Wet Stations	0.5	0	0	0	0	
Other Wet Process	0.5	0	NS	NS	NA	
Total	1.0	0	0	0	0	
Disco						-
LPCVD	0	2.7	0.9	0	0	
Diffusion	5.8	10.0	5.4	2.2	0	
Total	5.8	12.7	6.3	2.2	0	

(Continued)

Table 5-4 (Continued)
Semiconductor Wafer Fab Equipment Companies (Other than Top 40) by 1994 Sales Rank and Company Name (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Drytek						-
Dry Strip	0	0	0	0	0	
Low Density Etch	22.0	25.0	17.1	4.5	0	
Total	22.0	25.0	17.1	4.5	0	
Eiko						-
Other Deposition	2.6	2.2	NS	NS	NS	
Elionix						-
High Density Etch	1.2	0.7	0.4	0	0	
Emcore						-
Other Deposition	12.6	12.2	NS	NS	NS	
Fuji Electric						-
Automated Wet Stations	2.0	1.6	1.2	0	0	
Other Wet Process	0	0	NS	NS	NA	
ECR CVD	0	0	4.0	2.2	0	
Total	2.0	1.6	5.2	2.2	0	
GCA						-
Steppers	78.2	46.8	33.5	0	0	
General Signal Thinfilm						-
Diffusion	9.0	3.0	0	0	0	
LPCVD	7.0	3.0	0	0	0	
APCVD	1.3	0.5	0	0	0	
Sputtering	0	0	0	0	0	
Total	17.3	6.5	0	0	0	
Hampshire Instruments						-
X-Ray	0	2.4	0	0	0	
Insystems						-
Patterned Wafer Inspection and Review	16.8	13.0	0	0	0	

(Continued)

Table 5-4 (Continued)
Semiconductor Wafer Fab Equipment Companies (Other than Top 40) by 1994 Sales Rank and Company Name (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Ion Tech						-
Sputter	0.1	0.2	0.1	0	0	
Innotec						-
Sputtering	0.8	0.7	0.4	0	0	
Other Deposition	0.4	0.5	NS	NS	NS	
Total	1.2	1.2	0.4	0	0	
Intevac						-
Other Deposition	0	5.2	NS	NS	NS	
ISA Riber						-
Other Deposition	20.3	14.0	NS	NS	NS	
Japan Storage Battery						-
Dry Strip	0	0	0.2	0.2	0	
Karl Suss						-
Contact Proximity	13.5	12.9	NS	NS	NS	
X-Ray	1.6	1.8	5.0	2.0	0	
Total	15.1	14.7	5.0	2.0	0	
Kyoritsu						-
Other Wet Process	3.1	0	NS	NS	NA	
Leybold-Heraeus						-
Sputtering	7.8	4.4	0	0	0	
Other Deposition	1.5	2.0	NS	NS	NS	
Total	9.3	6.4	0	0	0	
LFE						-
Dry Strip	1.4	1.5	0	0	0	
Machine Technology Inc.						-
Resist Processing Equipment	21.0	26.6	17.2	13.2	0	
Dry Strip	0.2	0	0	0	0	
Total	21.2	26.6	17.2	13.2	0	
Metrologix						-
Critical Dimension	0	0	2.2	4.4	0	

(Continued)

Table 5-4 (Continued)
Semiconductor Wafer Fab Equipment Companies (Other than Top 40) by 1994 Sales Rank and Company Name (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
m.FSI						-
Dry Strip	0	1.7	0.9	0	0	
Other Wet Process	0	0	4.2	11.7	NA	
Total	0	1.7	5.1	11.7	0	
Micro-Controle						-
Critical Dimension	4.4	0	0	0	0	
Patterned Wafer Inspection and Review	5.0	0	0	0	0	
Total	9.4	0	0	0	0	
MR Semicon						-
Other Deposition	3.0	4.6	NS	NS	NS	
Nano-Master						-
Critical Dimension	0	6.0	7.1	0	0	
Patterned Wafer Inspection and Review	0	5.4	5.4	0	0	
Total	0	11.4	12.5	0	0	
Nanosil						-
RTP	0.5	0.3	0	0	0	
Nippon EMC						-
Other Deposition	1.7	2.2	NS	NS	NS	
Nippon Sanso						-
Other Deposition	5.6	6.9	NS	NS	NS	
Oxford Plasma Technology						-
High Density Etch	2.4	2.2	1.4	1.0	0	
Low Density Etch	3.1	4.1	2.4	4.6	0	
ECR CVD	2.5	1.5	0.8	1.1	0	
PECVD	0	0	0	2.4	0	
Total	8.0	7.8	4.6	9.1	0	
Pacific Western						-
PECVD	2.5	1.0	1.0	1.2	0	
Diffusion	0.6	0.4	0.6	1.5	0	
Total	3.1	1.4	1.6	2.7	0	

(Continued)

Table 5-4 (Continued)
Semiconductor Wafer Fab Equipment Companies (Other than Top 40) by 1994 Sales Rank and Company Name (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Peak Systems						-
Rapid Thermal Processing	8.4	8.6	10.1	3.5	0	
Plasma-Therm						-
Low Density Etch	18.0	13.8	6.5	1.0	0	
PECVD	3.0	1.2	0.8	0	0	
Total	21.0	15.0	7.3	1.0	0	
Pokorny						-
Automated Wet Stations	6.2	6.6	5.2	14.0	NA	
Other Wet Process	1.2	1.2	NS	NS	NA	
Total	7.4	7.8	5.2	14.0	NA	
Poly-Flow Engineering						-
Other Wet Process	0.5	0.2	NS	0.3	NA	
Process Products						-
RTP	1.2	1.5	0	0	0	
Pure Aire Corporation						-
Automated Wet Stations	1.1	1.2	1.0	0	0	
Other Wet Process	0.2	0.2	NS	NS	NA	
Total	1.3	1.4	1.0	0	0	
Ramco						-
Dry Strip	16.0	10.3	14.9	0	0	
Rapro						-
Silicon Epitaxy	0.9	0	0	0	0	
Ryokosha						-
Critical Dimension	1.0	0.7	0.3	0.3	0	
S&K Products International						-
Automated Wet Stations	3.0	0	0	0	0	
Other Wet Process	5.0	8.2	NS	9.9	NA	
Total	8.0	8.2	0	9.9	0	

(Continued)

Table 5-4 (Continued)
Semiconductor Wafer Fab Equipment Companies (Other than Top 40) by 1994 Sales Rank and Company Name (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Semiconductor Systems Inc.						-
Resist Processing Equipment	14.0	0	0	0	0	
Semifab						-
Automated Wet Stations	3.5	3.0	0	0	0	
Other Wet Process	3.0	3.5	NS	6.4	NA	
Total	6.5	6.5	0	6.4	0	
SiScan Systems						-
Critical Dimension	2.0	2.2	0.9	0.2	0	
Sitesa						-
Silicon Epitaxy	0	0	0	0	0	
RTP	1.0	0	0	0	0	
Total	1.0	0	0	0	0	
Solitec						-
Resist Processing Equipment	5.8	4.9	2.9	1.1	0	
LPCVD	5.0	0	0	0	0	
Diffusion	0	0	0	0	0	
Total	10.8	4.9	2.9	1.1	0	
Spectrum CVD						-
LPCVD	3.2	0	0	0	0	
Spire						-
Other Deposition	1.7	1.0	NS	NS	NS	
Temescal						-
Sputtering	0.1	0	0	0	0	
Other Deposition	13.0	10.8	NS	NS	NS	
Total	13.1	10.8	0	0	0	
Tempress (Postmanagement Buyout)						-
LPCVD	0	0	1.4	1.9	0	
Diffusion	0	0	1.0	1.0	0	
Total	0	0	2.4	2.9	0	

(Continued)

Table 5-4 (Continued)
Semiconductor Wafer Fab Equipment Companies (Other than Top 40) by 1994 Sales Rank and Company Name (End-User Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1994 Rank
Tokuda						-
Low Density Etch	24.1	0	0	0	0	
Sputtering	5.8	0	0	0	0	
Total	29.9	0	0	0	0	
Ulvac/BTU						-
LPCVD	6.2	0	0	0	0	
Diffusion	16.5	0	0	0	0	
Total	22.7	0	0	0	0	
Universal Plastics						-
Automated Wet Stations	4.5	5.5	6.0	8.0	0	
Other Wet Process	3.5	3.6	NS	4.7	NA	
Total	8.0	9.1	6.0	12.7	0	
VG Instruments						-
Other Deposition	17.4	15.0	NS	NS	NS	
Wellman Furnaces						-
LPCVD	0	0	0	0	0	
Diffusion	0.2	0.5	0	0	0	
Total	0.2	0.5	0	0	0	
Yamato						-
LPCVD	0.7	0.3	0	0	0	
APCVD	0.2	0	0	0	0	
Other Deposition	3.3	7.0	NS	NS	NS	
Diffusion	0.7	0.8	0.3	0	0	
Total	4.9	8.1	0.3	0	0	

NA = Not applicable
NS = Not surveyed. In Dataquest's 1992 Market Statistics program for wafer fabrication equipment, company activities in the categories of Contact/Proximity, Other Wet Process Equipment (Manual Wet Benches, Rinser/Dryers, Acid Processors, and Megasonics), and Other Deposition Equipment (Evaporation, MOCVD, and MBE) were not surveyed. Market coverage for Chemical Mechanical Polishing (CMP) and Thin Film Measurement started in 1991.
Note: For this table, Other Wet Process includes Post-CMP and Vapor Phase Clean Equipment. Additionally, Other Clean Process equipment includes Spray Processors, Vapor Phase Clean and Post-CMP Equipment as well as Manual Wet Benches, Dryers and Megasonics.
Source: Dataquest (June 1995)

Appendix A
Semiconductor Equipment Product Category Hierarchy

The semiconductor equipment product category hierarchy in Table A-1 begins with total semiconductor equipment and indents each subcategory in the left-hand column according to its position in the hierarchy. At each level in the hierarchy, all subcategories that contribute to this level are indicated as a subcategory summation in the right-hand column. Any level in the hierarchy that does not depend on any subcategories is marked as "Data Point."

Table A-1
Semiconductor Equipment Product Category Hierarchy

Total Wafer Fab Equipment	Total Lithography + Resist Processing Equipment + Total Clean Process + Dry Strip + Total Dry Etch + Chemical Mechanical Polishing + Total Deposition + Diffusion + Rapid Thermal Processing + Total Ion Implantation + Total Process Control + Other Equipment
Patterning	
Total Lithography	Contact/Proximity1 + Projection Aligners + Total -Steppers + Total Direct-Write + Total Maskmaking + X-Ray
Contact/Proximity[1]	Data Point
Projection Aligners	Data Point
Steppers	Data Point
Total Direct-Write	Direct-Write E-Beam + Direct-Write Optical
Direct-Write E-Beam	Data Point
Direct Write Optical	Data Point
Total Maskmaking	Maskmaking E-Beam + Maskmaking Optical
Maskmaking E-Beam	Data Point
Maskmaking Optical	Data Point
X-Ray	Data Point
Resist Processing Equipment (Track)	Data Point
Etching/Cleaning	
Total Clean Process (Formerly Total Wet Process)	Auto Wet (Immersion) Stations + Spray Processors[2] + Vapor Phase Clean[3] + Post-CMP Clean[4] + Other Clean Process[2]
Auto Wet (Immersion) Stations	Data Point
Spray Processors[2]	Batch Spray Processor[2] + Single-Wafer Spray Processor[2]
Batch Spray Processor[2]	Data Point
Single-Wafer Spray Processor[2]	Data Point
Vapor Phase Clean[3]	Data Point
Post-CMP Clean[4]	Data Point
Other Clean Process[2]	Manual Wet Benches + Rinsers/Dryers + Megasonics + Scrubbers
Manual Wet Benches	Data Point
Rinser/Dryers	Data Point
Megasonics	Data Point

(Continued)

Table A-1 (Continued)
Semiconductor Equipment Product Category Hierarchy

Dry Strip	Data Point
Total Dry Etch	Low-Density Etch + High-Density Etch
Low-Density Etch	Data Point
High-Density Etch	Data Point
Chemical Mechanical Polishing[4]	Data Point
Deposition	
Total Deposition	Total CVD + Sputtering + Silicon Epitaxy + Other Deposition[1]
Total CVD	Tube CVD + Nontube CVD
Tube CVD	Horizontal LPCVD + Vertical LPCVD + Horizontal PECVD
Nontube CVD	LPCVD Reactors + PECVD Reactors + Atmospheric Pressure CVD/Subatmospheric Pressure CVD + High-Density Plasma CVD
Total LPCVD	LPCVD Reactors + Horizontal LPCVD + Vertical LPCVD
LPCVD Reactors	Data Point
Horizontal LPCVD	Data Point
Vertical LPCVD	Data Point
Total PECVD	PECVD Reactors + Horizontal PECVD Reactors + High-Density Plasma CVD
PECVD Reactors	Data Point
Horizontal PECVD Reactors	Data Point
High-Density Plasma CVD	Data Point
Atmospheric Pressure CVD/ Subatmospheric Pressure CVD	Data Point
Sputtering	Data Point
Silicon Epitaxy	Data Point
Other Deposition[1]	Molecular Beam Epitaxy[1] + Metalorganic CVD[1]+ Evaporation[1]
Molecular Beam Epitaxy[1]	Data Point
Metalorganic CVD[1]	Data Point
Evaporation[1]	Data Point
Modification	
Diffusion	Vertical Diffusion + Horizontal Diffusion
Vertical Diffusion	Data Point
Horizontal Diffusion	Data Point
Rapid Thermal Processing	Data Point
Total Ion Implantation	Medium-Current Implanter + High-Current Implanter + High-Voltage Implanter
Medium-Current Implanter	Data Point
High-Current Implanter	Data Point
High-Voltage Implanter	Data Point

(Continued)

Table A-1 (Continued)
Semiconductor Equipment Product Category Hierarchy

Verification	
Total Process Control	Total CD/Wafer Inspection + Other Process Control[1]
Total CD-Overlay/Wafer Inspection	Optical CD Metrology + CD SEM-Overlay + Patterned Wafer Inspection + Thin Film Measurement[4]
Optical CD Metrology	Data Point
CD SEM-Overlay	Data Point
Patterned Wafer Inspection	Data Point
Thin Film Measurement[4]	Data Point
Other Process Control[1]	Data Point
Other Categories	
Other Equipment[1]	Factory Automation[1] + Ion Milling[1] + Other[1]
Factory Automation[1]	Data Point
Ion Milling[1]	Data Point
Other[1]	Data Point

[1]Not surveyed since 1991.
[2]Starting from 1994
[3]Starting from 1992
[4]Starting from 1991
Source: Dataquest (June 1995)

Appendix B
Worldwide Geographic Region Definitions

North America

Includes Canada, Mexico, and the United States (50 states).

Japan

Japan is the only single-country region.

Europe

Western Europe

Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and rest of western Europe (Andorra, Cypress, Gibraltar, Iceland, Liechtenstein, Malta, Monaco, San Marino, Turkey, and Vatican City).

Eastern Europe

Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (including Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan).

Asia/Pacific

Includes Asia/Pacific's Newly Industrialized Economies (NIEs) and the Rest of Asia/Pacific regions. NIEs include Hong Kong, Singapore, Korea, and Taiwan. The Rest of Asia/Pacific region includes Australia, Bangladesh, Brunei, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.

Rest of World

Includes Africa, Caribbean, Central America, Middle East, Oceania, and South America.

Appendix C
Exchange Rate Definitions

When converting a company's local currency sales into U.S. dollars, or vice versa, it is important to use the 1994 exchange rates provided in Table C-1. These rates will prevent inconsistencies in the conversion of offshore sales between companies. These exchange rates will be used in the 1994 market share survey. Exchange rates for historical years are available on request.

Table C-1
Average 1994 Exchange Rates per U.S. Dollar

Country	1994 Rate	1993 Rate	U.S.$ Appreciation (%)
Austria (Schilling)	11.40	11.65	-2.07
Belgium (Franc)	33.36	34.67	-3.76
China (Renminbi)	8.54	5.76	48.28
Denmark (Krone)	6.35	6.49	-2.15
European Community	0.84	0.86	-1.62
Finland (Markka)	5.21	5.73	-9.17
France (Franc)	5.54	5.67	-2.38
Germany (Mark)	1.62	1.66	-2.13
Great Britain (Pound)	0.65	0.67	-1.97
Greece (Drachma)	242.06	229.33	5.55
Hong Kong (Dollar)	7.73	7.74	-0.10
India (Rupee)	31.15	30.84	1.00
Ireland (Punt)	0.67	0.68	-2.33
Italy (Lira)	1,609.34	1,577.85	2.00
Japan (Yen)	101.81	111.20	-8.44
Malaysia (Ringgit)	2.62	2.58	1.65
Netherlands (Guilder)	1.82	1.86	-2.22
Norway (Krone)	7.04	7.11	-0.86
Portugal (Escudo)	165.63	161.08	2.83
Singapore (Dollar)	1.53	1.62	-5.54
South Korea (Won)	802.84	799.52	0.42
Spain (Peseta)	133.48	127.87	4.38
Sweden (Kroner)	7.70	7.82	-1.60
Switzerland (Franc)	1.37	1.48	-7.72
Taiwan (Dollar)	26.45	26.16	1.13
Thailand (Baht)	25.36	25.31	0.19

Source: Dataquest (June 1995)

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Market Analysis

Semiconductor Equipment, Manufacturing, and Materials Worldwide

Market Analysis

The Move toward 300mm Wafers: The Issues Surrounding When and How—Money Will Talk

Abstract: *The semiconductor industry has recently "decided" on the next wafer size as 300mm. There have been many presentations made and seminars held on the technical issues, standards, and milestones needed to achieve 300mm reality. Equipment and material companies are only beginning to assess the costs of development, with some surprises both negative and positive. We at Dataquest, through our DQ Monday weekly publication, have been following the progress as events toward 300mm reality unfold. As usual, the industry is being aggressive in its desires, but perhaps underestimating the true scope of the costs. In this article we review the issues to be solved and the costs of development, and provide our perspective on the timing of "the 300mm era."*
By Clark J. Fuhs

In the Beginning ...

The semiconductor industry began facing the question of the next wafer size beyond 200mm as early as 1991, merely because it was a normal progression for the industry—time goes on, wafers get bigger. At that time the discussion was about whether to go to 250mm or 300mm. Because the industry was in the middle of recession then, which continued into 1992, the debate went on without definitive action or motivation.

Dataquest published a newsletter in April 1993 entitled "Is the 12-Inch Wafer Age Looming?" where we analyzed the relative cost advantages of moving to 250mm or 300mm, based on the apparent transition from 150mm to 200mm wafers then beginning for 0.5-micron capacity. As chip sizes increase to achieve more complex levels of circuit integration, the increase in wafer diameter offers great economic advantages by bringing a higher efficiency than the mere increase in surface area. At the same time, the

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increase in wafer size brings economic disadvantages such as higher equipment costs because of the increase in equipment size, and an increased risk related to process technology. Thus a decision to introduce larger wafers to a fab line needs to be made by weighing economic advantages—namely, the increase in effective chip numbers—against disadvantages such as the process risk.

In that article, we believed that the industry had to realize a cost per die advantage of at least 30 percent before the costs of an actual transition would be incurred. Our analysis at that time indicated that a move to 250mm wafers would simply not be able to bring that kind of cost advantage, but that 300mm potentially could.

Once the 250mm size was dismissed, the questions became: What about 400mm? Or 350mm? By late 1993, as the semiconductor industry recovered economically, debates became more intense about the next size. Further, leaders of the effort (and a source of funds for development) began to be sought ... but none could be found!

SEMI's Consortia Summit

A summit meeting of worldwide consortia, sponsored by SEMI in Geneva during April 1994, was the first real committed effort to bring focus on the implementation strategy for 300mm wafers. But the catalyst could have come a few months earlier.

At a Dataquest panel discussion at the January 1994 ISS Conference sponsored by SEMI, we were asked about the outlook for consumption of wafers larger than 200mm over a four-year horizon. The response of "zero," which caused some debate, resulted from the observation that the funding for the development of equipment and materials, as well as the infrastructure to support consumption, was at a virtual standstill from ground zero. The size of the wafer was still a debate, no funds were committed, and an industry leader was unclear. At best, from ground zero, the first fab line would roll out these larger substrates in five to seven years with commercial volumes some three to four years behind that. IBM led the charge in the mid-1980s and footed the bill for helping solve the jump to 200mm wafers. IBM worked closely with equipment and material suppliers to develop the hardware and technology to gain effective yield on these larger wafers. Five years and billions of dollars later, wafers could effectively be made and process equipment could operate within specification.

Who would lead the charge toward 300mm wafers? Paul Catrucci (involved with the IBM effort for 200mm wafers) said that in his view only Intel could take on the enormous risks associated with this effort. Don Rose from Intel was in the audience, and stated that Intel, although it would be interested in participating in a development effort, would not be able to drive the effort alone. We pointed out that the semiconductor world is different today than it was when IBM began its effort toward 200mm in 1985, the primary issues being the global nature of the supplier and producer base. Dataquest went on record stating that nothing short of a global consortium action would be effective, perhaps including several governments. The first step would be "to get SEMATECH, JESSI, and MITI in one room together and begin talking."

SEMI figured out how to do what was then thought to be improbable. More than a dozen consortia from all major regions of the world participated in a two-day event in an effort to open dialogue on difficult and far-reaching issues in semiconductor manufacturing that would require cooperation on a worldwide scope in order to execute successfully. The key focus of this summit meeting turned out to be the next wafer size.

SEMATECH took the lead in the keynote address, and some closed-door sessions brought forth a game plan for the industry. The recommendation was to provide a platform to exchange information, taking the form of a committee with key representatives from semiconductor, equipment, and materials companies worldwide. The first step would be to develop and exchange detailed economic and technical analysis on the movement to 300mm, 350mm, or 400mm wafers. This committee was recommended to meet under a SEMI forum, with a formal meeting during SEMICON/West in July 1994.

Tactics on the development were not addressed specifically there, but it was hinted that funding would come directly from companies and not from any government or consortia. We believe this was proposed in order to speed up the development process. If governments were to get involved, the actual project work would probably be delayed two to three years.

Decisions Since the Geneva Summit

Meetings of the "steering committee" have now been held on essentially a quarterly basis, with fairly large media coverage following in each case, and the rumor mill has been very active. We stated in mid-1994 that a series of announcements and meetings will be held to solidify what could be a very complicated set of tactical issues. Any announcement or proposal should be taken with a grain of salt until a consensus plan emerges toward mid-1995 at the earliest.

The Next Size Is 300mm

In July 1994, associated with the SEMICON/West trade show, the industry basically decided the next wafer size would be 300mm. Semiconductor manufacturers were represented through affiliations with SEMATECH, SIAJ, and JESSI. Members of the supplier community, including equipment and silicon suppliers, also were in attendance.

The next step in the process was the creation of a task force to develop a set of SEMI standards for 300mm wafers. The target time frame would be to have draft standards by December and approved standards during 1995. That effort is ongoing.

Tactical Plan Milestones

Associated with SEMICON/Japan in December 1994, another meeting was held among semiconductor companies, equipment, and silicon suppliers to develop milestones and potential tactical plans for a 300mm development program.

Those present at this meeting committed to a pilot line capable of processing a 300mm wafer from start to finish, yielding ICs, that would come online in 1998 or 1999. No wafer nor equipment company expressed concern at meeting this milestone nor believed that the date could be beaten. This milestone was consistent with our timing outlook for 300mm wafers.

Why Should the Next Size Be 300mm?

We will not review the excruciating details of the debate here, but the bottom line is that the decision for the 300mm diameter rather than another size has more to do with feasibility for success and quickness to implement rather than any sure-fire economic situation.

SEMATECH presented an economic scenario in mid-1994 that mentioned that the cost per square inch ratio for 300mm and 400mm were so close that it would be more realistic to do the easier 300mm size first. Its model showed that an optimum cost savings per die was 350mm, but it was believed that the engineering challenges, particularly in the wafer manufacturing process, would introduce sufficiently more risk compared to 300mm relative to the incremental difference in cost between 300mm and 350mm. Thus the 300mm size was a compromise offering the optimum risk/reward ratio.

Is Cost per Die Really the Driving Reason for 300mm Wafers?

The (calculated) fact is that processing with 300mm wafers for 0.25-micron is potentially more cost-effective than at 200mm wafers. As noted earlier, this has been portrayed as the key reason the move to the next wafer size has attracted such interest. But is there another, more basic, reason for the move to 300mm?

There is an argument, not well documented to date but having merit, derived from the perspective of "constraints" in raw resource planning and that is driven by wafer throughput—the ability to plan sufficient materials, construction, and labor to support the higher growth rates of the semiconductor industry when compared to other industrial sectors of the world.

Think about it—if we stayed at the same wafer size too long, the growth of the industry would eventually drive raw wafer unit consumption to much higher growth rates than experienced today—driving the requirement for more cement and people. In an industry that is striving to attract the necessary talent, this becomes a realistic constraint. The semiconductor industry has grown at a 13.5 percent compound annual growth rate (CAGR) from 1989 to 1994, while wafer consumption has grown at a much lower 3.2 percent CAGR (measured in terms of wafer slices). The latter growth figure is one more consistent with general long-term industrial expansion in developed countries.

The average wafer size has increased by more than 25 percent over this period. Going to larger wafers enables the industry good growth through more die while placing a lower, more achievable growth requirement on the use of brick and mortar, labor, and equipment in terms of units. Although this could lead to lower die cost, other things such as yield ramps come into play, making the actual return difficult to calculate beyond theoretical models.

This "constraint-driven" need to move to larger wafers is one likely to come into play within two to three years after the turn of the decade, according to the argument, regardless of the reality of reduced cost per die.

Who Will Do This?

There have been rumors and rumblings that Samsung or Motorola would be building a 300mm fab to come online before the dates noted earlier. However, we believe these rumors to be statement of intent rather than firm commitment of hard dollars. We would agree that Samsung and Motorola, along with Intel, are among the most aggressive companies in the movement toward 300mm wafers, and we would also not be surprised if these companies are among the key drivers showing the least patience. But we continue to believe that no one company will bear the burden of building a 300mm fab alone—the costs are simply too great. We would expect a team of companies, perhaps two, to emerge over the next six to nine months as the tactical coordinators of this development effort.

We do believe that these three companies will be involved in fabs that will come online in 1998 to 1999 running 300mm wafers, with equipment shipping as early as 1997, but we have yet to hear anything definitive to date. In fact, we believe so strongly that something will happen that we have put a bit of speculation in our fab database. In that database there now is a planned Intel fab in Oregon for 0.25-micron production that includes an R&D center. This has been publicly announced to come online in 1998, but we have not seen any public statement about the wafer size at this site. We believe that Intel may make this facility part of the 300mm wafer effort. Even though our planned fab database denotes this particular fab tentatively as 300mm, nothing has been confirmed by Intel.

What about the Japanese? Based on the fact that the Japanese have lagged going to 200mm wafers, we believe they will lag even further for 300mm in general. More than half of the major manufacturers may actually delay the implementation of 300mm to 1Gb DRAMs, or at the very least shrink 256Mb DRAMs. Only a few companies, those with significant microprocessor and advanced logic semiconductor products, will be part of the leading-edge movement. We believe strongly that NEC will be there, but other possibilities include Hitachi, Toshiba, and Mitsubishi.

We do not expect any companies in Southeast Asia or Europe to be part of the initial leader group, because these regions have producers that are either mainstream or lagging-edge manufacturers, or have business models (such as foundry) that necessitate lower-risk strategies to manufacturing.

What Are the Real Costs?

Now let's talk money. We have heard several estimates about the cost to the industry for the development and implementation of 300mm wafers, including our own, that have been quoted in the press. There are debates about who should fund the effort, the timing of that funding, and the risks involved. Although we will not speculate here as to the specific players that will commit first nor how the funding will occur, we have stated that the costs are too great for one company to bear.

So what are the costs? Dataquest is on record that a $15 billion to $30 billion industry effort is required to convert and set up the infrastructure for commercial implementation of 300mm wafers. This is probably the highest figure among the estimates, and we should summarize how our number is derived.

First, the framework from which we are making this estimate needs to be clearly understood. Some key parts of that framework are:

- We are including all significant aspects of the cost of conversion, including costs of development and dedicated capital across the semiconductor producer, equipment supplier, and material supplier—from the beginning of the development to the transfer to commercial manufacturing. Capital spending to add or initiate commercial production capacity is not included.
- We are equating the 300mm era to match 0.25-micron technology and capacity requirements, and including 0.25-micron technology development as part of the cost. This is an inclusion that is an issue with other prognosticators because the "purist" would want to try to separate the costs into the component parts, but we would make the following points:
  - There will be no 300mm fabs at greater than 0.25-micron.
  - Because arguments have been made on the cost-effectiveness of 300mm wafers generally at 0.25-micron technology and that cost benefits at the turn of the century relative to 200mm wafers would be the most critical at this technology, any development program for 300mm should be expected to be qualified at 0.25-micron as a measure of success.
  - Any development consideration for 300mm that does not take into consideration 0.25-micron technology requirements will not be successful in the market—and a waste of money.

It is therefore meaningless to consider anything but the total cost.

- To consider the true development cost to the industry, one needs to include development costs by all suppliers expected to compete in every segment of the market, which will be larger than any one development project being sponsored.

Now let's review the various groups for development costs.

Material Supplier Development Costs

Our estimate for material suppliers will include primarily silicon wafer suppliers, photoresist suppliers, and sputtering target manufacturers. Wet chemical and gas suppliers are not expected to appreciably accrue significant development costs associated with a transition to 300mm wafers beyond their normal costs of development.

Stanley Myers, president of Siltec Silicon (Mitsubishi Materials), is on record at the ISS Conference in January 1995 with a development cost estimate of $250 million a year for four years, with a new fixed investment estimate of $700 million a year. We believe it will take a bit longer than that, say six years, given the nature of the recent 200mm ramp-up issues. Also, we consider his new fixed investment estimate a bit high with reference to development costs, because a large part of that investment will be in capacity once transfer to manufacturing occurs. Still, a fixed investment of $300 million to $500 million for the silicon industry is reasonable for prototype lines. Technical challenges of crystal growth (while meeting

0.25-micron dislocation and dopant specifications) and epitaxial growth were cited as development challenges.

Photoresist suppliers face the technical challenge of a larger substrate for which to cover material in a consistent manner. This issue is different from the flat panel display implementation because it will require the primary material to be a deep-UV photoresist. We estimate about $100 million cumulative investment by each of four to five suppliers. Target manufacturers' development costs are expected to be limited to prototype support of equipment manufacturers and to qualification programs.

Total cost for material suppliers at $2.4 billion to $2.8 billion ($1.8 billion to $2.0 billion silicon, $400 million to $500 million photoresist, and $200 million to $300 million target manufacturers). Adding a 20 percent contingency places the figure at $3.0 billion to $3.5 billion.

Equipment Supplier Development Costs

Equipment suppliers represent the largest development effort when considering gross dollars being spent. Each company will have to undergo a major equipment development effort (including design, prototype, process development, documentation, and transfer costs to manufacturing). This requires significant resources and capital costs for each model and classification of equipment across several suppliers. The most severe technical challenges are those surrounding higher temperature processes such as tube CVD and diffusion. Although development costs vary among the segments, we estimate that the average major equipment development program costs about $110 million to $125 million. There are 19 major segments, with anywhere from two to five suppliers that would effectively compete in each in order to have a healthy infrastructure. Doing the multiplication, we estimate a $6.5 billion to $8.5 billion total cost. We are refraining from putting a contingency on this figure because there will also be an efficiency created by common architectures across segments by the larger manufacturers.

For reference, the 19 equipment segments considered are: steppers, track, dry strip, auto wet stations, CMP, sputtering, metal etch, poly etch, dielectric etch, dedicated dielectric CVD, dedicated metal CVD, tube CVD (or equivalent replacement), epitaxial silicon deposition, diffusion, rapid thermal processing/annealing, medium-current implant, high-current implant, high-voltage implant, and wafer inspection/review.

Some will argue, quite rightly, that the development cost to develop a major piece of equipment is more on the order of $50 million, rather than the $110 million to $125 million noted. Dataquest performed a survey summarized in a recent report entitled "Productivity and R&D Demands for Equipment and Material Suppliers," dated February 24, 1994 (SEMM-WW-UW-9301). In this survey, equipment suppliers generally responded at the $50 million level for 0.25-micron technology (compared to $15 million to $20 million for 0.8-micron technology).

Two things should be noted for this $50 million figure, however. First, the move to 300mm wafers was not included in this number—and we would expect that to add 20 to 40 percent. Second, when we called and asked what was included in this number—the response was "initial development to achieve first shipment." Two large factors were excluded:

- Redesign after first shipment—There is rarely a first-shipment-class machine that could be called a true production tool. A redesign effort that makes the tool not only production worthy but also transfers in to manufacturing in such a way that it is easily manufacturable usually is required. This is typically a project on the order of 40 to 60 percent of the original project. Equipment companies typically will not plan that such a project is necessary, but invariably it is for 70 to 80 percent of the products.
- Sustaining engineering—Equipment companies, especially today, have a sustaining engineering group to support current products in the midst of transfer to full production. This normally is accounted for as an R&D expense. In this case, we are talking about the process/equipment engineers on-site with the second and third sites, among others (not the first), in order to work out the kinks for production transfer by the IC manufacturer. This can be a two- to three-year stage that can consume R&D dollars, in sometimes untrackable ways.

When these factors are included, the $50 million-per-project development cost clearly is low—and taking these factors into account, we have derived the $110 million to $125 million cost range per project, which leads to the comprehensive $6.5 billion to $8.5 billion cost estimate for equipment suppliers noted earlier.

We also understand that equipment companies may be somewhat less aggressive in the pursuit of the next wafer size this time around. Why? Well, in the migration to 200mm, the older 150mm systems were made obsolete fairly quickly. A company that wanted to build a 150mm fab basically had to buy 200mm equipment to run it—and pay extra for the effort. Semiconductor companies will not tolerate paying 300mm equipment prices to fill a 200mm fab six to eight years from now. This means that the return on investment by the equipment companies toward development of the 300mm tool must be made on the merits of the 300mm-specific market, and that is not expected to be very large relative to the market for at least 10 years.

The Cost of Integration

The cost of integrating the process, primarily borne by the group of semiconductor suppliers, is a more difficult number to estimate. We have heard estimates about IBM's experience with 200mm engineering and integration costs being as low as $2.5 billion and as high as $4 billion, including initial prototype purchases. Equipment companies usually built several prototypes to support development, so there is no double counting here. We believe development costs have at least doubled since IBM's effort started some 10 years ago and increased more for the capital prototypes, so we have penciled in a figure of $6 billion to $10 billion.

Rolling It Up—The Total Development Costs for 300mm

Adding these figures up, we arrive at the total cost of $15.5 billion to $22.0 billion. The higher figure was raised to take into consideration dedicated facilities for the integration effort, wafer-handling development projects by suppliers (inter- and intrabay transport systems, and cassette and cassette-handling issues), time toward standards development, and any back-end systems that would require special development projects, among others.

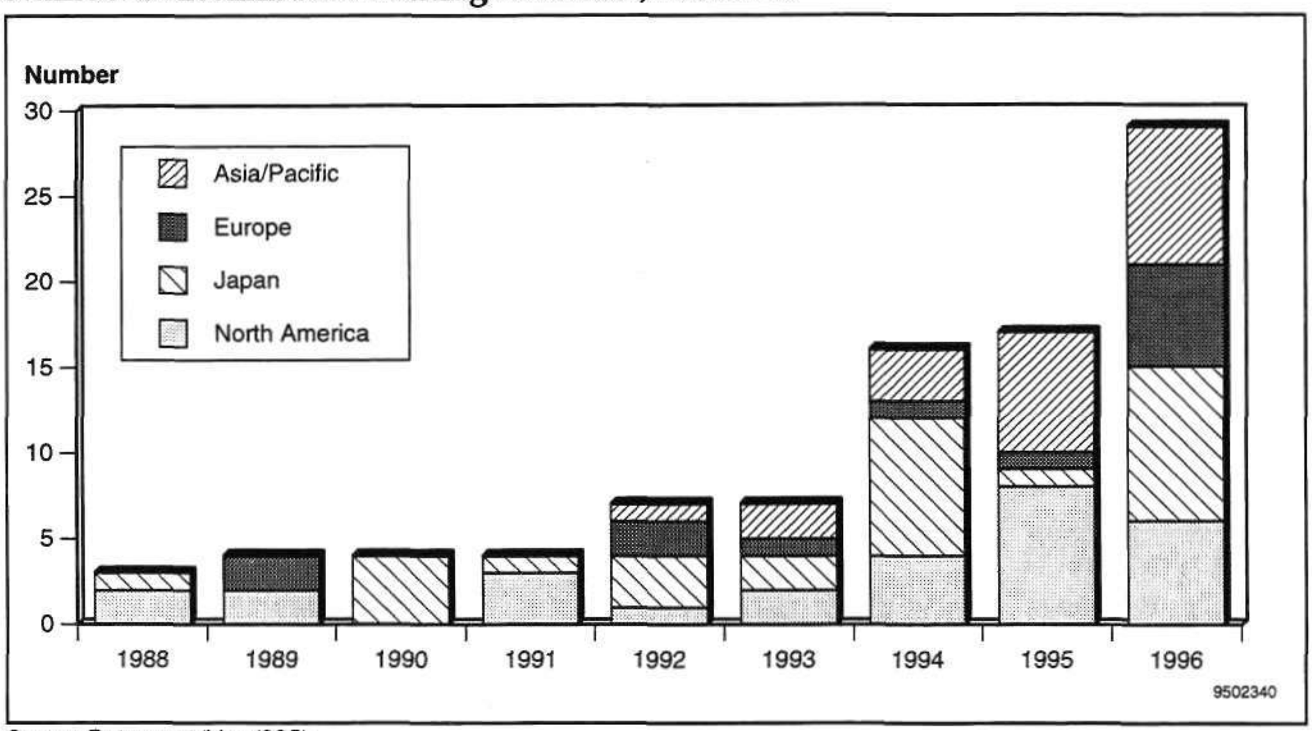
Given this analysis, Dataquest's cost estimate for development of a 300mm infrastructure for the semiconductor industry in the range of $15 billion to $30 billion seems reasonable.

Dataquest Perspective and Forecast

Now that the picture is becoming somewhat clearer, our challenge is to develop a forecast for consumption of 300mm wafers. The answer is still commercially zero before the year 2000.

The process to commercialize 200mm wafer processing, spearheaded by IBM, took some four years, from start of development to putting the first 200mm wafer through a commercially productive plant, and another four years for significant commitment to building 200mm fabs. Figure 1 shows the number of 200mm fabs started or planned from 1988 through 1996. As shown clearly, the "knee" in the curve started in 1993, with 1994 being the first year of true commercial consumption of 200mm wafers. Dataquest estimates that 6.4 million 200mm wafers were consumed in 1994, versus 1.8 million in 1993 and 1.2 million in 1992. In comparison, about 130 million wafers of all sizes were consumed in 1994.

Figure 1
Number of 200mm Fabs Starting Each Year, 1988-1996



Source: Dataquest (May 1995)

The 200mm effort was focused, within one company, and with dedicated funds. We will not speculate whether this effort will be more or less efficient through an organization of international groups/companies. But one thing is clear—there will be no plan or dedicated funds before mid-1995. Without these issues clearly identified, no substantive and coordinated work will start. The stated milestone of first silicon through a fab in 1998 to 1999 is aggressive, but within the realm of feasibility. Equipment would ship to this fab as early as 1997. We believe the first commercially productive plant will be started in the 2000 to 2002 time frame, with serious volume ramp-up in the years 2004 to 2005. This would be consistent with 0.25- or 0.18-micron technology being primarily produced on 300mm wafers, and an eight- to 10-year lag between initial committed funds and the knee in volume consumption.

This means that 200mm wafers represent a two-technology-generation wafer size, and fabs being built today may have longer lives than history would indicate. We also believe that not all companies will run 0.25-micron at 300mm, making 200mm a three-generation size. The companies that would fall into this category would be Southeast Asian foundries and DRAM manufacturers, primarily because these companies wish to have well-tested equipment sets and manufacturing processes to gain a cost advantage in the market, because they tend to lag technology by a half a generation or more. We also believe some Japanese companies will actually delay the implementation of 300mm as well, preferring to avoid the risk and costs.

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Market
Analysis

Semiconductor Equipment, Manufacturing, and
Materials Worldwide

Market Analysis

A Market Perspective on the SIA Lithography Road Map

Abstract: *This article will review the 1994 Semiconductor Industry Association (SIA) lithography road map. We offer a perspective on the market dynamics that will strongly influence the milestones along the road map, and on the evolution of this critical technology. Our goal is to share with the reader a viewpoint that incorporates the market forces in adoption and proliferation of this critical technology.*
By Näder Pakdaman

Introduction

According to the German writer Heinrich Böll, "Too many things happen in the foreground, and we do not know anything about what happens in the background." We believe that Böll's statement would correctly describe events in the evolution of technology if the market vector is taken out of a technology road map. Without an understanding of the market, every event and opinion could propose a valid alternative—and this spells chaos. Therefore, from our perspective, the market is the parameter that will dominate the course of events, and it offers the canvas that history will be painted upon. The dynamics of the interaction between the market and the technical demands of the industry are the driving forces of technology.

The history of lithography is a perfect example of how the technical demands of the industry along with the market's need for cost-effective manufacturing have shaped the technology. History also teaches us that the past is not a perfect guiding light to the future. For lithography, many of the "correct" beliefs of the past did not bear truth for the future. For example, it was believed in the late 1970s that optical lithography will not be able to process below 1 micron. Later in the 1980s the "final" limit was set at 0.5 microns. We know now optical lithography has shown the potential to

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expose critical device layers below 0.25 microns. Recent work in research laboratories suggests that this capability could be extended to 0.18 microns.

The goal of this article is to offer an insight into evolution of lithography technology by using the recently published 1994 Semiconductor Industry Association (SIA) Technology Roadmap as the background for our discussion. We will offer our perspective on the market conditions that will be a determining factor in adoption and success of the technologies discussed in the SIA Roadmap. Here we will focus on the near-term future of lithography, namely the optical technology. Our goal is to continue this discussion throughout 1996 on the latter subject.

The SIA Roadmap

Table 1 shows the technical demands for lithography technology, as outlined by the SIA. The major change form the 1993 version is that the die sizes for microprocessors predicted in the previous version were believed to follow a faster growth rate than shown here. The SIA Roadmap is shown in Figure 1. For further discussion on the technology road map, the reader may also choose to refer to a recent publication of Dataquest (Semiconductor Equipment Road Map, SEMM-WW-FR-9401).

The major underlying assumption embedded throughout the SIA Roadmap is its adherence to Moore's Law, which states that since the early 1970s the device count per chip quadruples every three years. It is believed that the industry must adhere to Moore's Law for it to continue its rather high (when compared to other large-scale industries) rate of growth.

Moore's Law is an important barometer of the industry's demand for improved performance. However, as Dr. Gordon Moore has repeatedly said, this law is not a natural law. His analysis shows that, in the early 1970s, after the first several generations of integrated circuit implementations, the "smarts" for circuit design (or how to "pack" the devices with the most efficient use of the silicon real estate) as a means for staying on the law's curve were exhausted. Therefore it has been the ability to make the devices smaller that has kept the industry on the law's curve. There is no reason to believe that the industry may not find other means to become "smart" again in designing ICs. However, today and for the foreseeable future, the industry has to outperform its own record on the fab floor. Therefore the focus has been on manufacturing technology.

SEMATECH Manufacturing Productivity Study

Recent reports from SEMATECH propose that the industry has managed to continuously improve its productivity by lowering the cost of manufacturing 25 to 30 percent each year. The contributions have been made by shrinking device features and using larger wafer sizes, along with making improvements in yield and tool use. Figure 2, from a SEMATECH study, shows the factors that have sustained the lowered manufacturing cost, along with their relative contributions. This figure may be seen as an extension of Moore's Law, as it goes beyond device count into other realms of manufacturing technology.

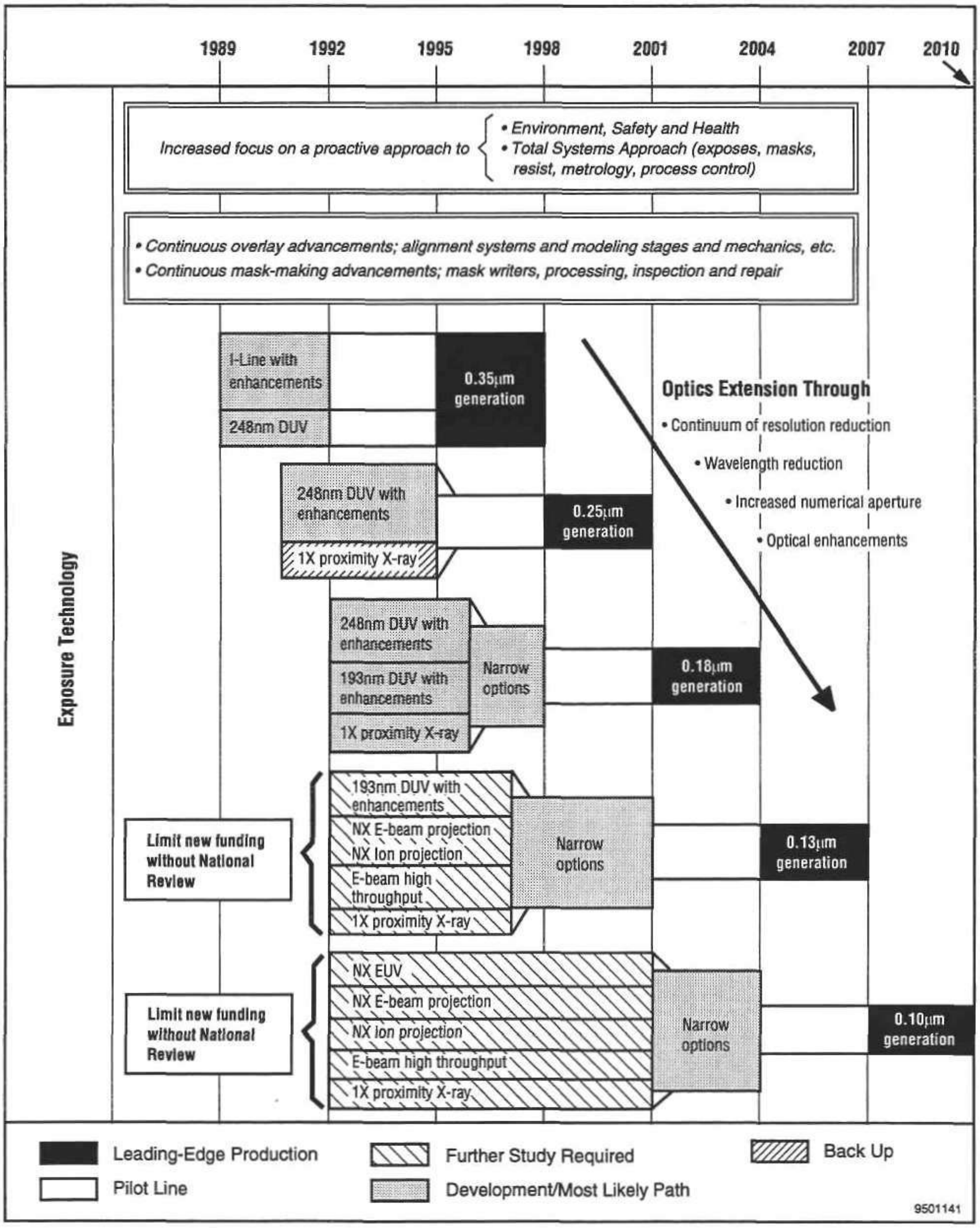
This study showed that, although the share of contributions from feature size shrinks and equipment productivity has increased, yield and wafer

Table 1
Critical Level Lithography Requirements

	1995—0.35μm	1998—0.25μm	2001—0.18μm	2004—0.13μm	2007—0.10μm	2010—0.07μm
Function						
DRAM (Bits)	64M	256M	1G	4G	16G	64G
Microprocessor (Logic Transistors /cm^2)	4M	7M	13M	25M	50M	90M
ASIC (Transistors/cm^2 Auto Layout)[1]	2M	4M	7M	12M	25M	40M
Resolution (μm)	0.35	0.25	0.18	0.13	0.10	0.07
Gate CD Control at Post Etch (nm)	35	25	18	13	10	7
Overlay (nm)	100	75	50	40	30	20
Chip Size						
DRAM (mm^2)	190	280	420	640	960	1,400
Microprocessor (mm^2)	250	300	360	430	520	620
DRAM (mm x mm)	10 x 20	12 x 24	15 x 30	18 x 36	22 x 44	28 x 50
Microprocessor (mm x mm)	16 x 16	18 x 18	19 x 19	21 x 21	23 x 23	25 x 25
Minimum Field Size						
Number of DRAM/Field	2	2	1	1	1	1
(mm x mm)	22 x 22	26 x 26	26 x 30	26 x 36	26 x 44	28 x 50
(mm^2)	484	676	780	936	1,144	1,400
Depth of Focus (Usable) (μm) (Full Field/ ±10 Percent Exposure)	1.0	0.8[2]	0.7[2]	TBD	TBD	TBD
Minimum Mask Count	18	20	20	22	22	24
Defect Density, Lithography Only (per Layer/m^2 at Defect Size μm)	690 at 0.12	320 at 0.08	135 at 0.06	TBD	TBD	TBD
Market Size (Inches) (Quartz)	6x6	6x6	6x6 Next Size	Next Size	Next Size	Next Size

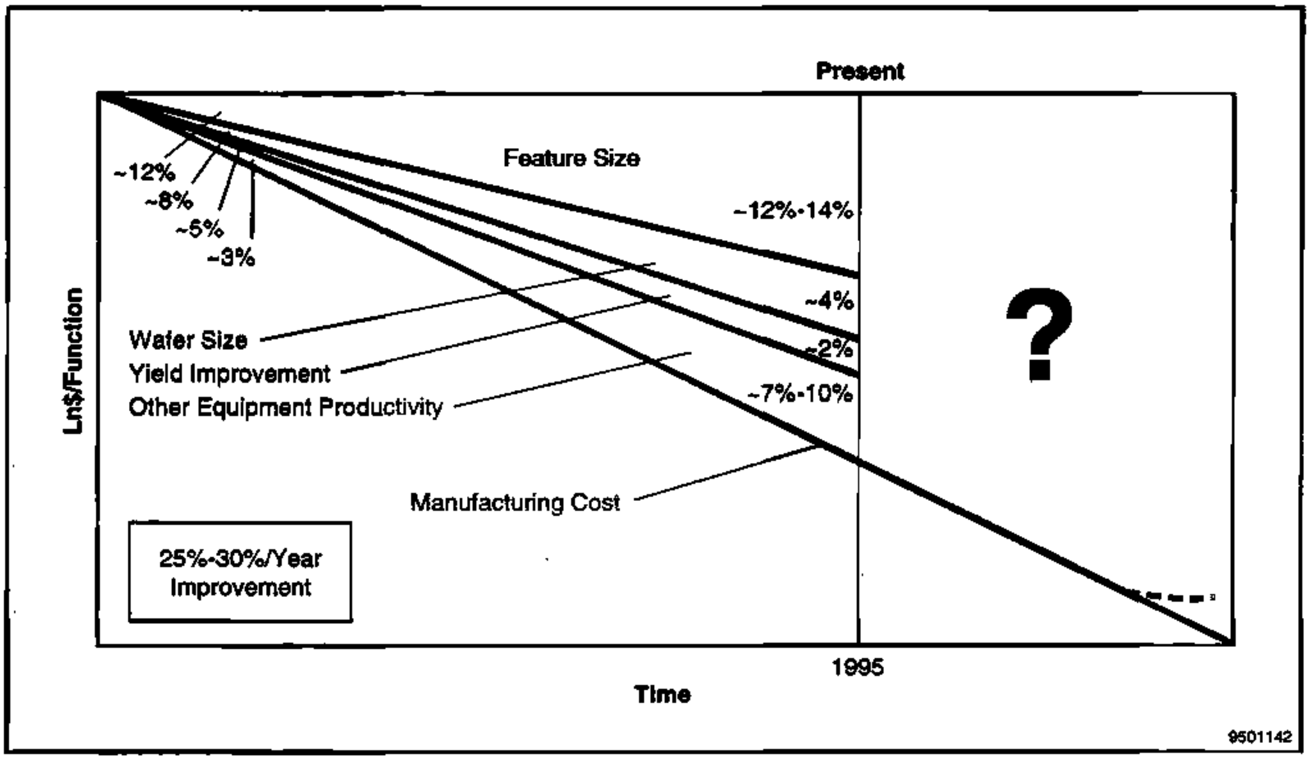
TBD = To be determined
[1]ASIC will use maximum available field size.
[2]Assumes advanced techniques to maximize the usable depth of focus. Further analysis is needed.
Source: SIA, The National Technology Roadmap for Semiconductors (1994)

Figure 1
Critical Level Exposure Technology Potential Solutions Roadmap



Source: SIA, The National Technology Roadmap for Semiconductors (1994)

Figure 2
Keeping the Productivity Engine on Track



Source: SEMATECH (SEMI Industry Strategy Symposium, January 1994, Pebble Beach, California)

size seem to be increasingly playing a smaller role. This may be because yield improvements have almost increased to a point of perfection, and die sizes have increased to compensate for the increases in wafer diameter. As the figure shows, SEMATECH views the future with a question mark. Will we fall off the curve? And if so, when?

One may answer these questions with another question. What has prevented the industry from falling off the improving productivity trend curve in the past? If we cannot find somewhat similar scenarios unfolding today that would increase manufacturing productivity at the rate that would satisfy Moore's Law, then two options exist:

- Manufacturing productivity would not enjoy the historical rate of increase it has enjoyed, and the industry will diverge (negatively) from the curve
- Or, we will have to adhere to the rather aggressive plan outlined by the SIA in Figure 1

We believe that the first option will not impose itself on the industry for at least well into the first decade of the next century. Our discussion that follows will further elaborate on this.

On the second option, we must first understand some of the underpinning definitions and assumptions of the SIA Technical Working Group (TWG). We summarize these points in the road map as:

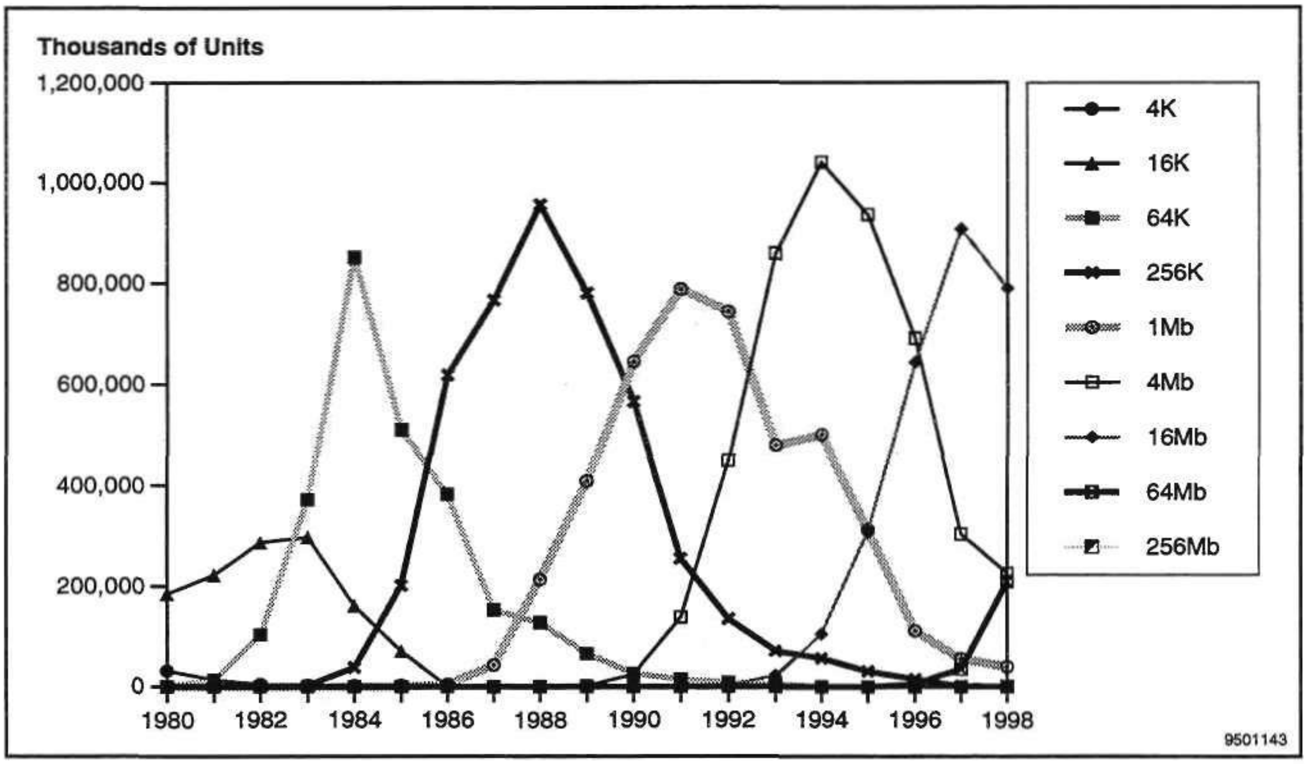
- The "safe margin" factor
- Snapshot view of the Roadmap
- The Roadmap and the market

The SIA Roadmap and the "Safe Margin"

In Figure 1, SIA's Roadmap shows the onset of a capable technology with "pilot line" production. For example 0.25-micron technology should be available in 1995. Or, by 1998, the industry should have 0.18-micron lithography capability. However, to many players in the industry, pilot production may be perceived as a stage in the product cycle that would immediately lead into volume production. On the other hand, according to Figure 3, the ramp-up for volume production of the 0.35-micron technology (the 64Mb DRAM) will begin in 1997, with 64Mb pilot production preceding it in 1996, whereas the SIA Roadmap calls for 0.35-micron pilot lines in 1992. Along the same definitions, the SIA calls "leading-edge production" as the step in the product cycle that will immediately precede volume production. Every generation of technology will have a three-year "pilot line" followed by three-year "leading-edge production."

The reason for this difference in semantics is that SIA, by definition of its charter for the Roadmap, assumes that technical capability should exist five

Figure 3
Annual DRAM Production



Source: Dataquest (March 1995)

to seven years preceding volume production. This "safe margin" is to ensure the availability (and proven capability) of a given technology.

The Roadmap Is a Snapshot

The other, and perhaps less appreciated, point that must be understood about the SIA Roadmap is its underlying methodology. The TWG looks at the needs of the industry with a snapshot view of what technologies are available today, and how far they may be extended. The Roadmap is not meant as a prescription for tomorrow's alternatives, but as an overview of what needs to be done if we had the same capabilities of today in addressing tomorrow's needs.

The Roadmap and the Market

The SIA, because of its charter, also does not include market conditions in its Roadmap. It is our belief that, without this facet of the industry, increases in manufacturing productivity could have not taken place. The difference lies in the response to this question: Does technology drive the market, or does the market drive technology?

Dataquest Perspective

Because our focus for this article is on the optical portion of the Roadmap, we will discuss the SIA's view from 1995 to 2001. The SIA Roadmap calls for a three-year period for the implementation of the next technology generation. This is the period that the SIA uses going from what it terms "pilot production" of one device generation to the next.

Therefore, according to the Roadmap, in the seven-year period preceding the year 2002, 0.35-micron technology will be developed with i-line and deep-UV exposure tools and 0.18 devices with deep-UV (248nm and/or 193nm) systems and/or proximity X-ray tools. The 0.25-micron, 248nm deep-UV and proximity X-ray are the primary candidates for the interim device generation. In short, very drastic enhancements coupled with revolutionary technology shifts are needed to adhere to Moore's Law. This technology road map must be cost-effective to adhere to the cost-performance requirements outlined by SEMATECH.

Market-Driven Evolution of Technology

What the Roadmap does not show is that even the most revolutionary changes in lithography have taken place on a gradual basis. Roadblocks have existed at every step. Most, if not all, of the time these roadblocks have been overcome by investments directed at the most cost-effective approach(es). For example, when optical steppers were first considered to address and alleviate the limitations of projection aligners as the exposure tool, it was believed that optical lithography would have a much shorter lifetime and massive investments were being made in nonoptical alternatives. Those other alternatives have yet to be deployed in volume manufacturing. The market has continued to invest in optical technology because it is the most cost-effective technical alternative in manufacturing.

Because of this sheer momentum we believe that the industry will most probably continue to develop optical technology as far as it can push the envelope. According to the SIA Roadmap, 0.13-micron devices may be exposed with 193nm deep-UV exposure tools. Our viewpoint does not exclude the use of other alternatives in volume production. However, the measuring stick will be the optical systems.

The embedded "snapshot" viewpoint in the Roadmap does not account for investment patterns, both by the manufacturers and the suppliers. Therefore it reverts to a rather linear outlook in technology development. Technology investments can and have only taken place when the capital has become available by favorable market conditions. The return on investment governs the equipment and material suppliers' decision on the direction, level, and timing of their investments.

Technology Cost Performance—Deep-UV versus i-Line

Lithography historically has managed to respond to the technical innovations needed to ensure more advanced and yet cost-effective manufacturing capability. Therefore, the physical law of the "path of least action" also holds true in the technology development field. This law dictates that the industry (supplier and user) will continue to incrementally develop mature technologies to minimize cost. Better performance or potential cost benefit of a technology in manufacturing do not guarantee the use and proliferation of that technology. For example, deep-UV step and scan systems have been on the market since 1989. It is only recently that all the players in the lithography market have declared their strategies in introducing their version of the step and scan deep-UV system. Along with these announcements we also see aggressive, yet incremental, plans by the same stepper suppliers to further develop and enhance the i-line exposure tools. The exposure enhancements techniques, along with improvements in the mask and photoresist used for i-line lithography, have proven that i-line systems may even be used for the critical layers below 0.35-micron device generations. This may be extended to 0.25 microns, contrary to the current SIA Roadmap.

The bottom line is cost. The resiliency of an "old" technology in lithography lies in the cost/performance ratio. We believe that deep-UV technology (exposure tool, photoresist, and mask) performance (yield and throughput) will have to displace i-line on a cost basis also. This holds true for the migration from 248nm to 193nm, and for the postoptical period. However, this will by no means be a smooth ride. Technical capabilities will not be developed along a smooth curve. The markets that generate the revenue needed to make the investment in R&D of new technologies also will not scale linearly.

Market Forecast

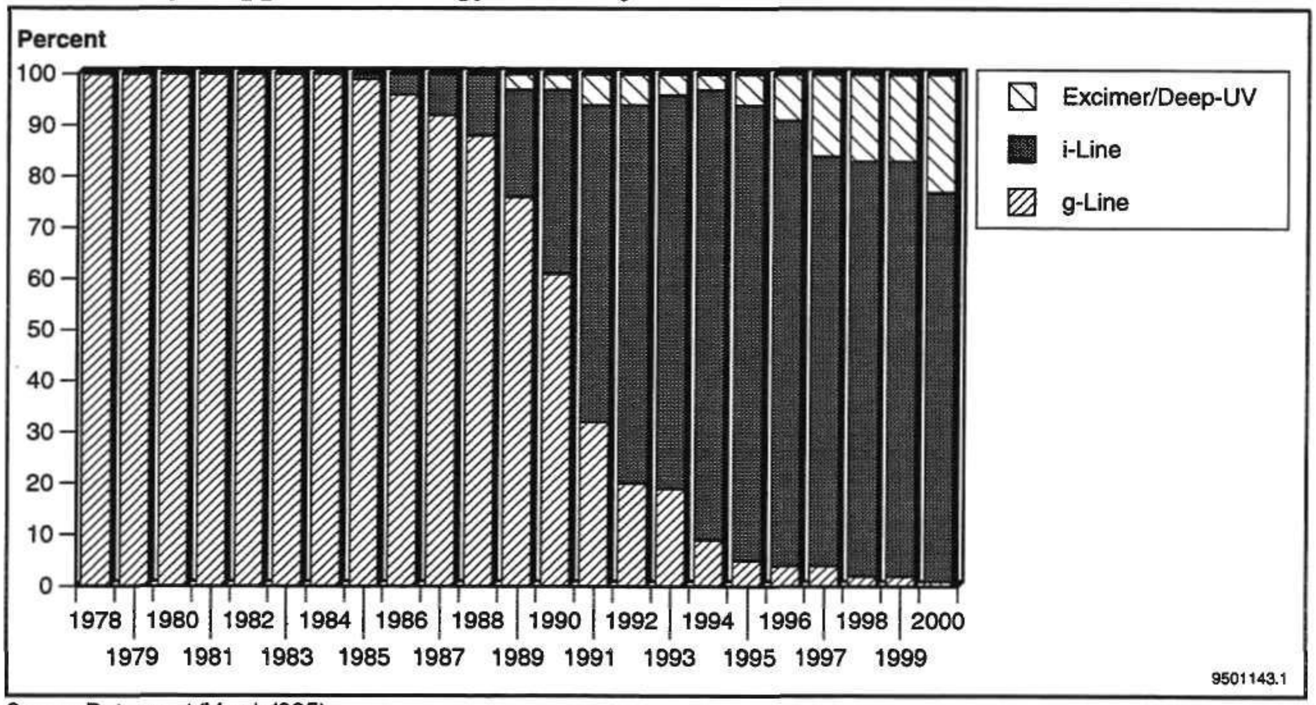
Figure 4 shows the preliminary estimates for the stepper market to the year 2000. We believe that many manufacturers in 1997 and 1998 will ramp up to volume production using i-line steppers for the critical mask layers. This by no means excludes the deep-UV systems. Cost performance of deep-UV technology could be different for each manufacturer, depending on device type and level of understanding deep-UV processing for volume manufacturing. I-line will challenge, and may even dominate, deep-UV steppers used for the critical geometries of the 0.35-micron devices.

Dataquest Conclusions

The more things change, the more they remain the same?

It is not the role of SEMATECH or the SIA to outline the course of technology development beyond their announced charters. Market conditions and ensuing investment patterns eventually will have to respond to the technical demands outlined by the industry consortia. We believe that the

Figure 4
Preliminary Stepper Technology Share, by Unit



Source: Dataquest (March 1995)

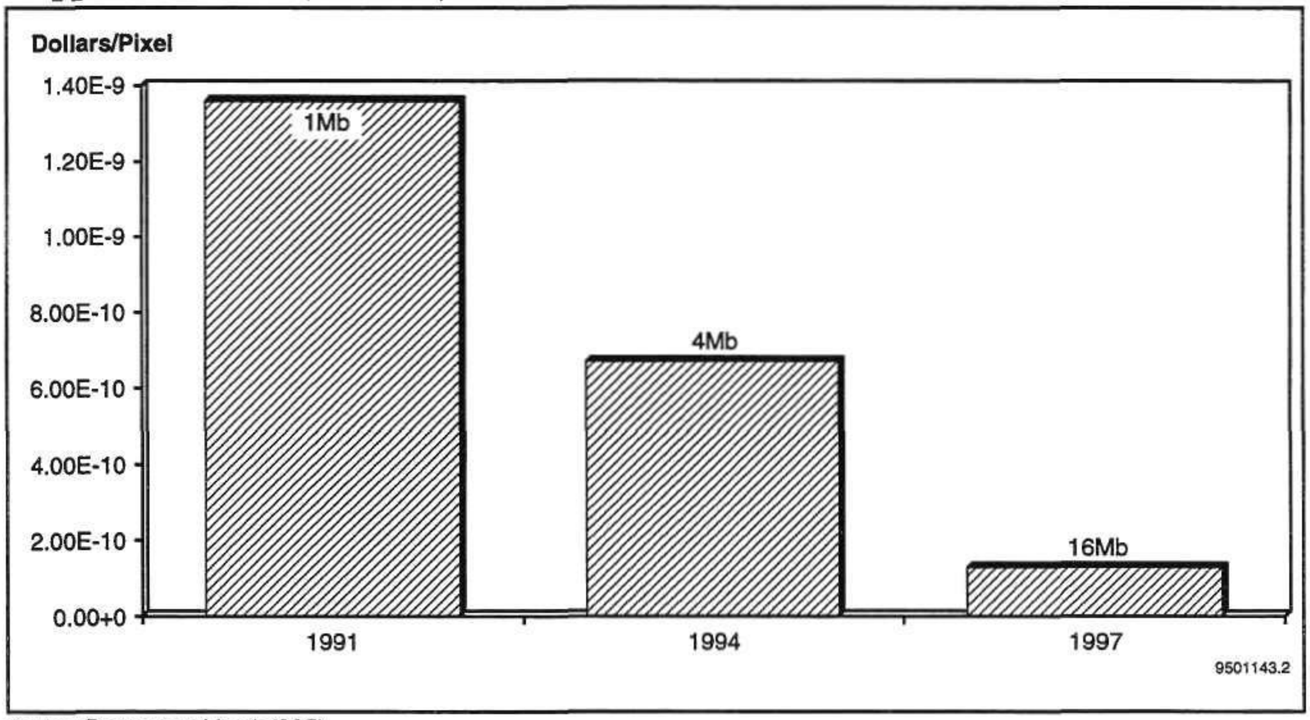
industry will find the means to remain on course with Moore's Law well into latter parts of the first decade of the next century.

The industry may have to revisit some of the areas that it believes it has exhausted in its quest for increased productivity. Yield curves are maturing at a very fast rate. New and rather revolutionary yield-enhancement strategies have only recently been incorporated on the fab floor. By our estimate, the impact on productivity from yield may grow. Product cycles of different device types may be overlapped to increase tool use of leading-edge technologies. Along with increases in tool use and yield enhancement, new strategies in product developments and shorter cycles from prototype to manufacturing may soon be realized. We are already seeing some of these trends in the microprocessor arena. Adoption of larger wafer diameter may also become more aggressive and common if the needed investments could be justified by the suppliers and users.

More on Mix and Match

Strategically significant trends have emerged in manufacturing in the past several years that will play an important role in productivity enhancements of the future. Among them is the ongoing acceptance and proliferation of mix and match of critical- to high-throughput stepper systems on the fab floor. This trend has been accelerated by the continuing increases in the throughputs of systems (both critical and noncritical). Mix and match lithography has just begun to impact the productivity picture. Although every fab cost model incorporates this important strategy in its cost structure, we believe the full potential has yet to be realized. Figure 5 shows the importance of mix and match strategies in reducing costs. The figures and assumptions behind Figure 5 appeared in the Dataquest's Semiconductor Equipment Road Map (SEMM-WW-FR-9401). The estimates

Figure 5
Stepper Cost Factor (Estimate)



Source: Dataquest (March 1995)

used to generate this chart were based on rather low and "conservative" figures for the throughput of the critical and non-critical steppers.

Showstoppers

What conditions and events may derail the industry from the productivity curve? The semiconductor industry is in a state of flux. This translates into uncharted market conditions for technology development. The manufacturers that defined and led technology development for several decades with massive investments in R&D—and spurred the technical and market growth of the suppliers—have more or less relinquished that role. With the lower government and research investments in the post-Cold War era, semiconductor research in the United States is redefining itself. The weak Japanese economy of the past several years has also slowed the pace of advanced research. Perhaps this could translate into new opportunities for a new generation of players, or it may spell warning signs for staying on the productivity curve. However, we believe that the needs of the exponential growth of information technology will find the means to address the voracious growth for advanced development of cost-effective technology.

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Market Analysis

Semiconductor Equipment, Manufacturing, and Materials Worldwide

Market Analysis

1994 North American Semiconductor Gas Market: Strong Year for Specialty Gases

Abstract: *The North American semiconductor gas market had an estimated U.S.$364 million in sales in 1994, a gain of 10.5 percent over 1993. Strong sales in specialty gases, such as etchants and dopants, on top of a solid bulk gas market gave the North American electronic gas industry its best performance in five years.*
By Calvin Chang

Bulk Gas Market

The bulk gas market is estimated to have reached U.S.$228.8 million in 1994, a growth of 4.4 percent from 1993, the highest year-to-year growth rate since 1989. Table 1 shows the semiconductor bulk gas sales in North America from 1990 to 1994.

Nitrogen Continues to Go On-Site

All segments of the semiconductor bulk gas market except liquid nitrogen saw growth in 1994. Although liquid nitrogen continues to be the largest component (54 percent) of the nitrogen market, its market revenue and share of the total nitrogen sales have declined in each of the last five years. Mirroring this trend but going in the opposite direction is the consistent year-to-year rise in both revenue and percentage of total nitrogen sources for on-site nitrogen plants. The migration toward the building of larger fabs, a lower cost in nitrogen generation, and a business environment of relatively low-cost capital have all contributed to the continued increase in the adoption of on-site nitrogen plants in the semiconductor industry.

After a continued decline during the last few years, sales of pipeline nitrogen picked up a handsome 20 percent gain in 1994 from a low of

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Table 1
North American Semiconductor Bulk Gas Market Sales (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994*	CAGR (%) 1990-1994
Nitrogen	159.5	162.3	164.0	160.9	165.4	0.9
On-Site	40.8	44.2	51.5	54.9	57.1	8.7
Pipeline	22.1	22.8	21.4	19.3	23.2	1.2
Liquid	96.6	95.3	91.1	86.7	85.2	-3.1
Hydrogen	28.5	29.0	26.9	30.3	32.5	3.4
Oxygen	6.6	7.4	8.7	8.2	8.6	6.8
Argon	14.4	15.1	16.1	19.8	22.2	11.4
Semiconductor Bulk Gas Sales Total	209.1	213.7	215.7	219.2	228.8	2.3
Change from Previous Year (%)	2.6	2.2	0.9	1.6	4.4	

*Preliminary
Source: Dataquest (February 1995)

U.S.$19.3 million in 1993. The rise is in no small part due to the increased IC manufacturing that has returned to the Silicon Valley (for example, Intel's D2), where the largest pipeline network is located.

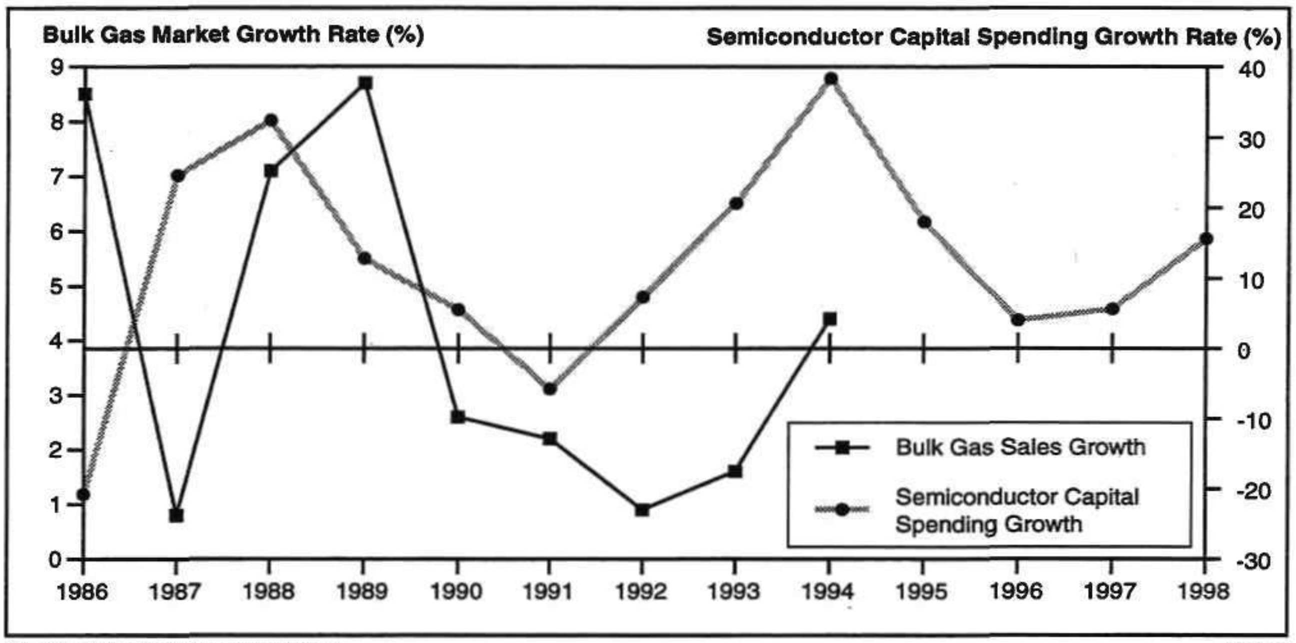
In terms of compound annual growth rates (CAGR) from 1990 to 1994, argon has experienced the highest growth with 11.4 percent, followed by oxygen (6.8 percent) and hydrogen (3.4 percent). Argon consumption has been consistent and has increased every year, even during 1992 to 1993, when the overall bulk gas market was flat.

Semiconductor Capital Spending: The Principal Market Driver

We continue to find a close correlation between the growth rate of semiconductor capital spending and that of the bulk gas market. The basis of this correlation has to do with the level of new semiconductor fab construction and expansion that will be populated with production equipment that use bulk gases for purge, dilution, and processing. As shown in Figure 1, the peak growth year for bulk gases lags the peak growth year in semiconductor capital spending by about one year, which is consistent with the general period of time between the construction of a new fab—during which capital is spent—and the onset of ramp-up production when equipment is in operation.

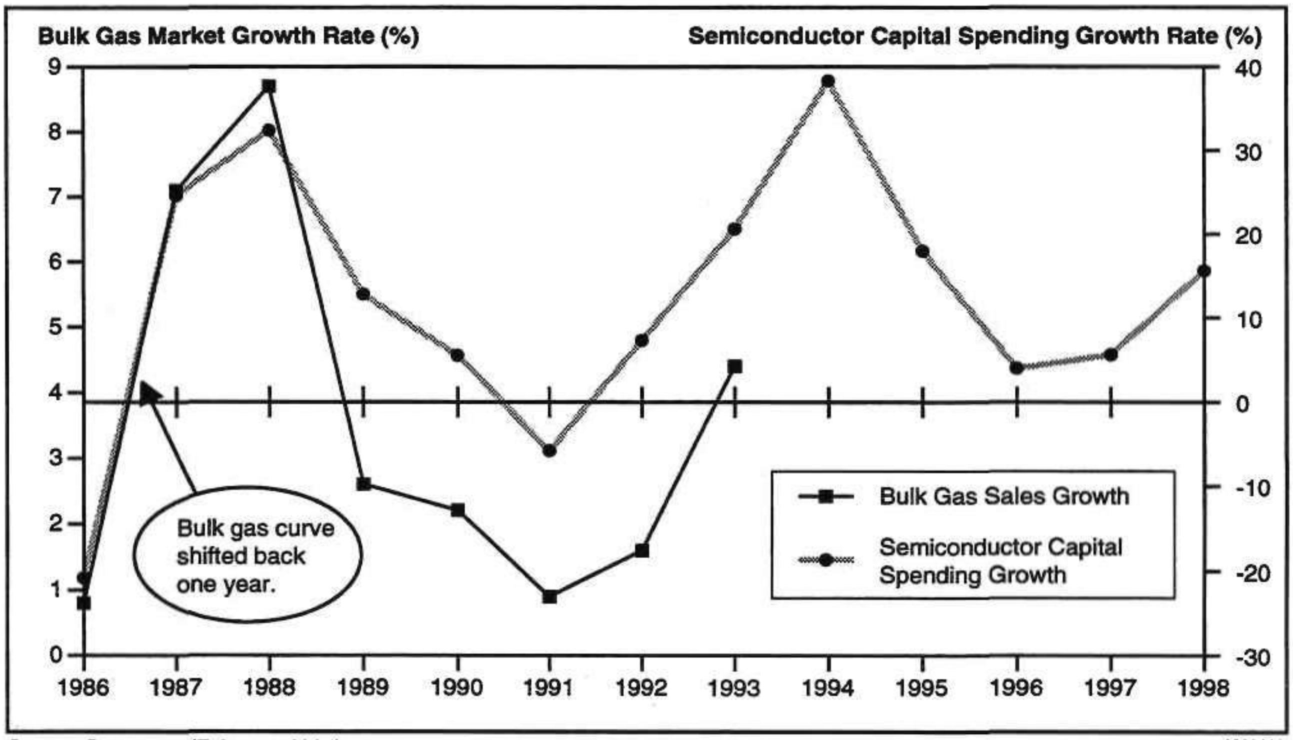
When the capital spending rate curve is shifted one year, as shown in Figure 2, the bulk gas market growth coincides nicely (scale adjusted) with the level of capital spending for the years before 1990. After 1990, while the bulk gas market growth rate still trends with the changing rate of capital spending, the "carrying" effect of capital spending on bulk gas consumption is significantly lower. For example, a 30 percent rise in capital spending in 1988 would bring about a 9 percent increase in bulk gas consumption in 1989, a carrying effect of about three to one. But in 1993, a 21 percent increase in capital spending resulted in only a 4.4 percent growth in the bulk gas market in 1994, a ratio of almost five to one. In other words, the same level of capital spending increase does not generate the same level of "bang" in bulk gas consumption in the era of the billion-dollar fabs as it did before 1990.

Figure 1
Comparison of Growth Rates of North American Semiconductor Capital Spending and Bulk Gas Market (Percentage)



Source: Dataquest (February 1995) 9500889

Figure 2
Semiconductor Capital Spending as a Leading Indicator for the North American Bulk Gas Market (Percentage)



Source: Dataquest (February 1995) 9500890

This phenomenon is also reflected in the different degrees of impact that semiconductor capital spending has on the semiconductor equipment and material industries. The 21 percent increase in North American capital spending in 1993 lead to a 25 percent rise in semiconductor production equipment sales but only a 4.4 percent growth in the bulk gas market in 1994. The 38 percent increase in capital spending in 1994, which produced a 45 percent rise in semiconductor equipment sales, would probably result in a comparatively much smaller growth, approximately 7 to 8 percent, in the bulk gas market in 1995.

Looking forward, the semiconductor capital spending projection (see Figure 2), as a leading indicator, suggests that the slowing rate of capital spending in the 1995 to 1998 time frame will lead to a corresponding slowdown in the bulk gas market from 1996 to 1999.

Specialty Gas Market

Table 2 shows the North American semiconductor specialty gas market from 1990 to 1994. Etchants, dopants, and reactant gases are the fastest-growing segments in specialty gases. Etchants are now 40 percent of the specialty gas market, and this share will continue to rise because the proportion of etch steps in IC fabrication process flow is expected to increase with each new generation of technology. The specific gases in the etchants category as well as those in the other gas categories are listed in the section entitled "Dataquest's Classification of Semiconductor Bulk and Specialty Gases." Growth in silicon precursors has been small or flat except in 1994, when there was a gain of nearly 20 percent. This is due in part to the recent expansion of epi wafer manufacturing in the United States. Reactant gases, which showed a CAGR of 37.2 percent during 1990 to 1994, actually grew at an annual rate of 13 percent during the last three years. WF_6 and N_2O are expected to continue to outperform the other reactant gases in sales.

Table 2
North American Semiconductor Specialty Gas Market Sales (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994*	CAGR (%) 1990-1994
Silicon Precursors	21.9	22.0	22.2	25.5	30.3	8.5
Silane	15.2	15.6	15.6	17.3	22.2	9.9
Dichlorosilane	4.2	3.3	3.5	3.9	3.7	-2.9
Trichlorosilane	1.6	2.0	2.2	3.0	3.2	18.2
Silicon Tetrafluoride	0.8	1.1	0.9	1.0	1.2	9.3
Disilane	0	0	0.01	0.01	0.01	NM
Dopants	7.2	7.4	7.5	12.7	15.9	22.0
Plasma Etchants	18.6	20.2	25.3	37.6	53.9	30.4
Reactant Gases	6.7	16.3	18.2	19.5	23.6	37.2
Atmosphere/Purge	9.6	11.9	13.6	14.7	11.1	3.6
Semiconductor Specialty Gas Total	64.0	77.8	86.8	110.0	134.8	20.5
Change from Previous Year (%)	9	22	12	27	23	

*Preliminary
NM = Not meaningful
Source: Dataquest (February 1995)

Etchant Gas Market Booms

A bright spot in the specialty gas market is the etchant gas market, which saw an impressive 49 percent gain in 1993 followed by a 43 percent rise in 1994. Table 3 provides a breakout of etchant gases and shows the 1992/1993 growth rate in each etchant gas. Despite the concern about their impact on the environment, Freons 14, 116, and 23 all grew over 40 percent. Potentially a global-warming substance, CF_4 is used in oxide etch and is unlikely to go away anytime soon because so far there is no replacement etchant that can deliver the same etch performance. However, consumption of Freon 115, an ozone-depletion substance banned by the Montreal Protocol, has essentially been eliminated, although a very limited supply, at increasingly higher cost, is available to research institutions. NF_3, used in chamber clean, has benefited from increasing use of single-wafer chemical vapor deposition (CVD) and etch systems. Both BCl_3 and Cl_2 are used in metal etch and should continue to experience high growth from applications in fabrication of IC's multilevel interconnection. HBr is used in poly etch, and its major U.S. consumers are DRAM manufacturers, such as IBM, Texas Instruments (TI), and Micron. ClF_3, an etchant used in Hitachi etchers, is relatively unknown to the U.S. etch community, but interest will rise if U.S. sales of Hitachi etchers pick up or if Hitachi decides to build more fabs in the United States.

Table 3
North American Semiconductor Plasma Etchant Gas Market Sales (Millions of U.S. Dollars)

	1993	1992	Growth Rate (%) 1992-1993
Plasma Etchant Gases			
CF_4 (Halo 14)	4.11	2.91	41
CF_4 (Halo 14/O_2)	0.41	0.29	41
CHF_3 (Freon 23)	3.12	1.94	61
C_2F_6 (Freon 116)	11.20	8.01	40
C_2ClF_5 (Freon 115)	0.004	0.001	NM
Other Halocarbons (13, 13b, 21)	0.18	0.05	NM
NF_3	7.38	5.09	45
SF_6	1.99	1.52	31
BCl_3	4.53	2.62	73
C_3F_8	0.14	0.09	64
HF	0.33	0.27	22
Cl_2	1.95	1.30	50
ClF_3	0.004	0.003	50
HBr	2.02	1.00	103
Others	0.25	0.09	183
Plasma Etchant Market	37.61	25.18	49

NM = Not meaningful
Source: Dataquest (February 1995)

King of Silicon Precursor in IC Processing: Not Silane!

Silane and the liquid source, TEOS, are both used as a silicon precursor in IC processing. Silane is required in deposition of polysilicon, nitride, and BPSG films. TEOS is used primarily in the fabrication of silicon dioxide film at relative lower temperature (350°C to 400°C). The low temperature feature of the TEOS-based oxide deposition process has positioned TEOS as the principal beneficiary in the industry's continual drive toward increasing levels of interconnect in ICs.

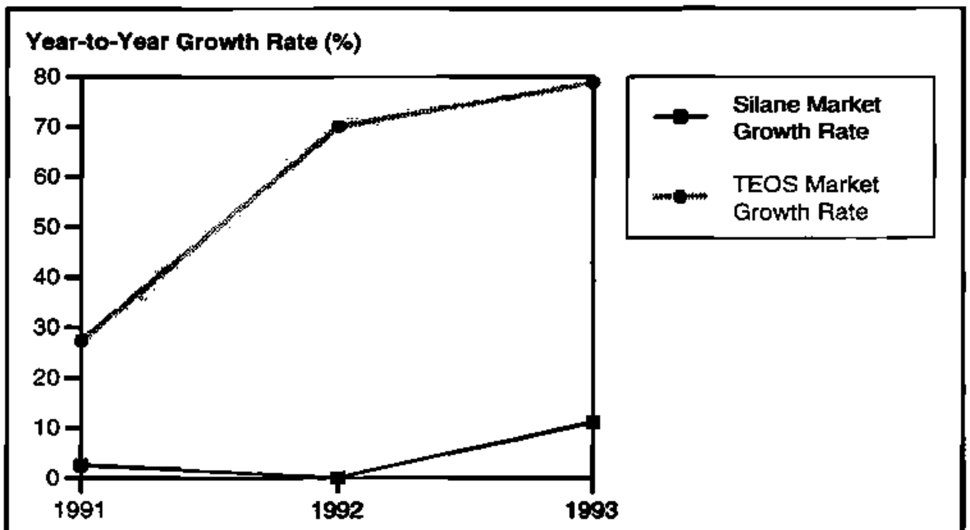
Table 4 compares the silane and the TEOS market in 1990 to 1993. North American TEOS sales nearly quadrupled in revenue terms during the period and increased by more than 500 percent in volume consumption. Silane market growth has been flat, compared to the spectacular growth in TEOS (see Figure 3). From what was only about one-third of the silane market in 1990, TEOS has surpassed it in two short years and is now a much larger market and with no sign of slowing down in the short term.

Table 4
Comparison of North American Silane, Epi Wafer, and TEOS Consumption

	1990	1991	1992	1993
TEOS Market (Revenue in U.S.$M)	5.7	7.2	12.3	21.9
TEOS Market (Volume in Kilograms)	9,417	15,778	30,045	57,422
Silane (Sales in U.S.$M)	15.2	15.6	15.6	17.3
Percentage Change from Previous Year	5.2	2.6	0.1	11.1

Source: Dataquest (February 1995)

Figure 3
Comparison of North American TEOS and Silane Growth Rates (Percentage)



Source: Dataquest (February 1995) 9500891

North American Market Semiconductor Gas Market Share

Table 5 shows market share in the total, bulk, and specialty gas markets for North American semiconductor gas suppliers. The four major gas companies continue to dominate in the North American semiconductor gas market, accounting for nearly 90 percent of the total. Less than 4 percent of the bulk gases consumed in North America is provided by a company not among the four majors. The consolidation in the bulk gas market has been effectively complete. The year 1993 was very good in the specialty gas market, with four suppliers achieving greater than 45 percent growth. Matheson, with its success in dopants and etchants, is closing in on Praxair in the No. 3 position in the specialty gas market. Moreover, with the acquisition of Bandgap, Matheson is now well positioned in one of the most lucrative segments (WF_6) of the specialty gas market. Sales figures from the first six

Table 5
North American Semiconductor Gas Suppliers Market Share Summary (Million of U.S. Dollars)

	1994*	1993	1992	1991
Air Liquide	17.77	32.09	27.09	26.16
Air Products and Chemicals	71.86	131.65	121.20	116.95
BOC Gases	32.20	61.80	57.57	58.28
Matheson	10.90	16.30	10.91	10.61
Praxair	34.30	68.10	71.98	67.30
Scott Specialty	3.18	5.67	3.90	3.27
Solkatronic Chemicals	2.88	4.10	3.10	2.22
Tri-Gas	1.56	2.54	NA	NA
Other Companies	3.40	6.90	6.72	6.69
Total North American Semiconductor Gas Market	178.05	329.16	302.47	291.48
North American Bulk Gas Suppliers Market Share (Revenue in U.S.$M)				
Air Liquide	14.60	28.60	24.80	24.00
Air Products and Chemicals	53.45	101.55	101.30	100.35
BOC Gases	15.20	30.00	26.77	30.08
Praxair	24.60	50.70	57.20	53.70
Tri-Gas	1.56	2.54	NA	NA
Other Companies	2.75	5.80	5.62	5.59
Total North American Bulk Gas Market	112.16	219.19	215.68	213.72
North American Specialty Gas Suppliers Market Share (Revenue in U.S.$M)				
Air Liquide	3.17	3.49	2.29	2.16
Air Products and Chemicals	18.41	30.10	19.90	16.60
BOC Gases	17.00	31.80	30.80	28.20
Matheson	10.90	16.30	10.91	10.61
Praxair	9.70	17.40	14.78	13.60
Scott Specialty	3.18	5.67	3.90	3.27
Solkatronic Chemicals	2.88	4.10	3.10	2.22
Other Companies	0.65	1.10	1.10	1.10
Total North American Specialty Gas Market	65.89	109.97	86.78	77.76

*First six months
NA = Not available
Source: Dataquest (February 1995)

months of 1994 indicate that Matheson has carried much of the growth momentum into 1994, followed by Air Products, which is also maintaining a healthy growth rate of more than 20 percent.

Dataquest's Classification of Semiconductor Bulk and Specialty Gases

The following bullets show Dataquest's classification of semiconductor bulk and specialty gases.

- Semiconductor bulk gases:
  - Nitrogen (on-site, multicustomer pipeline, and bulk liquid delivery)
  - Oxygen (O_2)
  - Hydrogen (H_2)
  - Argon (Ar)
- Semiconductor specialty gases (delivered in cylinders):
  - Silicon precursors gases:
    - SiH_4
    - SiH_2Cl_2
    - $SiHCl_3$
    - $SiCl_4$
  - Dopant gases:
    - AsH_3
    - PH_3
    - B_2H_6
    - BF_3, $B_{11}F_3$, PF_5, etc.
  - Etchant gases:
    - CF_4
    - CF_4/O_2 (Halo $14/O_2$)
    - CHF_3 (Freon 23)
    - C_2F_6 (Freon 116)
    - C_2ClF_5 (Freon 115)
    - Other halocarbons (13, 13b1, 21)
    - NF_3
    - SF_6
    - BCl_3
    - C_3F_8
    - HF
    - Cl_2

- ClF_3
- HBr
- SiF_4

- Reactant gases:
  - NH_3
  - HCl
  - N_2O
  - WF_6
  - CO_2

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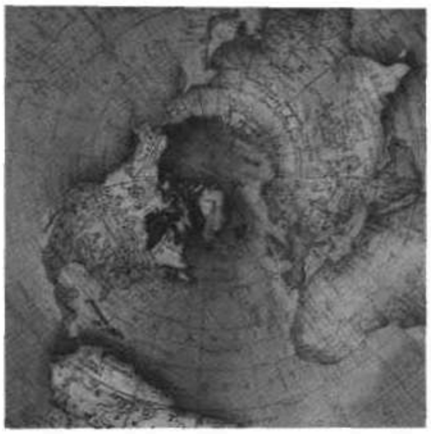

Dataquest

Market Definitions—Semiconductor Equipment

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Table of Contents

List of Tables

Chapter 1

Market Share Survey Overview

Each year, Dataquest surveys semiconductor equipment vendors to estimate their annual revenue derived from front-end semiconductor equipment sales. The survey covers 133 semiconductor equipment vendors worldwide (this varies according to mergers, acquisitions, liquidations, and start-ups, among others) by 49 individual semiconductor equipment product categories (excluding subtotals), in five world regions. This exercise helps Dataquest maintain its dynamic database of semiconductor equipment supply by company and semiconductor equipment shipment by world region and product. The information gained is supplemented and cross-checked with Dataquest's various other information sources. Dataquest conducts this research on an annual basis. The categories for which semiconductor equipment revenue is reported are comprehensively defined for the purpose of clarity and guidance to survey participants. These definitions may occasionally be revised, altered, or expanded to reflect changes in semiconductor manufacturing technology. To support these definitions, Dataquest will issue an annual survey guide to all participants in its semiconductor equipment market share survey program. This comprises the 1995 survey guide.

Chapter 2
Semiconductor Equipment Companies Surveyed Worldwide for 1994

European Companies

ADDAX SA

ASM International

ASM Lithography

AST Electronic

Centrotherm GmbH

Convac

E.T. Electrotech

Jipelec

Karl Suss

Leica

Leybold

LPE

Oxford Instruments (formerly Oxford Plasma Technology)

Pokorny/Steag

Presi

Sapi Equipment

Japanese Companies

Amaya

Advanced Film Technology

Anelva

Canon

Dainippon Screen

Dalton

Dan Science

Disco

Elionix

Enya

ETE

Fuji Electric

Fujikoshi

Hitachi

Holon

Japan Production Engineering

Japan Storage Battery

JEOL

Kaijo

Kokusai Electric

Koyo Lindberg

Kuwano Electric

LaserTec

Maruwa

Matsushita Electric

MC Electronics

MRC

Musashi

Nidek

Nikon

Nissin Electric

Plasma Systems

Ryokosha

Samco

Sankyo Engineering

Shibaura Engineering

Shimada

Shinko Electric

Shinko Seiki

Sugai

Sumitomo Metals

Tazmo

Tohokasei

Tokyo Aircraft Instruments

Tokyo Electron

Tokyo Ohka Kogyo

Topcon

Toshiba Machine

Toyoko Chemical

Ulvac

Yamato Semico

Yuasa

Joint Venture Companies (Cross-Region)

Alcan Technology

m.FSI

Sumitomo/Eaton Nova

TEL/Varian

Varian/TEL

North American Companies

Advanced Crystal Sciences

AG Associates

Amray

Applied Materials

ASM Epitaxy (subsidiary of ASM International)

Biorad Micromeasurements

Bruce Technologies

CFM Technology

CHA Industries

Concept Systems Design

CVC Products

Cybeq Systems

Denton Vacuum

Eaton

Etec Systems

FSI International

Fusion Semiconductor Systems

Gasonics

Genus

High Temperature Engineering

IPEC/Westech Systems

IVS

KLA Instruments

Kurt J. Lesker

Lam Research

LFE Plasma Systems

Materials Research Corporation

Matrix Integrated Systems

Mattson Technologies

Moore

Nanometrics

Novellus Systems

OnTrack Systems

Opal

Optical Specialties

Pacific Western

Plasma & Materials Technologies

Process Technology Ltd.

Rudolph Research

Santa Clara Plastics

SCI Manufacturing

Semiconductor Systems

Semitherm

Semitool

Silicon Valley Group

Solitec

Speedfam

Sputtered Films

Strasbaugh

SubMicron Systems

Tegal

Tempress

Tencor Instruments

Thermawave

Tystar

Ultratech Stepper

Universal Plastics

Varian

Verteq

Watkins-Johnson

Summary

16 European companies

52 Japanese companies

5 joint venture companies

60 North American companies

Chapter 3
General Sales Definitions

All sales are reported according to customer location, that is, shipping destination. These destinations are defined regionally. The regions are North America, Europe, Japan, Asia/Pacific, and Rest of World. Sales do not include spare parts or service, but do include retrofits and upgrades. In addition, our market estimates only include equipment used in the front-end wafer fabrication process. We do not include equipment used in other market applications such as flat panel display manufacturing, thin-film head manufacturing, or multichip modules. Finally, as part of our convention to report end-user revenue, the revenue associated with equipment kits sent from one company to be fabricated and assembled by another company is valued at the full system shipment price paid by the semiconductor manufacturer. This revenue is assigned to the company that originated the kit, with the exception of implant joint ventures. Thus, for public companies, the sales reported here may differ from the sales reported in annual reports.

Research Metrics

The following metrics apply to how Dataquest views and analyzes the semiconductor equipment market.

End user. The final purchaser of the equipment.

End-user spending. End-user average purchase price times shipments to end users.

End-user average purchase price. The average price paid for a branded, finished product by the final purchaser of the product.

Shipments to end users. The sum of branded finished products delivered to the final purchaser.

Chapter 4
Exchange Rate Definitions

When converting a company's local currency sales into U.S. dollars, or vice versa, it is important to use the 1994 exchange rates provided in Table 4-1. These rates will prevent inconsistencies in the conversion of offshore sales between companies. These exchange rates will be used in the 1994 market share survey. Exchange rates for historical years are available on request.

Table 4-1
Average 1994 Exchange Rates per U.S. Dollar

Country	1994 Rate	1993 Rate	U.S.$ Appreciation (%)
Austria (Schilling)	11.40	11.65	-2.07
Belgium (Franc)	33.36	34.67	-3.76
China (Renminbi)	8.54	5.76	48.28
Denmark (Krone)	6.35	6.49	-2.15
ECU	0.84	0.86	-1.62
Finland (Markka)	5.21	5.73	-9.17
France (Franc)	5.54	5.67	-2.38
Germany (Mark)	1.62	1.66	-2.13
Great Britain (Pound)	0.65	0.67	-1.97
Greece (Drachma)	242.06	229.33	5.55
Hong Kong (Dollar)	7.73	7.74	-0.10
India (Rupee)	31.15	30.84	1.00
Ireland (Punt)	0.67	0.68	-2.33
Italy (Lira)	1609.34	1577.85	2.00
Japan (Yen)	101.81	111.20	-8.44
Malaysia (Ringgit)	2.50	2.58	-3.04
Netherlands (Guilder)	1.82	1.86	-2.22
Norway (Krone)	7.04	7.11	-0.86
Portugal (Escudo)	165.63	161.08	2.83
Singapore (Dollar)	1.53	1.62	-5.54
South Korea (Won)	802.84	799.52	0.42
Spain (Peseta)	133.48	127.87	4.38
Sweden (Krona)	7.70	7.82	-1.60
Switzerland (Franc)	1.37	1.48	-7.72
Taiwan (Dollar)	26.45	26.16	1.13
Thailand (Baht)	25.36	25.31	0.19

Source: Dataquest (January 1995)

Chapter 5
Semiconductor Equipment Product Category Hierarchy

The following semiconductor equipment product category hierarchy begins with total semiconductor equipment and indents each subcategory in the left-hand column according to its position in the hierarchy. At each level in the hierarchy, all subcategories that contribute to this level are indicated as a subcategory summation in the right-hand column. Any level in the hierarchy that does not depend on any subcategories is marked as "Data Point."

Total Wafer Fab Equipment	Total Lithography + Resist Processing Equipment + Total Clean Process + Dry Strip + Total Dry Etch + Chemical Mechanical Polishing + Total Deposition + Diffusion + Rapid Thermal Processing + Total Ion Implantation + Total Process Control + Other Equipment
Patterning	
Total Lithography	Contact/Proximity[1] + Projection Aligners + Total Steppers + Total Direct-Write + Total Maskmaking + X-Ray
Contact/Proximity[1]	Data Point
Projection Aligners	Data Point
Steppers	Data Point
Total Direct-Write	Direct-Write E-Beam + Direct-Write Optical
Direct-Write E-Beam	Data Point
Direct Write Optical	Data Point
Total Maskmaking	Maskmaking E-Beam + Maskmaking Optical
Maskmaking E-Beam	Data Point
Maskmaking Optical	Data Point
X-Ray	Data Point
Resist Processing Equipment (Track)	Data Point
Etching/Cleaning	
Total Clean Process (Formerly Total Wet Process)	Auto Wet (Immersion) Stations + Spray Processors[2] + Vapor Phase Clean[2] + Scrubbers[2] + Post-CMP Clean[2] + Other Clean Process[1]
Auto Wet (Immersion) Stations	Data Point
Spray Processors[2]	Batch Spray Processor[2] + Single-Wafer Spray Processor[2]
Batch Spray Processor[2]	Data Point
Single-Wafer Spray Processor[2]	Data Point
Vapor Phase Clean[2]	Data Point
Scrubber[2]	Data Point
Post-CMP Clean[2]	Data Point
Other Clean Process[1]	Manual Wet Benches[1] + Rinsers/Dryers[1] + Megasonics[1]

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Manual Wet Benches[1]	Data Point
Rinser/Dryers[1]	Data Point
Megasonics[1]	Data Point
Dry Strip	Data Point
Total Dry Etch	Low-Density Etch + High-Density Etch
Low-Density Etch	Data Point
High-Density Etch	Data Point
Chemical Mechanical Polishing[3]	Data Point
Deposition	
Total Deposition	Total CVD + Sputtering + Silicon Epitaxy + Other Deposition[1]
Total CVD	Tube CVD + Nontube CVD
Tube CVD	Horizontal LPCVD + Vertical LPCVD + Horizontal PECVD
Nontube CVD	LPCVD Reactors + PECVD Reactors + Atmospheric Pressure CVD/Subatmospheric Pressure CVD + High-Density Plasma CVD
Total LPCVD	LPCVD Reactors + Horizontal LPCVD + Vertical LPCVD
LPCVD Reactors	Data Point
Horizontal LPCVD	Data Point
Vertical LPCVD	Data Point
Total PECVD	PECVD Reactors + Horizontal PECVD Reactors + High-Density Plasma CVD
PECVD Reactors	Data Point
Horizontal PECVD Reactors	Data Point
High-Density Plasma CVD	Data Point
Atmospheric Pressure CVD/ Subatmospheric Pressure CVD	Data Point
Sputtering	Data Point
Silicon Epitaxy	Data Point
Other Deposition[1]	Molecular Beam Epitaxy[1] + Metalorganic CVD[1]+ Evaporation[1]
Molecular Beam Epitaxy[1]	Data Point
Metalorganic CVD[1]	Data Point
Evaporation[1]	Data Point
Modification	
Diffusion	Vertical Diffusion + Horizontal Diffusion
Vertical Diffusion	Data Point
Horizontal Diffusion	Data Point
Rapid Thermal Processing	Data Point

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Total Ion Implantation	Medium-Current Implanter + High-Current Implanter + High-Voltage Implanter
Medium-Current Implanter	Data Point
High-Current Implanter	Data Point
High-Voltage Implanter	Data Point
Verification	
Total Process Control	Total CD/Wafer Inspection + Other Process Control[1]
Total CD-Overlay/Wafer Inspection	Optical CD-Overlay + CD SEM-Overlay + Patterned Wafer Inspection + Thin-Film Measurement[2]
Optical CD-Overlay	Data Point
CD SEM-Overlay	Data Point
Patterned Wafer Inspection	Data Point
Thin-Film Measurement[2]	Data Point
Other Process Control[1]	Data Point
Other Categories	
Other Equipment[1]	Factory Automation[1] + Ion Milling[1] + Other[1]
Factory Automation[1]	Data Point
Ion Milling[1]	Data Point
Other[1]	Data Point

[1]Not surveyed since 1991.
[2]Starting from 1994
[3]Starting from 1993
Source: Dataquest (January 1995)

Chapter 6
Semiconductor Equipment Product Category Definitions

The following semiconductor equipment product category definitions begin with total wafer fab equipment and continue through each subcategory in the same order as shown in the preceding semiconductor equipment hierarchy. At each level in the hierarchy, all subcategories which continue to this level are shown as a subcategory summation in the right-hand column. Comprehensive definitions are furnished at every level. Dataquest has organized the wafer fab equipment market into five major categories of front-end processing equipment. The equipment is defined on the basis of the function it performs in the manufacturing process.

Total Wafer Fab Equipment	Total Lithography + Resist Processing Equipment + Total Clean Process + Dry Strip + Total Dry Etch + Chemical Mechanical Polishing + Total Deposition + Diffusion + Rapid Thermal Processing + Total Ion Implantation + Total Process Control + Other Equipment
Patterning of a thin film (lithography and track)	
Total Lithography	Contact/Proximity[1] + Projection Aligners + Total Steppers + Total Direct-Write + Total Maskmaking + X-Ray
Contact/Proximity[1]	Defined as an optical patterning system in which a wafer size photomask is manually aligned over or directly on top of a wafer and then exposed to collimated light to create an image.
Projection Aligners	Defined as an optical exposure system in which an image on the mask is projected onto the wafer to create an image.
Stepper	Defined as an optical exposure system that projects a reticle image directly onto the wafer, stepping to cover the wafer with the reticle image. The advantage of stepper technology over projection aligners and contact/proximity methods is that a reticle can be produced to a lower defect level and with tighter dimensions than an entire wafer mask. Alignment of the reticle to the wafer is accomplished by transmitting a laser beam through an alignment target on the reticle and reflecting it off a corresponding pattern on the wafer.
Total Direct-Write	Direct-Write E-Beam + Direct-Write Optical
Direct-Write E-Beam	Defined as an electron beam lithographic process used in semiconductor manufacturing to directly transfer the circuit pattern to the integrated circuit being fabricated. This equipment uses no photomask or reticle to generate the pattern.
Direct Write Optical	Defined as a lithographic process, similar to direct-write e-beam, that uses a laser to transfer the circuit pattern directly to the wafer.
Total Maskmaking	Maskmaking E-Beam + Maskmaking Optical

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Maskmaking E-Beam	Defined as lithographic equipment used in semiconductor manufacturing to generate patterns on photomasks. An electron beam is used to transfer the circuit pattern to a photoresist-coated photoblank.
Maskmaking Optical	Defined as a lithographic process similar to maskmaking e-beam, but uses a laser to transfer the circuit pattern to a photoresist-coated photoblank.
X-Ray	Defined as an imaging system using X-rays as the exposure source. The main advantage of this system over conventional exposure systems is that X-ray systems provide depth of focus superior to optical lithographic techniques, and produce a much shorter wavelength than UV light, thus can resolve smaller feature sizes.
Resist Processing Equipment (Track)	Defined as equipment used to coat, bake, and develop photoresist material on wafer surfaces.
Etching and cleaning of thin films and/or substrate surfaces (clean process, dry strip, and dry etch equipment)	
Clean Process (Formerly Wet Process)	Refers to a wide range of liquid and gaseous cleaning process equipment used throughout semiconductor manufacturing whereby photoresist, organic residue, trace metal and/or dielectric, or particles are removed from the wafer surface.
Total Clean Process (Formerly Total Wet Process)	Auto Wet (Immersion) Stations + Spray Processors[2] + Vapor Phase Clean[2] + Scrubbers[2] + Post-CMP Clean[2] + Other Clean Process[1]
Auto Wet (Immersion) Stations	Defined as a cleaning station whereby the wafer and/or the wafer carriers are automatically transported through the equipment and the various immersion cleaning steps.
Spray Processors[2]	Batch Spray Processor[1] + Single-Wafer Spray Processor[2]
Batch Spray Processor[2]	A standalone piece of equipment, manual or automated, which uses nozzles inside of a chamber to spray liquid process chemicals as the reagent over a carrier of wafers. This is a cleaning/etching application on the wafer surface, and does not include chemical reprocessors that reclaim spent chemicals from the manufacturing process.
Single-Wafer Spray Processor[2]	A standalone piece of equipment (manual or automated) that uses nozzles inside of a chamber to spray liquid process chemical as the reagent over a single wafer, used as a cleaning application.
Vapor Phase Clean[2]	Defined as a piece of equipment that introduces cleaning reagents to the surface of the wafer in a gaseous or vapor form, and where by-products are pumped away using a vacuum-type pump.
Scrubber[2]	Defined as an equipment set using a brush (or similar physical structure) to remove particles from wafers. This cleaning technique may be augmented with an ultrasonic energy source.

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Post-CMP Clean[2]	Refers specifically to equipment that removes from the wafer surface the slurry residue from a chemical mechanical polishing (CMP) process.
Other Clean Process[1]	This category includes equipment that is not included as part of the equipment specifically addressed in Total Clean Process, and used as standalone wafer processing equipment. Examples include manual wet benches, wet etch, rinser/dryers, and megasonic cleaners.
Manual Wet Bench[1]	Defined as a cleaning station whereby the wafer carriers must be manually transported through the equipment.
Rinser/Dryers[1]	Defined as a technique for removing wet chemicals from the surface of a wafer, and/or drying the wafer.
Megasonics[1]	Defined as equipment that uses acoustical energy, in the 700- to 1,200-kHz frequency range, that augments standard cleaning chemicals.
Dry Strip	Defined as a process that removes a material (usually photoresist) from a wafer surface after etching using an oxygen plasma or ozone.
Total Dry Etch	Low-Density Etch + High-Density Etch
Low-Density Etch	Defined as a process that selectively removes unwanted material from a wafer by using a radio frequency (RF) plasma as the primary etch medium whereby the wafers are etched without wet chemicals. Dry etch includes both plasma etching (barrel and planer) and reactive ion etching (RIE).
High-Density Etch	Defined as a dry etch process in which the plasma is generated using a source designed to generate a high-density plasma ($\leq 10^{11}$ ions/cm^3) in a low-pressure environment. Sources in this category include inductively coupled plasma (ICP), transformer-coupled plasma (TCP), helicon wave, HRe-, and microwave-based sources (for example, ECR and microwave).
Chemical Mechanical Polishing[3]	Defined as a process that removes unwanted material from a wafer by using a corrosive liquid/solid slurry inside equipment designed to apply pressure on the active surface. This segment is specifically limited to removal of significant amounts of dielectric or metal material and does not include the process of contamination removal by chemical "scrubbing." This latter type of equipment is considered under wet processing.
Deposition of a thin film (chemical vapor deposition, physical vapor deposition, molecular beam epitaxy, and metalorganic CVD equipment)	
Total Deposition	Total CVD + Sputtering + Silicon Epitaxy + Other Deposition[1]
Chemical Vapor Deposition	Defined as a method for depositing thin films of materials that function as dielectrics, conductors, or semiconductors. A chemical containing atoms of the material to be deposited reacts with another chemical, either at an elevated temperature or in a plasma, producing the desired material, which is deposited on the wafer surface while by-products of the reaction are removed from the process chamber.

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Atmospheric Pressure CVD/ Subatmospheric Pressure CVD	Defined as a chemical vapor deposition process in which both the reaction and deposition occur at atmospheric or subatmospheric pressure.
LPCVD Reactors	Defined as a reactor in which the reaction and deposition occur at an elevated temperature and low pressure. Reactors in this category include W, WSi_x, CVDTiN, and other metal CVD systems.
PECVD Reactors	Defined as a reactor in which the reaction and deposition occur in an RF plasma, usually at reduced pressure.
High-Density Plasma CVD	Defined as a reactor in which the reaction and deposition occur in a high-density plasma (for example, ECR, ICP, and helicon), usually at reduced pressure.
Horizontal LPCVD	Defined as a CVD process in which both the reaction and the deposition take place at an elevated temperature and reduced pressure, in a horizontally oriented furnace tube.
Vertical LPCVD	Defined as a CVD process in which both the reaction and deposition take place at an elevated temperature and reduced pressure, in a vertically oriented furnace tube.
Horizontal PECVD	Defined as a system based on a standard horizontal tube furnace design in which reaction and deposition occur in an RF plasma, usually at reduced pressure.
Sputtering	A method of depositing a thin film of material on wafer surfaces. A given material (target) is bombarded with ions generated in an RF plasma, which dislodge atoms of the target material. The displaced target material atoms are deposited on the wafer surface.
Silicon Epitaxy	Defined as a process for depositing single-crystal silicon on a substrate by decomposition of a silicon precursor gas such as silane, silicon tetrachloride, or dichlorosilane.
Other Deposition[1]	Metalorganic CVD[1] + Molecular Beam Epitaxy[1] + Evaporation[1]
Metalorganic CVD[1]	Defined as a CVD technique using metalorganic precursors such as trimethylgallium that react at elevated temperatures to deposit thin films of compound semiconductor materials such as GaAs.
Molecular Beam Epitaxy[1]	Defined as a process for depositing thin films of elemental or compound materials by direct transport of the film materials from a heated source to the wafer surface, carried out in a high vacuum. This process is similar to evaporation.
Evaporation[1]	A process that uses heat to change a material (usually a metal or metal alloy) from a solid to a gaseous state, with the atoms in the resulting vapor being deposited on the wafer as a solid thin film.
Modification properties of a thin film or substrate (diffusion, RTP, and ion implantation)	
Diffusion	A high-temperature annealing process that allows impurities (dopants) introduced into a substrate material to spread or diffuse into the substrate.
Rapid Thermal Processing	A process that performs a high-temperature diffusion, CVD, or epitaxial process in a short period.

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Ion Implantation	A process that introduces impurities into a substrate by means of ion bombardment to achieve the desired electrical properties in defined areas of a wafer.
Verification that all previous steps in the fabrication process have been performed correctly (process control equipment including optical critical dimension (CD) measurement, CD scanning electron microscopy (SEM), and wafer inspection).	
Critical Dimension Measurement Equipment (CD-Overlay)	A critical dimension of a semiconductor device refers to a line, element, or feature that must be manufactured and controlled to tight specifications. CD measurement equipment checks the widths of the line, elements, or features of critical circuit patterns as well as contact areas.
Scanning Electron Microscope	A microscope used to magnify images by using an electron beam rather than light.
Patterned Wafer Inspection	Wafer inspection refers to the inspection of patterned wafers for process defects by visual and image processing techniques.
Thin-Film Measurement[2]	Defined as a measurement tool used to ascertain the composition, thickness, and quality of the thin-film layer deposited on the wafer. The tool may use some assumptions on the physical parameters of the film to measure its reflectivity, thickness, and refractive index. Semiconductor manufacturing processes such as planarization, PVD, CVD, diffusion, etch, and lithography are among the segments that may use these tools.
Other Process Control[1]	Other process control represents a broad market that includes mask, metrology, inspection and repair equipment, surface particle detection systems, film thickness measurement equipment, as well as other categories of process monitoring equipment, surface analysis equipment, and analytical instrumentation. This is a highly fragmented market with dozens of companies selling into a multitude of noncompetitive market niches.
Other Categories	
Other Equipment[1]	Factory Automation[1] + Ion Milling[1] + Other[1]
Factory Automation[1]	Includes CIM software for shop floor control, factory host computer systems, cell controllers and interface hardware, and wafer transport systems, including automatic guided vehicles and rail transport systems.
Ion Milling[1]	Defined as a process that uses a beam of charged particles to remove material from a wafer. Also known as sputter etching or ion beam etching.
Other[1]	A general catchall category that includes the other capital equipment used throughout the fab but not classified within the other five major types of wafer processing equipment. Included in this segment are decontamination systems, wafer markers, gas analyzers, storage stations, and other types of equipment.

[1]Not surveyed since 1991
[2]Starting from 1994
[3]Starting from 1993
Source: Dataquest (January 1995)

Chapter 7
Worldwide Geographic Region Definitions

North America

Includes Canada, Mexico, and the United States (50 states).

Japan

Japan is the only single-country region.

Europe

Western Europe

Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and rest of western Europe (Andorra, Cypress, Gibraltar, Iceland, Liechtenstein, Malta, Monaco, San Marino, Turkey, and Vatican City).

Eastern Europe

Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (including Armenia, Azerbaijan, Belorussia, Georgia, Kazakhstan, Kirgystan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan).

Asia/Pacific

Includes Asia/Pacific's Newly Industrialized Economies (NIEs) and the Rest of Asia/Pacific regions. NIEs include Hong Kong, Singapore, Korea, and Taiwan. The Rest of Asia/Pacific region includes Australia, Bangladesh, Brunei, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.

Rest of World

Includes Africa, Caribbean, Central America, Middle East, Oceania, and South America.

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WORLDWIDE 1995
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TABLE OF CONTENTS

FOCUS STUDIES

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Focus Studies

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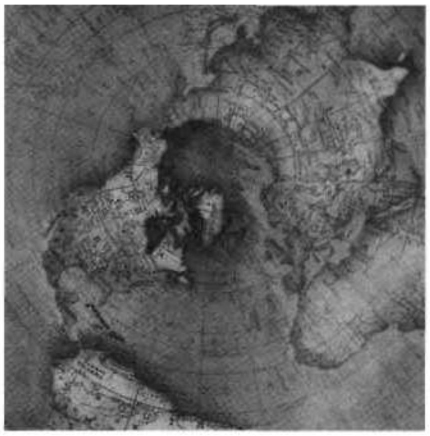

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Focus Report

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
Product Code: SEMM-WW-FR-9502
Publication Date: November 13, 1995
Filing: Focus Studies

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Product Code: SEMM-WW-FR-9502
Publication Date: November 13, 1995
Filing: Focus Studies

Table of Contents

List of Figures

List of Tables

Chapter 1
Executive Summary

The last silicon shortage occurred during the semiconductor boom of 1984, and the silicon industry invested heavily. In 1985, the silicon industry was hit very hard, with consumption down over 30 percent in terms of million square inches (MSI) of silicon. The industry had been dramatically overbuilt, with factory utilization under 50 percent commonplace. Even the boom of 1988 to 1989 did not fully use the capacity added during the previous expansion.

The silicon industry has the most capital-intensive cost structure in the semiconductor food chain. With the high fixed costs of the business during 1983 to 1985, the industry has been awash in red ink, accumulating losses collectively for nine consecutive years, from 1985 through 1993. This year, 1995, will likely be the first year when nearly all companies in the group will be profitable in recent memory. It is not too surprising that silicon manufacturers have been relatively cautious about adding capacity until recently.

Only one supply constraint has been considered in recent forecasts, the supply of 200mm wafers starting in 1996. No others were considered because it was generally assumed that capacity would be available to meet this demand. We know now, however, that four constraints need to be considered, as follows:

- Supply constraint of 200mm wafers
- The recent emergence of a supply squeeze on 100mm and 125mm wafers
- The industry's capacity for supplying 150mm wafers and its willingness (or unwillingness) to invest in these plants
- The raw material supplied to all crystal pulling operations

The basic concept of this report is to review all these constraints and to perform analyses considering reactions in the semiconductor market to availability and supplier response and considering dynamics in the supply side of the market.

This report is intended to describe issues and alternative outcomes and is not intended to present a specific forecast. This silicon supply market is interactive and complex, and many things now need to be considered to develop a forecast. Our next silicon forecast update is scheduled to be released near the end of December.

Some basic conclusions can be drawn from this report:

- At this point, the semiconductor industry's ability to achieve the forecast $330 billion by 2000 is not at risk, but the industry is really close to its limit with the current infrastructure.

- The silicon market is in or near shortage today, depending on the segment, and is expected to impact the operation of semiconductor companies by mid- to late 1996.
- The two most serious shortages will be the polysilicon raw material (1996) and 150mm wafers (long term).
- With the help of capital from semiconductor companies and other sources, silicon companies will have to invest significantly in 150mm capacity. We expect that "capital-for-guaranteed-supply" deals will be required for eight to fifteen new 150mm plants by 2000.
- Test wafer usage will need to be dramatically reduced, particularly at 200mm.
- The use of reclaim wafers will explode within the next year.
- Semiconductor companies face difficult investment challenges as 100mm and 125mm wafers become scarce. The choices are to build new fabs, convert older fabs to process 150mm wafers, pay significantly higher prices for wafers, or use alternative sources of capacity such as foundries.

Chapter 2
Setting the Stage

The last silicon shortage was during the semiconductor boom of 1984. At that time, the semiconductor industry offered a new and exciting place to invest. Silicon plant expansions were plentiful, with many new entrants, particularly the large and traditionally industrial Japanese conglomerates.

We remember many examples of double-ordering on the chip component side, but there was much double-ordering in silicon as well, and allocations were common. When 1985 came, the silicon industry was hit very hard, with consumption down over 30 percent in terms of million square inches (MSI) of silicon. The industry had been dramatically overbuilt, with factory utilization under 50 percent commonplace. Even the boom of 1988-1989 did not fully use the capacity that had been built during that period.

The silicon industry has the most capital-intensive cost structure in the food chain. With the high fixed costs of the business during 1983 to 1985, the industry has been awash in red ink, accumulating losses collectively over the nine years, from 1985 through 1993. (The industry had one or two marginally profitable years during this span but remained in a trend of losses.)

The silicon industry has only recently recovered from these times, with marginal profitability in 1994 (although some Japanese suppliers still suffered losses). This year, 1995, will likely be the first year in some time when nearly all companies in the group will be profitable. The industry is now very concentrated, with the top seven companies holding about 92 percent of the market—far different from 1985. A list of the top 10 companies and their 1994 revenue is shown in Table 2-1.

Table 2-1
Top 10 Silicon Wafer Manufacturers Worldwide Revenue Market Share and Ranking, 1994

1994 Rank	Company	Revenue ($M)	Market Share (%)
1	Shin-Etsu Handotai	1,174.3	25.6
2	MEMC Electronic Materials (Including Joint Ventures)	757.6	16.5
3	Sumitomo Sitix	582.4	12.7
4	Wacker-Siltronic	500.4	10.9
5	Mitsubishi Materials Silicon	475.2	10.3
6	Komatsu Electronic Metals	452.9	9.9
7	Toshiba Ceramics	275.0	6.0
8	Nittetsu Denshi (NSC Electron)	105.8	2.3
9	Lucky Advanced Materials (Siltron)	89.8	2.0
10	UniSil	40.0	0.9
	Total Silicon Wafer Market	4,591.9	100.0
	Top 10 Companies as a Group	4,453.4	97.0

Source: Dataquest (November 1995)

It is not too surprising, given this history, that silicon manufacturers have until very recently been relatively cautious about adding capacity. Memories of 1985 still haunt the industry, but manufacturers have learned many lessons about this marketplace.

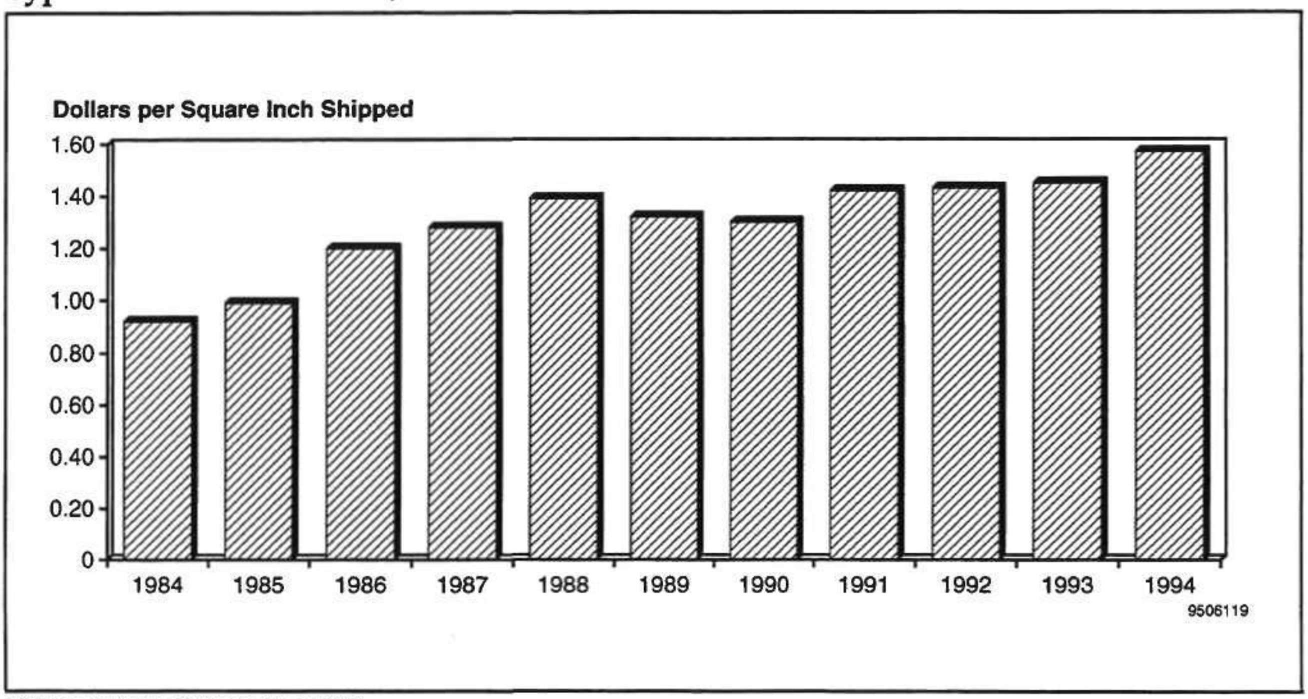
Within the silicon industry, several balancing acts must be performed in managing capacity additions. This report will review the many facets of the industry, how they are linked, how shortages can emerge and as easily disappear, and what dynamics and adjustments are in store.

On the Road to Good Health

Today's strong market conditions and the semiconductor industry's migration to 200mm wafers will offer the silicon industry the opportunity to heal completely over the next five years. There is a fine line to be walked, however, between a perpetual balanced-to-tight market and the temptation to overbuild (or attract new entrants to the market to overbuild).

Figure 2-1 represents the average revenue realized by wafer companies per square inch consumed. On the surface, there is a general upward trend, but this is deceiving. There was a large jump from 1984 to 1988 from about 90 cents to the $1.30-to-$1.40-per-square-inch range. This is indicative of the semiconductor's migration to 150mm wafers as the primary wafer used and of the increased use of epitaxial silicon (which sells for a higher price) for microprocessors. Both of these migrations were to higher cost structures—margins did improve, but not to the point of overall profitability. Wafer sizes smaller than 150mm still represent a loss product in the mix.

Figure 2-1
Worldwide Silicon Wafer Industry Average Revenue per Square Inch, 1984-1994 (All Types and Sizes of Wafers)



Source: Dataquest (November 1995)

Revenue remained fairly stable per square inch from 1988 through 1993, but then took another jump in 1994 (and this upward trend is expected to continue through the rest of the decade). This is primarily the result of the semiconductor industry's migration to 200mm wafers, which generally sell for over $2 per square inch (epitaxial wafers are significantly higher). This migration to 200mm wafers spells health returning to the industry.

The silicon industry is becoming vibrant again, with capital commitments for expansions in the area of several billion dollars announced within the last twelve months. New entrants have not come into the market because of the current high entry barriers (a new plant can cost between $250 million and $600 million), but new sources of capital are being tapped. Examples are MEMC's two joint ventures with Samsung (Posco-Hüls) and China Steel (Taisil) and Komatsu's recently announced joint venture with Formosa Plastics in Taiwan. MEMC also recently floated an initial public offering on the New York Stock Exchange that netted about $440 million. This offering represents the first significant tapping of the public market for capital specifically for the silicon industry.

Our Current Silicon Wafer Forecast

Every July and December, Dataquest updates the silicon consumption forecast by region. Factors taken into account in this forecast are semiconductor demand, trends in regional revenue per square inch generated by semiconductor companies in their use of silicon, and size distribution analysis through our extensive fab database. We have also begun taking into consideration the supply constraint expected in 200mm wafers (discussed more fully in Chapter 4).

Tables 2-2 through 2-4 represent our July 1995 forecast for the silicon industry. Table 2-2 shows the worldwide wafer size distribution forecast, and Table 2-3 and 2-4 provide more detail behind the use of test and monitor wafers by size. We will discuss the test and monitor wafer market at length through the course of this report. (A bookmark of some kind placed at these tables may be helpful to those who wish to refer to them later.)

As mentioned previously, only one supply constraint was considered in this forecast, the supply of 200mm wafers starting in 1996. A supply constraint in the 200mm market will mean that more 150mm wafers will be processed for a longer period and that moderately fewer 200mm wafers will be used for test wafers. Both these factors have been included in the silicon wafer size distribution forecast in Table 2-2, and, for 200mm wafers, the forecast is close to supply-side constraints.

No other supply constraints were considered because it was generally assumed that capacity would be available to meet this demand. We know now, however, that four constraints need to be considered, as follows:

- The supply constraints for 200mm wafers
- The recent emergence of a supply squeeze on 100mm and 125mm wafers
- The industry's capacity for supplying 150mm wafers and its willingness (or unwillingness) to invest in these plants
- The raw material supplied to all crystal pulling operations

Table 2-2
Worldwide Total Wafer Size Distribution Forecast, 1993-2000

Diameter	Area (Sq. In.)	1993	1994	1995	1996	1997	1998	1999	2000
Percent Square Inches by Diameter									
2 Inches	3.14	0.1	0.1	0.1	0.1	0	0	0	0
3 Inches	7.07	1.6	1.4	1.2	1.0	0.8	0.7	0.6	0.5
100mm	12.17	16.1	14.8	13.2	11.6	10.3	9.5	9.0	8.4
125mm	19.02	28.8	24.7	22.6	19.8	17.8	16.6	15.4	14.3
150mm	27.38	49.6	48.0	46.5	46.2	45.0	43.8	42.5	41.2
200mm	48.67	3.6	11.0	16.4	21.4	26.1	29.3	32.3	35.5
300mm	109.56	0	0	0	0	0	0	0.1	0.1
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total—MSI		2,450	2,919	3,409	3,987	4,478	4,743	5,133	5,681
Growth (%)		16.8	19.2	16.8	16.9	12.3	5.9	8.2	10.7
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 Inches	3.14	1.01	1.10	1.18	0.73	0.57	0.63	0.35	0
3 Inches	7.07	5.59	5.72	5.89	5.72	5.33	4.70	4.60	4.01
100mm	12.17	32.49	35.51	36.85	37.86	37.89	37.15	37.96	39.13
125mm	19.02	37.13	37.89	40.51	41.43	41.89	41.37	41.55	42.60
150mm	27.38	44.41	51.17	57.95	67.29	73.53	75.86	79.72	85.48
200mm	48.67	1.84	6.60	11.46	17.53	23.99	28.55	34.04	41.45
300mm	109.56	0	0	0	0	0	0.02	0.06	0.07
Total Wafers (M)		122.5	138.0	153.9	170.6	183.2	188.3	198.3	212.8
Average Wafer Diameter (Inches)		5.05	5.19	5.31	5.45	5.58	5.66	5.74	5.83

Source: Dataquest (November 1995)

The basic concept of this report is to review the situation regarding all these constraints and to perform the following analysis:

- For all cases except 200mm wafers we will produce two scenarios that will describe a forecast window. One scenario in all cases will be the forecast described in Table 2-2. An alternative will reflect what might be possible based on reactions in the market to availability and supplier response.
- We will describe dynamics in the supply side of the market and how companies may change in their supply of specific wafer sizes.
- We will describe reactions to the supply side that we believe are occurring on the demand side (that is, semiconductor manufacturers) that we expect will occur.

This report is intended to describe issues and alternative outcomes and is not intended to present a specific forecast. This silicon supply market is interactive and complex, and many things now need to be considered to develop a forecast. Our next silicon forecast update is scheduled to be released near the end of December.

Table 2-3
Worldwide Test/Monitor Wafer Size Distribution Forecast, 1993-2000

Diameter	Area (Sq. In.)	1993	1994	1995	1996	1997	1998	1999	2000
Million Square Inches by Diameter									
2 Inches	3.14	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0
3 Inches	7.07	2.0	2.0	2.1	2.0	1.9	1.7	1.6	1.4
100mm	12.17	41.4	34.9	29.3	30.4	30.5	29.8	30.2	31.1
125mm	19.02	87.8	82.2	75.0	72.8	69.4	68.4	64.3	66.1
150mm	27.38	221.4	212.8	241.7	281.2	308.2	296.9	290.2	298.5
200mm	48.67	56.3	176.7	278.9	384.0	467.0	528.0	596.5	665.8
300mm	109.56	0	0	0	0	0	1.7	5.5	6.2
Total MSI Test/ Monitor		409.0	508.8	627.2	770.6	877.1	926.7	988.4	1,069.0
Percentage of Total MSI		16.70	17.43	18.40	19.33	19.59	19.54	19.26	18.82
Growth Rate (%)		18.3	24.4	23.3	22.9	13.8	5.7	6.7	8.2
Millions of Wafers									
2 Inches		0.05	0.06	0.06	0.04	0.03	0.03	0.02	0
3 Inches		0.28	0.29	0.29	0.29	0.27	0.24	0.23	0.20
100mm		3.40	2.86	2.41	2.50	2.51	2.45	2.48	2.55
125mm		4.62	4.32	3.94	3.83	3.65	3.60	3.38	3.47
150mm		8.09	7.77	8.83	10.27	11.26	10.85	10.60	10.90
200mm		1.16	3.63	5.73	7.89	9.59	10.85	12.26	13.68
300mm		0	0	0	0	0	0.02	0.05	0.06

Source: Dataquest (November 1995)

Table 2-4
Worldwide Test/Monitor Wafer Use by Size, 1993-2000 (Percent Square Inches by Diameter)

Diameter	1993	1994	1995	1996	1997	1998	1999	2000
2 Inches	5.0	5.0	5.0	5.0	5.0	5.0	5.0	NA
3 Inches	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
100mm	10.5	8.1	6.5	6.6	6.6	6.6	6.5	6.5
125mm	12.4	11.4	9.7	9.2	8.7	8.7	8.1	8.2
150mm	18.2	15.2	15.2	15.3	15.3	14.3	13.3	12.8
200mm	63.0	55.0	50.0	45.0	40.0	38.0	36.0	33.0
300mm	NA	NA	NA	NA	NA	80.0	80.0	80.0

NA = Not applicable
Source: Dataquest (November 1995)

Chapter 3
Polysilicon—The Raw Material Outlook

All single-crystal silicon wafers manufactured come from the same raw material—pure silicon. Industrial metal grade is not pure enough for semiconductor applications, so the silicon must be purified through chemical processing. The method initially converts the industrial grade metal silicon to a gaseous or liquid silicon compound, such as silane or trichlorosilane, and then processes the chemical through distillation or other purification method to produce a very high-grade chemical. Once purified, the silicon-containing material is then broken down into its components through a form of crystallization to produce semiconductor-grade silicon. This crystallization process produces a polycrystalline material, so the industry refers to this material as "polysilicon." Polysilicon is purchased by wafer manufacturers to melt before the single-crystal growing process.

Polysilicon Producers

There are only a handful of polysilicon producers in the world, and the top two producers will supply just under 50 percent of the world's requirements in 1995. The suppliers fit into three basic categories: captive, hybrid-captive, and merchant.

Captive Producers

Captive producers are silicon wafer manufacturers that have polysilicon production within their companies and consume virtually all of the material internally. Sumitomo Sitix and Hüls (MEMC) are considered by Dataquest to be captive producers, and their operations are discussed in the Appendix of this report. Both these producers use the trichlorosilane process to produce polysilicon.

Hybrid-Captive Producers

Hybrid-captives are silicon companies that produce polysilicon and consume the majority of production. A minor portion, therefore, is sold to other silicon wafer producers. However, for this class of producer, distribution outside the company is limited—either amounts are small or the polysilicon is sold to a few companies only. Two companies fall into this category.

Albemarle Corporation

Albemarle Corporation (recently acquired by MEMC Electronic Materials) is the only company to produce polysilicon in granular, or pellet, form. The nature of its proprietary fluidized bed reaction process creates polysilicon in this form rather than in conventional rod or block form. Albemarle first commercialized this process in 1987, when it was a division of Ethyl Corporation. Polysilicon operations and the plant in Pasadena, Texas, were spun off to Albemarle Corporation in 1993. Since this form of polysilicon requires that special feeding equipment be attached to the crystal growers, the material has gained only limited acceptance.

Earlier this year, MEMC Electronic Materials, which was purchasing over 90 percent of Albemarle's production, acquired the polysilicon operations. Because the amount of material now being shipped outside of MEMC represents less than 10 percent, Dataquest considers the Albemarle operation to be a hybrid-captive. Although we understand that the granular polysilicon produced by Albemarle will be available for sale outside of MEMC, the proposals for the acquisition that we have reviewed expect the vast majority of production to be locked up to MEMC.

We expect Albemarle's production to be about 950 metrics tons in 1995. Even though the capacity of the plant is rated at 1,250 metric tons, the plant and the process have never run at that rate. Dataquest believes that the near-term (1996) maximum production is about 1,100 tons, and we have factored growth to the 1,200 ton level for the rest of the decade. Beyond the existing plant, it is unclear whether MEMC will invest in more internal production from this facility in this decade. The key advantages of the granular form are believed to be clearly evident for 300mm wafers, but we do not expect demand for polysilicon driven by 300mm wafers to be significant before 2002. After that, we would expect MEMC to expand the capacity of this operation aggressively. The only reason MEMC would invest in expansion before then would be to avert shortages in the market, so a major expansion could occur as early as 1998.

Hi-Silicon (Kojundo Silicon)

Hi-Silicon Co. Ltd. (also known as Kojundo Silicon) is located in Yokkaichi City, Mie Prefecture, Japan. Hi-Silicon was originally formed in 1967 as a 50-50 joint venture between Mitsubishi Metal and Osaka Titanium Company (now Sumitomo Sitix). In October 1987, Osaka Titanium announced that it had sold its 50 percent position in Hi-Silicon to Mitsubishi Metal for an undisclosed sum. Mitsubishi Materials Silicon currently consumes more than half the production from this operation, with the remainder distributed to a limited number of companies. For this reason, Dataquest considers Hi-Silicon to be a hybrid-captive producer.

Dataquest estimates that Hi-Silicon's production in 1995 will be expanded slightly to 1,200 tons and then capped at 1,400 tons in 1996 through 1998. Hi-Silicon uses the trichlorosilane process in the production of polysilicon. A major expansion is forecast, with production starting to ramp during 1999.

Merchant Producers

Merchant producers are those companies with a wide distribution of silicon wafer companies as customers. As is customary in this industry, consumption of polysilicon can be concentrated and account for a large block of production capacity for even the largest producer. There are four merchant producers, and these four also happen to rank as the four largest producers.

Advanced Silicon Materials Incorporated

Even though Advanced Silicon Materials (ASiMI) is owned by Komatsu, a silicon wafer manufacturer, and Komatsu consumes a significant portion of capacity (although estimated to be less than 50 percent), ASiMI's wide distribution (over a dozen outside customers) qualifies it as a merchant supplier. ASiMI's plant is located in the Pacific Northwest region of the United States, in Moses Lake, Washington.

ASiMI manufactures polysilicon by a proprietary method that converts trichlorosilane first to monosilane gas. This method, known as the Komatsu method, refines the silane gas to high purity, then decomposes it into very high-purity polycrystalline silicon material. This high-grade material has advantages in the float-zone crystal growing process. An example of parts that use float-zone crystal is high-voltage power devices.

Dataquest estimates that ASiMI is running its plant essentially at full capacity, producing 1,200 metric tons during 1995. Some incremental expansion, plus a new plant, will double its production capacity in the next three years.

Besides its internal usage of silane in polysilicon production, ASiMI is also a major supplier of high-purity silane to the semiconductor industry for processing applications such as epitaxy and chemical vapor deposition (CVD).

Hemlock Semiconductor Corporation

Initially formed as a wholly owned subsidiary of Dow-Corning, Hemlock started production at its first polysilicon plant in 1963. Hemlock gets its name from the city where the plant was built— Hemlock, Michigan, northwest of Detroit. In 1984, Hemlock became a joint-venture company, with two major silicon wafer manufacturers purchasing interests in the company. Shin-Etsu Handotai (SEH) and Mitsubishi Materials Silicon own 24.5 percent and 12.25 percent, respectively, while Dow-Corning retains 63.25 percent ownership.

Hemlock took the honor of being the largest producer of polysilicon from Wacker-Siltronic, with an estimated production of 2,800 tons in 1995 (about 24 percent of the world's production) and a capacity of 3,400 tons to be in place by the end of the year. Hemlock is expanding aggressively, bringing Phase I fully on line this year, with a Phase II production recently accelerated to start at the beginning of 1997. Hemlock has not made a formal commitment to Phase III, but Dataquest estimates that the company will start Phase III production in late 1999 or early 2000. This expansion will propel Hemlock well ahead of Wacker-Siltronic as the largest producer of polysilicon.

While a good portion of its capacity is allocated to the joint-venture companies, Hemlock enjoys a broad list of customers as a merchant supplier. Hemlock uses the trichlorosilane process to produce polysilicon rods and chunks. Its manufacturing techniques are similar to Wacker-Siltronic in that Hemlock is linked to a chemical manufacturer, Dow-Corning, as its source of supply of the liquid trichlorosilane.

Hemlock is also a supplier of high-purity silicon tetrachloride, a natural by-product of the manufacturing process, and serves a niche market in fiber optics and some medical applications.

Tokuyama

Tokuyama is unique in the polysilicon market in one respect—it is the only company that is not at least partly owned by a silicon wafer manufacturer. It is ranked as the third-largest polysilicon producer, with estimated production of 1,650 tons in 1995. Improvement and expansion of their existing plant will take this to 2,000 tons in 1996, and Tokuyama recently announced a new plant that will expand its capacity to 3,000 tons in the beginning of 1997.

Tokuyama Soda entered the polysilicon market in 1984; by 1985 its 1,200 ton plant was the largest of its kind in Japan. Tokuyama also uses the trichlorosilane process to produce polysilicon. Silicon tetrachloride, a high-grade byproduct of the process, is used by Tokuyama Soda as the raw material for a fumed silica used in several applications in electronics, including encapsulation materials for semiconductor packaging.

Wacker-Siltronic

Wacker-Siltronic has the distinction of being the most experienced company in the polysilicon manufacturing business. Built in the late 1950s, Wacker-Siltronic's Burghausen facility continues to use the trichlorosilane process to produce polysilicon. Today, as is also true for Hemlock/Dow-Corning, its supply of chemicals for the process is at least partly linked with its parent chemical company, Hoechst.

Wacker-Siltronic lost the lead in the production of polysilicon to Hemlock, producing an estimated 2,500 metric tons in 1995 (versus Hemlock's 2,800). Wacker-Siltronic has expanded continually to meet its and its customer's demands and is expected to almost double production by the year 2003.

Even though Wacker-Siltronic consumes close to half of its own production of polysilicon, it has a broad customer base in the silicon wafer market. This broad base of customers qualifies Wacker-Siltronic as a merchant supplier. Wacker-Siltronic is also a major manufacturer of high-grade chlorosilanes and ultrapure hydrogen chloride, natural by-products of the manufacturing process.

Supply-Side Forecast through the Year 2000

Based on known and estimated expansion plans, Dataquest has developed a supply forecast for polysilicon production through 2000. This forecast is shown in Table 3-1. It should be noted that these figures refer to actual production estimates and not facility capacity. In many cases, we have factored in ramp-up schedules.

Demand Forecast for Polysilicon

Before presenting our demand forecast, a discussion about the approach, methodology, and assumptions used is in order. All of our forecast analysis has as a starting basis the wafer slice forecast by wafer size, initially presented in our Midyear Forecast Market Trends report (SEMM-WW-MT-9501, July 31, 1995). A summary of worldwide demand is shown in Table 3-2 (this is identical to the forecast shown previously in Table 2-2).

Table 3-1
Worldwide Actual and Projected Polysilicon Production by Supplier, 1992-2000 (Thousands of Metric Tons per Year)

	1992	1993	1994	1995	1996	1997	1998	1999	2000
U.S. Production									
Albemarle (Now MEMC)	0.60	0.65	0.85	0.95	1.10	1.20	1.20	1.20	1.20
Hemlock Semiconductor	1.40	1.40	2.30	2.80	3.40	4.20	5.00	5.00	5.40
Advanced Silicon Materials	1.10	1.10	1.10	1.20	1.40	2.00	2.10	2.10	2.10
Japanese Production									
Hi-Silicon (Kojundo Silicon)	0.80	0.90	1.10	1.20	1.40	1.40	1.40	2.10	2.40
Komatsu Electronic Metal	0.03	0	0	0	0	0	0	0	0
Sumitomo Sitix	0.50	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Tokuyama	1.10	1.15	1.65	1.65	2.00	3.00	3.00	3.00	3.00
European Production									
Hüls	0.40	0.70	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Wacker	2.30	2.30	2.40	2.50	2.50	2.75	3.35	3.60	3.95
Worldwide Total	8.23	8.65	10.60	11.50	13.00	15.75	17.25	18.20	19.25

Source: Dataquest (November 1995)

Table 3-2
Worldwide Wafer Size Distribution Forecast, 1993-2000 (Slices per Year; Includes Virgin Test/Monitor Wafers)

Diameter	Area (Sq. In.)	1993	1994	1995	1996	1997	1998	1999	2000
Unit Distribution by Wafer Starts (Millions of Wafers)									
2 Inches	3.14	1.01	1.10	1.18	0.73	0.57	0.63	0.35	0
3 Inches	7.07	5.59	5.72	5.89	5.72	5.33	4.70	4.60	4.01
100mm	12.17	32.49	35.51	36.85	37.86	37.89	37.15	37.96	39.13
125mm	19.02	37.13	37.89	40.51	41.43	41.89	41.37	41.55	42.60
150mm	27.38	44.41	51.17	57.95	67.29	73.53	75.86	79.72	85.48
200mm	48.67	1.84	6.60	11.46	17.53	23.99	28.55	34.04	41.45
300mm	109.56	0	0	0	0	0	0.02	0.06	0.07
Total Wafers (M)		122.5	138.0	153.9	170.6	183.2	188.3	198.3	212.8
Average Wafer Diameter (Inches)		5.05	5.19	5.31	5.45	5.58	5.66	5.74	5.83

Source: Dataquest (November 1995)

One item is notable about this forecast. The forecast ramp shown for 200mm wafers in Table 3-2 is below demand at present (derived through a bottom-up analysis of fabs) by about 35 percent and is slightly below supply (derived through bottom-up of suppliers)—within 3 percent (see Chapter 4 for further analysis). This represents a good starting point for calculating demand for polysilicon but has to be adjusted.

Using this data and forecast as a basis, we apply an estimate for the average number of grams of polysilicon used to manufacture one good polished wafer. In terms of grams per square inch, this varies among the various wafer sizes. For example, just over 3.1 grams per square inch was assumed for 100mm wafers and about 4.4 grams per square inch was assumed for 200mm wafers. The average per year varies based on the wafer size mix. When these assumed values were multiplied and added, we arrive at a gross polysilicon demand in thousands of tons per year.

For this analysis, we made one other basis adjustment. The wafer size distribution forecast shown in Table 3-2 uses an underlying semiconductor market forecast of $275 billion in 2000. As this report was being prepared, Dataquest's semiconductor forecast was revised and now forecasts the semiconductor market at nearly $330 billion. This was compared with the original basis, and a factor was calculated for each year in our polysilicon forecast. Of course, not all of the percentage increase in the underlying semiconductor market "trickles down" to polysilicon consumption (because semiconductor producers are yielding higher revenue per square inch over time). Therefore, the forecast was adjusted upward between 3 and 8 percent based on a year-to-year comparison for 1995 to 2000.

As a natural fallout of this methodology in forecasting polysilicon demand, we have now chosen a point for 200mm consumption that is about equal to the current supply scenario described in Chapter 4 for 2000. This forecast represents a conservative view of how the supply/demand imbalance will actually play in the market and represents a good basis for determining polysilicon demand.

Considering Two Scenarios

The result of this methodology and model yields "Scenario H" (see Table 3-3) for polysilicon demand, and we believe this represents the highest values for demand. We believe that two major forces need to be considered that will result in lower polysilicon demands, so we will construct "Scenario L" (also shown in Table 3-3) representing the lowest-demand scenario based on our underlying semiconductor forecast. These two factors are reduced use of virgin test or monitor wafers and implementation of wire saw technology for 200mm ingots.

First, we assume that as the shortage becomes pronounced during 1996 a combination of availability of wafers and a shrinking price differential between test and prime wafers will "permanently" change (at least through 2000) how semiconductor companies use test wafers. This "lifestyle" change will take two forms: elimination of test wafer use and migration to the use of reclaim wafers—both will reduce polysilicon demand. We have assumed across all wafer sizes that about 25 percent of virgin test wafer demand will disappear or change in 1996 and 35 percent for every year after 1996 through 2000.

Second, implementation of wire saws instead of blade saws will result in lower kerf losses and enable more 200mm wafers to be yielded per ingot. This will lower the ratio of grams per square inch for 200mm wafers. We have assumed that kerf losses can be reduced by about 30 percent (we have heard reductions from 20 to 50 percent). Further, this technology will not be fully implemented across the entire installed production base for 200mm wafers, so we are assuming "full" market penetration at 75 percent of the production base. We believe that the wire saws could be fully penetrated by 1999 at this level. We are assuming that no production today implements wire saws and that the technology will start at 15 percent penetration in 1996, ramping to the full 75 percent by 1999.

The result of the Scenario L calculation is shown in Table 3-3, which taken together with the initial high-demand scenario creates a "window" for demand. Reality lies somewhere between these two scenarios. Also included for reference is the percentage of the difference attributable to reduced virgin test wafer consumption.

Supply and Demand Compared

By comparing the supply from Table 3-1 with the demand outlooks from Table 3-3, we can create a supply and demand analysis that will describe the minimum and maximum number of 1,500-ton plants required for the rest of the decade.

However, we need to factor in one more variable—the industry's stock inventory of polysilicon, which Dataquest estimates was 2,730 metric tons at the end of 1994.

Tables 3-4 and 3-5 summarize the supply/demand issues for the polysilicon industry through 2000. The conclusion is that somewhere between one and three additional plants are required—above the already aggressive expansion plans of the industry. One of these is required quickly, and the others can wait until after 1998.

Table 3-3
Two Demand Scenarios for Polysilicon, 1993-2000 (Thousands of Metric Tons per Year)

	1993	1994	1995	1996	1997	1998	1999	2000
Highest-Demand Scenario	8.99	10.90	13.28	16.12	18.57	19.53	21.17	24.27
Lowest-Demand Scenario	8.99	10.90	13.28	15.33	17.02	17.65	18.90	21.60
Percentage of Difference Accounted for by Reduced Virgin Test Wafer Use	-	-	-	90	86	74	66	63

Source: Dataquest (November 1995)

Table 3-4
Worldwide Polysilicon Demand/Supply—Highest-Demand Scenario, 1992-2000 (Maximum Test Wafer Consumption, No Saw Technology Impact) (Thousands of Metric Tons per Year)

	1992	1993	1994	1995	1996	1997	1998	1999	2000
Polysilicon Demand	7.60	8.99	10.90	13.28	16.12	18.57	19.53	21.17	24.27
Polysilicon Production	8.23	8.65	10.60	11.50	13.00	15.75	17.25	18.20	19.25
Net Annual Surplus or Deficit	0.63	-0.34	-0.30	-1.78	-3.12	-2.82	-2.28	-2.97	-5.02
Industry Stock Inventory	-	-	2.73	0.95	-2.17	-4.99	-7.27	-10.24	-15.25
Number of New Plants Required (1,500-Ton)					2				1

Source: Dataquest (November 1995)

Table 3-5
Worldwide Polysilicon Demand/Supply—Lowest-Demand Scenario, 1992-2000 (Reduced Test Wafer Consumption, Saw Technology Impact Included) (Thousands of Metric Tons per Year)

	1992	1993	1994	1995	1996	1997	1998	1999	2000
Polysilicon Demand	7.60	8.99	10.90	13.28	15.33	17.02	17.65	18.90	21.60
Polysilicon Production	8.23	8.65	10.60	11.50	13.00	15.75	17.25	18.20	19.25
Net Annual Surplus or Deficit	0.63	-0.34	-0.30	-1.78	-2.33	-1.27	-0.40	-0.70	-2.35
Industry Stock Inventory	-	-	2.73	0.95	-1.37	-2.65	-3.05	-3.74	-6.09
Number of New Plants Required (1,500-Ton)					1				

Source: Dataquest (November 1995)

Dataquest Perspective

It appears that a polysilicon shortage is unavoidable during the second half of 1996, but it may last only nine to 12 months, based on reactions that are likely to occur. We believe that the most likely market response is the introduction of one or two new entrants into the polysilicon market. This is almost required, because the major polysilicon producers are expanding nearly as fast as they can through 1997.

Where would these new entrants come from? We would first look to Korea because it seems to be the most logical origination. Why? First, Korean companies have money. Second, Korean companies have a keen interest in anything semiconductor-related. But third, and most important, the Korean wafer suppliers Siltron and Posco-Hüls have the most to lose in a polysilicon shortage! Siltron, in particular, has no captive capacity nor does it have any ownership interest in a merchant polysilicon producer. Every other major silicon wafer supplier has one, if not both, elements. Siltron and Posco-Hüls are the most motivated in the market to seek a Korean supply of polysilicon. We would point out that MEMC does provide support for Posco-Hüls in the market, so we really expect only Siltron to be at risk.

The other place we would look is in the United States. Why? The U.S. manufacturer is eager to support parts of the semiconductor industry where there has historically been reliance on foreign-owned companies. Capital and customers should be available to support such a venture.

Will the impending polysilicon shortage hamper semiconductor industry growth? There is some danger, but we stop short of saying that semiconductor market revenue will suffer purely as a result of this particular shortage. The semiconductor companies will do everything in their power to prevent that. What can they do? Quite a bit, but it will require a semipermanent lifestyle change. Consumption of test wafers will be reduced, a move forced by a combination of price and availability.

Silicon wafer suppliers will try to shift their limited mix to the higher-profit prime wafers, and virgin test wafers of all sizes will go short. By early 1996, we believe we will see the traditional 20 percent discount for virgin test wafers compared to prime start to shrink, perhaps by the end of 1996 to only a 5 or 10 percent discount from prime wafers.

Test wafer consumption will be forced down, and the reclaim wafer market should start booming in 1996. We believe that a good portion of this lifestyle change will stick, as manufacturers learn to hit yield targets with fewer monitors, reducing costs of production. The initial shock may cause yields to suffer temporarily, but semiconductor companies will choose this route over wasting the wafer for no revenue. The cost of a test wafer will start to be measured in terms of revenue lost instead of the actual cost of the test wafer.

With the reduction in test wafer consumption and the probable new entrant(s) into the market, we believe that after a nine-to-12-month shortage there will be relief—for at least two years. But if the PC and semiconductor markets continue on their current pace, the expansion frenzy will need to be started again about the turn of the decade.

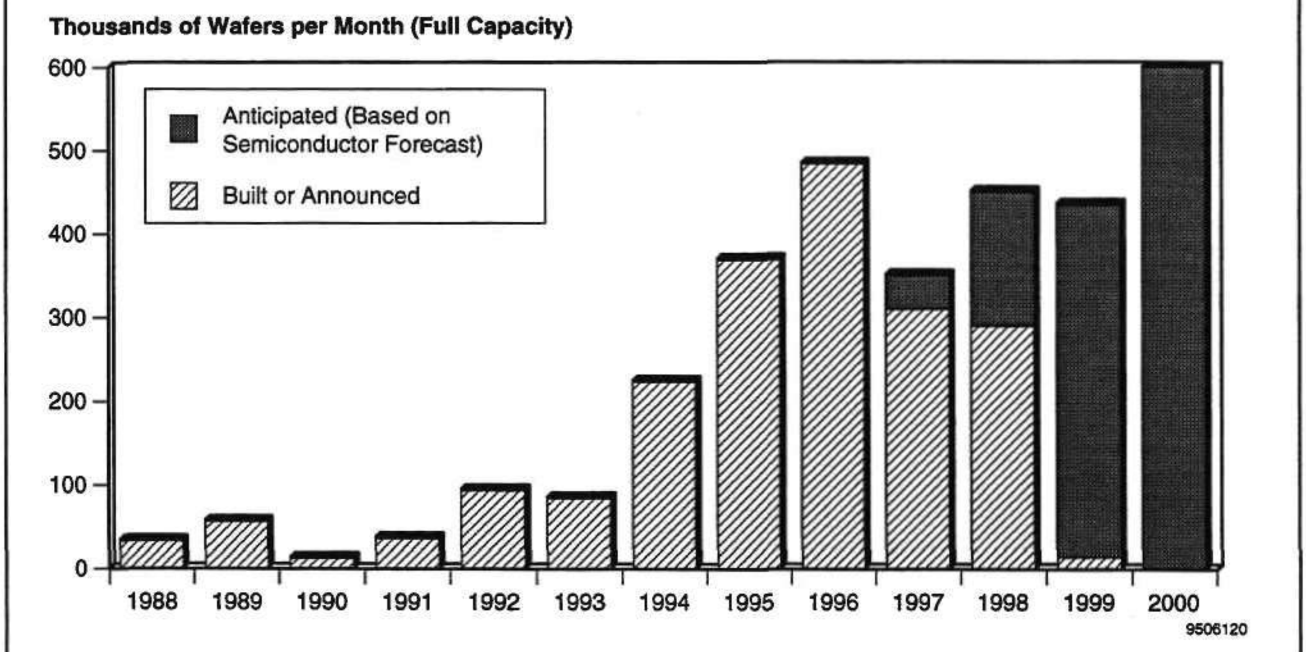
Chapter 4
200mm Wafers: Supply Getting behind the Power Curve

The reality of the 200mm ramp is here. The vast majority of new fabs announced are expecting to process 200mm wafers. The analysis for this part of the market is relatively straightforward—demand is driven by fabs, and supply is driven by silicon wafer manufacturing plant construction. New silicon wafer plants are required because the existing 150mm wafer plants cannot be upgraded—an entirely new toolset is required for manufacturing 200mm wafers. Comparing these two parts of the market can describe the situation cleanly, with one twist, which we will introduce near the end of the chapter.

The Demand for 200mm Wafers Is High

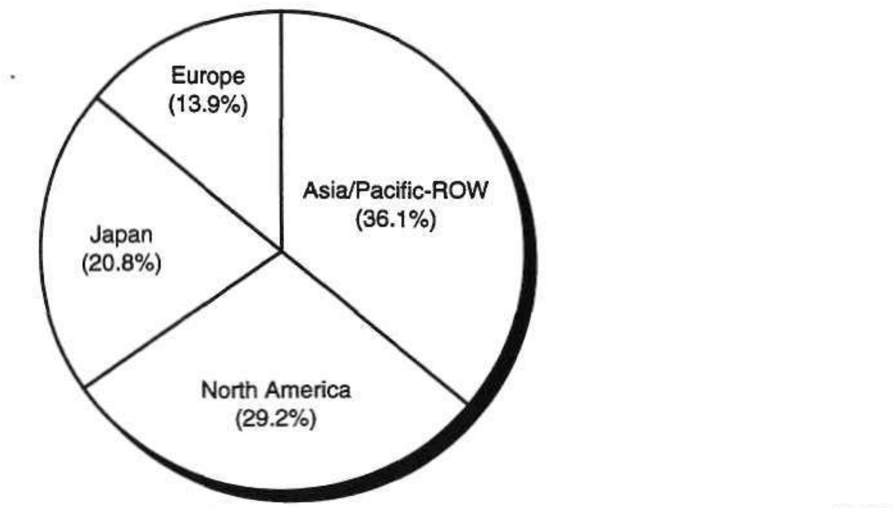
Figure 4-1 outlines the expected maximum added wafer start capacity for 200mm fabs expected through the rest of the decade. We have included all fabs announced to date (which give us a very solid 24-month horizon) and have taken into consideration how much capacity needs to be announced to meet the semiconductor demand expected by 2000. Figure 4-2 shows the product capacity split by region expected by 2000.

Figure 4-1
200mm Maximum Wafer Start Capacity Addition by Year, 1988-2000



Source: Dataquest (November 1995)

Figure 4-2
200mm Fab Capacity by Region in 2000



Source: Dataquest (November 1995)

Our methodology to derive demand is based on a bottom-up, fab-by-fab analysis of the expected ramp-up of 200mm wafers. This demand is segmented by polished wafers, epitaxial wafers, and test/monitor wafers. Test and monitor use was based on each semiconductor company's usage styles and by the age of the fab (near start-up, a higher percentage of test wafers is used). No consideration was given to the availability of supply. Also, a semiconductor company's desired level of test wafer use was viewed as the maximum limit for this analysis.

Demand based on today's knowledge and expected announcements is summarized in Table 4-1 on a regional basis. We note that test wafer usage based on demand is just under 40 percent in 2000. Based on known constraints at the time, our July forecast factored in a lower usage rate of 33 percent (see Table 2-4).

The supply of 200mm wafers is not expected to keep up, as is shown in a supplier analysis in Tables 4-2 and 4-3 for polished and epitaxial 200mm wafers. In Table 4-4, we combine the demand with the appropriate supply and calculate a net surplus or shortfall.

Our current forecast for 200mm wafers is supply constrained starting in 1996 and continuing throughout the decade. In 1995, we calculate a technical 17 percent oversupply, but we believe this represents an essentially balanced market because these plants are ramping more slowly than expected. In fact, we believe that the silicon industry is already behind the ramp-up power curve and is starting to experience the run-rate shortages calculated for 1996. This constraint peaks initially in 1997 but accelerates again in 1999, the 200mm market being in perpetual shortage during our forecast horizon.

Table 4-1
200mm Wafer Demand Forecast by Region, 1993-2000 (Thousands of Wafers per Month)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1993-2000
North America									
Prime	12.2	23.5	81.2	170.6	314.9	430.4	540.2	689.2	78.0
Epitaxial	32.8	46.0	82.6	130.0	181.5	205.5	219.7	230.7	32.2
Test/Monitor	59.9	117.7	260.9	445.6	660.2	708.4	723.4	754.6	43.7
Total	104.9	187.2	424.7	746.2	1,156.6	1,344.3	1,483.3	1,674.5	48.6
Japan									
Prime	29.2	67.4	125.9	226.4	285.4	380.4	473.4	628.4	55.1
Epitaxial	6.8	11.6	16.6	20.6	27.6	27.6	29.6	29.6	23.4
Test/Monitor	54.0	118.5	208.8	310.5	347.5	385.5	373.1	409.8	33.6
Total	90.0	197.5	351.3	557.5	660.5	793.5	876.1	1,067.8	42.4
Europe									
Prime	9.4	24.0	44.0	108.1	180.1	238.1	299.1	354.1	68.0
Epitaxial	0	6.0	15.0	29.0	48.0	68.0	79.0	84.0	NM
Test/Monitor	14.1	51.9	103.5	190.0	258.3	292.1	301.7	292.0	54.2
Total	23.5	81.9	162.5	327.1	486.4	598.2	679.8	730.1	63.5
ROW									
Prime	27.0	71.0	173.0	288.0	441.0	663.8	868.8	1078.8	69.4
Epitaxial	0	0	4.0	9.0	10.0	32.0	42.0	62.0	NM
Test/Monitor	27.0	66.0	165.0	278.0	362.6	455.6	546.5	599.4	55.8
Total	54.0	137.0	342.0	575.0	813.6	1,151.4	1,457.3	1,740.2	64.3
Worldwide									
Prime	77.8	185.9	424.1	793.1	1,221.4	1,712.7	2,181.5	2750.5	66.5
Epitaxial	39.6	63.6	118.2	188.6	267.1	333.1	370.3	406.3	39.5
Test/Monitor	155.0	354.1	738.2	1,224.1	1,628.6	1,841.6	1,944.7	2,055.8	44.7
Total	272.4	603.6	1,280.5	2,205.8	3,117.1	3,887.4	4,496.5	5,212.6	52.5
Test/Monitor as Percentage of Total	56.9	58.7	57.6	55.5	52.2	47.4	43.2	39.4	

NM = Not meaningful
Note: Analysis driven by bottom-up fab ramp schedules—depends on anticipated demand only (no supply issues taken into consideration).
Source: Dataquest (November 1995)

Table 4-2
200mm Polished Wafer Supply Capacity by Company, 1993-2000 (Thousands of Wafers per Month)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1993-2000
MEMC Electronic Materials (and All Joint Ventures)									
North America	50.0	50.0	75.0	75.0	130.0	200.0	225.0	225.0	
Japan	10.0	10.0	40.0	40.0	50.0	50.0	70.0	70.0	
Europe	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	
Posco-Hüls (Korea)	40.0	70.0	160.0	200.0	250.0	250.0	250.0	250.0	
Taisil (Taiwan)	0	0	0	50.0	115.0	195.0	195.0	195.0	
Total	120.0	150.0	295.0	385.0	565.0	715.0	760.0	760.0	30.2
Komatsu (and All Joint Ventures)									
North America	0	0	0	0	30.0	100.0	130.0	130.0	
Japan	40.0	40.0	100.0	100.0	100.0	100.0	100.0	100.0	
Taiwan	0	0	0	0	60.0	100.0	100.0	100.0	
Total	40.0	40.0	100.0	100.0	190.0	300.0	330.0	330.0	35.2
Mitsubishi Materials (Includes Siltec)									
North America	0	0	0	50.0	80.0	80.0	120.0	170.0	
Japan	20.0	40.0	70.0	150.0	150.0	170.0	180.0	200.0	
Total	20.0	40.0	70.0	200.0	230.0	250.0	300.0	370.0	51.8
NSC Electron									
Japan	0	10.0	10.0	20.0	20.0	20.0	20.0	20.0	
Total	0	10.0	10.0	20.0	20.0	20.0	20.0	20.0	NM
Shin-Etsu Handotai									
North America	30.0	80.0	120.0	120.0	160.0	220.0	240.0	240.0	
Japan	80.0	120.0	180.0	180.0	220.0	320.0	320.0	320.0	
Malaysia/Taiwan	0	100.0	200.0	200.0	220.0	240.0	240.0	280.0	
Total	110.0	300.0	500.0	500.0	600.0	780.0	800.0	840.0	33.7
Showa Denko									
Japan	0	0	0	0	0	50.0	50.0	100.0	
Total	0	0	0	0	0	50.0	50.0	100.0	NM
Siltron									
Korea	20.0	20.0	25.0	35.0	35.0	35.0	35.0	35.0	
Total	20.0	20.0	25.0	35.0	35.0	35.0	35.0	35.0	8.3

(Continued)

Table 4-2 (Continued)
200mm Polished Wafer Supply Capacity by Company, 1993-2000 (Thousands of Wafers per Month)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1993-2000
Sumitomo Sitix									
North America	0	0	0	0	50.0	100.0	150.0	200.0	
Japan	70.0	100.0	170.0	230.0	230.0	240.0	240.0	240.0	
Total	70.0	100.0	170.0	230.0	280.0	340.0	390.0	440.0	30.1
Toshiba Ceramics									
Japan	10.0	30.0	50.0	100.0	160.0	230.0	250.0	300.0	
Total	10.0	30.0	50.0	100.0	160.0	230.0	250.0	300.0	62.6
Wacker-Siltronic									
North America	15.0	15.0	15.0	50.0	100.0	150.0	150.0	150.0	
Europe	65.0	70.0	70.0	85.0	85.0	85.0	85.0	85.0	
Total	80.0	85.0	85.0	135.0	185.0	235.0	235.0	235.0	16.7
Total All Companies	470.0	775.0	1,305.0	1,705.0	2,265.0	2,955.0	3,170.0	3,430.0	32.8

NM = Not meaningful
Note: Figures for Shin-Etsu Handotai-America and Shin-Etsu Handotai-Taiwan are Dataquest estimates.
Source: Dataquest (November 1995)

Table 4-3
200mm Epitaxial Wafer Supply Capacity by Company, 1993-2000 (Thousands of Wafers per Month)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1993-2000
MEMC Electronic Materials (and All Joint Ventures)									
North America	25.0	25.0	30.0	40.0	55.0	75.0	90.0	110.0	
Japan	0	0	0	0	0	0	0	0	
Europe	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
Posco-Hüls—Korea	0	0	0	0	0	0	0	0	
Taisil—Taiwan	0	0	0	0	10.0	20.0	20.0	20.0	
Total	30.0	30.0	35.0	45.0	70.0	100.0	115.0	135.0	24.0
Komatsu (and All Joint Ventures)									
North America	0	0	0	0	0	0	0	0	
Japan	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	
Taiwan	0	0	0	0	0	0	0	0	
Total	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	0

(Continued)

Table 4-3 (Continued)
200mm Epitaxial Wafer Supply Capacity by Company, 1993-2000 (Thousands of Wafers per Month)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1993-2000
Mitsubishi Materials (Includes Siltec)									
North America	0	0	0	5.0	15.0	20.0	25.0	25.0	
Japan	5.0	5.0	15.0	15.0	15.0	20.0	25.0	25.0	
Total	5.0	5.0	15.0	20.0	30.0	40.0	50.0	50.0	39.0
NSC Electron									
Japan	0	0	0	0	0	0	0	0	
Total	0	0	0	0	0	0	0	0	NM
Shin-Etsu Handotai									
North America	10.0	15.0	30.0	30.0	30.0	35.0	45.0	45.0	
Japan	15.0	17.0	20.0	40.0	40.0	60.0	60.0	70.0	
Malaysia	0	0	0	0	0	0	0	0	
Total	25.0	32.0	50.0	70.0	70.0	95.0	105.0	115.0	24.4
Showa Denko									
Japan	0	0	0	0	0	10.0	10.0	10.0	
Total	0	0	0	0	0	10.0	10.0	10.0	NM
Siltron									
Korea	0	0	0	0	0	0	0	0	
Total	0	0	0	0	0	0	0	0	NM
Sumitomo Sitix									
North America	4.0	4.0	28.0	37.0	53.0	68.0	75.0	75.0	
Japan	10.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	
Total	14.0	23.0	47.0	56.0	72.0	87.0	94.0	94.0	31.3
Toshiba Ceramics									
Japan	0	0	0	0	0	0	0	0	
Total	0	0	0	0	0	0	0	0	NM
Wacker-Siltronic									
North America and Europe	24.0	30.0	30.0	50.0	50.0	50.0	50.0	50.0	
Total	24.0	30.0	30.0	50.0	50.0	50.0	50.0	50.0	11.1
Total All Companies	108.0	130.0	187.0	251.0	302.0	392.0	434.0	464.0	23.1

NM = Not meaningful
Note: Figures for Shin-Etsu Handotai-America are Dataquest estimates.
Source: Dataquest (November 1995)

Table 4-4
Worldwide 200mm Wafer Supply and Demand Summary, 1993-2000 (Thousands of Wafers per Month)

	1993	1994	1995	1996	1997	1998	1999	2000
Total Polished Demand	233	540	1,162	2,017	2,850	3,554	4,126	4,806
Total Polished Supply	470	775	1,305	1,705	2,265	2,955	3,170	3,430
Calculated Oversupply or Undersupply (%)	102	44	12	-15	-21	-17	-23	-29
Total Epitaxial Demand	40	64	118	189	267	333	370	406
Total Epitaxial Supply	108	130	187	251	302	392	434	464
Calculated Oversupply or Undersupply (%)	173	104	58	33	13	18	17	14
Total 200mm Demand	272	604	1,280	2,206	3,117	3,887	4,496	5,213
Total 200mm Supply	578	905	1,492	1,956	2,567	3,347	3,604	3,894
Calculated Oversupply or Undersupply (%)	112	50	17	-11	-18	-14	-20	-25

Source: Dataquest (November 1995)

The epitaxial market is expected to be in balance for two key reasons. First, the incremental addition of an epitaxial reactor is small compared to the investment and complexity of ramping 200mm polished capacity. Second, epitaxial wafers provide higher margins to silicon wafer manufacturers, so return is maximized when these market demands are being met.

Is this a correct scenario? Since the use of test wafers is so high, is the demand picture too optimistic?

Two things are almost certain to be different by 2000. The use of test wafers will be significantly lower, based on the constraint produced in the industry by the polysilicon shortage (see Chapter 3). Further, it is likely that there will be a new plant announcements that have not been considered in this supply analysis.

What would be the impact on supply and demand if test wafers were reduced? Table 4-5 shows one possibility. Case A represents the demand picture essentially unchecked (39 percent test wafer use); Case B takes into consideration significantly lower test wafer usage (25 percent). Case B represents lower test wafer use than our July forecast of 33 percent. If test wafer use were cut significantly, then a 25 percent undersupply would become a 1 percent undersupply—essentially in balance. This would become zero if test wafer usage were reduced to 22 percent.

Dataquest Perspective

So what will happen? Probably something between these two scenarios. We do expect silicon manufacturers to announce further expansions that would increase supply by 8 to 10 percent by 2000. But given the cautious nature of the suppliers, they can be expected to monitor test wafer usage closely. If there is an indication that test wafer use is going down significantly, those expansions in 1999 to 2000 could be delayed.

Table 4-5
Alternative Demand Scenario Summary with Reduced Test Wafer Usage, Year 2000 (Thousands of Wafers per Month)

	Demand Unchecked (as in Table 4-4)	Demand Reduced to 25% Test Wafer Ratio
Total 200mm Demand	5,213	3,946
Total 200mm Supply	3,894	3,894
Calculated Oversupply or Undersupply (%)	-25	-1

Source: Dataquest (November 1995)

We also have a demand scenario that is relatively conservative when compared to what may be required to drive a $330 billion semiconductor market. We made a conservative estimate of about 125 fabs between 1996 and 2000 because we believe that a significant number of new fabs will be for 150mm wafers (eleven such fabs have already been announced for 1996-1998).

We expect pricing to be firm and to increase for 200mm wafers through the rest of the decade. We would not be surprised to see increases of 3 percent to 5 percent per year, and we would expect the discount between prime and test wafers to shrink. The discount shrink is not expected to be as great as with other wafer sizes, because price elasticity may be more severe for the 200mm test wafer.

Will semiconductor revenue be affected by the 200mm wafer shortage? The answer is no. There is enough flexibility in this market for test wafers that product runs will not be affected by lack of wafers. There will be pain— the luxury of test wafers as a way to monitor and control yields will be severely impacted or removed, but the revenue of the semiconductor company is unlikely to be affected.

There is a small possibility that a few fabs that were planned to process 200mm wafers will have to be started at 150mm wafers, but we expect this to be short-lived. The risk of this is highest in late 1996 through 1997.

Chapter 5
The Smaller 100mm and 125mm Wafers: Under Siege

Over the past year, wafer suppliers have reached or nearly reached capacity in their existing silicon wafer plants. Because most capacity is either flexible among the 100mm, 125mm, and 150mm wafer sizes or is easily upgradable, large silicon wafer manufacturers are allocating their existing production capacity very carefully.

Because it is more profitable to produce 150mm wafers (current prices for polished prime are about $1.25 to $1.35 per square inch) rather than 100mm or 125mm wafers (priced at around $1.00 to 1.08 per square inch), silicon companies are reallocating their production away from the smaller wafers to meet increased demand for 150mm wafers. We understand from some semiconductor companies that the smaller wafers will no longer be available or that they have given notice for final order quantities. Prices for 100mm wafers in the United States have gone up 20 percent to 25 percent in the last year and 8 percent to 10 percent in Japan and Europe, and we expect prices to go even higher. Prices for 125mm wafers are also on the rise.

Semiconductor manufacturers with which we have spoken are scrambling to find 100mm and 125mm wafers, even investigating sources in the former Soviet Union or mainland China (both of which have tended to be of lower quality in the past). We are not aware of many successful searches, however.

Dataquest Had Been Forecasting a Flat Unit Market, But ...

In our current forecast (see Table 2-2), we have projected essentially a flat level of consumption through 2000, about at the capacity of the industry for these sizes: 37 million 100mm wafers and 41 million 125mm wafers per year. Increases over the last couple of years have resulted from increased semiconductor plant utilization, not from new fabs. These production levels represent numbers lower than peak levels in 1984 for 100mm wafers and the same as peak levels in 1990 for 125mm wafers. No new 100mm or 125mm fabs are expected to be built, although expansion of current facilities is likely. But we also believed that there would be a nearly equal migration to larger wafer sizes, maintaining a flat forecast.

With a restricted supply of 100mm and 125mm wafers, it is clear that we need to consider an alternative outlook for both these smaller sizes that is lower than the current forecast. As these sizes become restricted, we need to consider the possible choices for semiconductor companies, as follows:

- Migration of the supplier base to a second tier of silicon suppliers
- Conversion of fabs to process 150mm wafers
- Mothballing or closing fabs, replacing the capacity with their own new capacity or taking advantage of the emerging semiconductor contract manufacturing (SCM) industry, sometimes referred to as "foundry"
- Use of negotiating techniques that promote a supplier's loyalty to a customer

The first choice creates a net addition of MSI capacity for the industry as the smaller silicon companies expand to meet demand. The second choice shifts wafer slice demand to 150mm, and the third shifts MSI demand to 150mm or 200mm wafers (the 200mm market is constrained at present, so the effect is to add to 150mm demand). The fourth option limits the ability of the supplier to convert capacity away from smaller wafer sizes to 150mm wafers. These options will be considered here and in Chapter 6.

Conversion of Fabs

Fabs are being converted from the smaller sizes to 150mm in Europe today, and we expect the United States to follow suit soon. Many, many fabs will never move to larger wafers, so the market for smaller wafers will be significant for a long time. It is also our judgment that 125mm wafers will decline faster than 100mm wafers in some regions because it is easier to convert a 125mm fab to 150mm— the equipment designs are close. Going from 100mm to 150mm may be too costly for many companies in the longer term.

When investigating the likelihood of fabs being converted, it is necessary to look at each region to understand which companies have the primary capacity at 100mm and 125mm wafers.

Conversion of 100mm Fabs

The following estimates are for conversions by 2000.

Conversion in Europe has started, and for companies with 100mm capacity, we believe that about 80 percent of that capacity will convert to 150mm wafers or be mothballed. North American capacity conversion will also be high, but not as high as Europe's, about 60 percent.

In Japan, customer loyalty will play a role in keeping conversions near 40 percent of capacity. And in Asia/Pacific and rest of world (ROW) the mixture of companies is dominated by developing areas such as mainland China, Russia, and Eastern Europe, and some companies in Korea. It is not likely that these fabs will convert more than 20 percent of capacity.

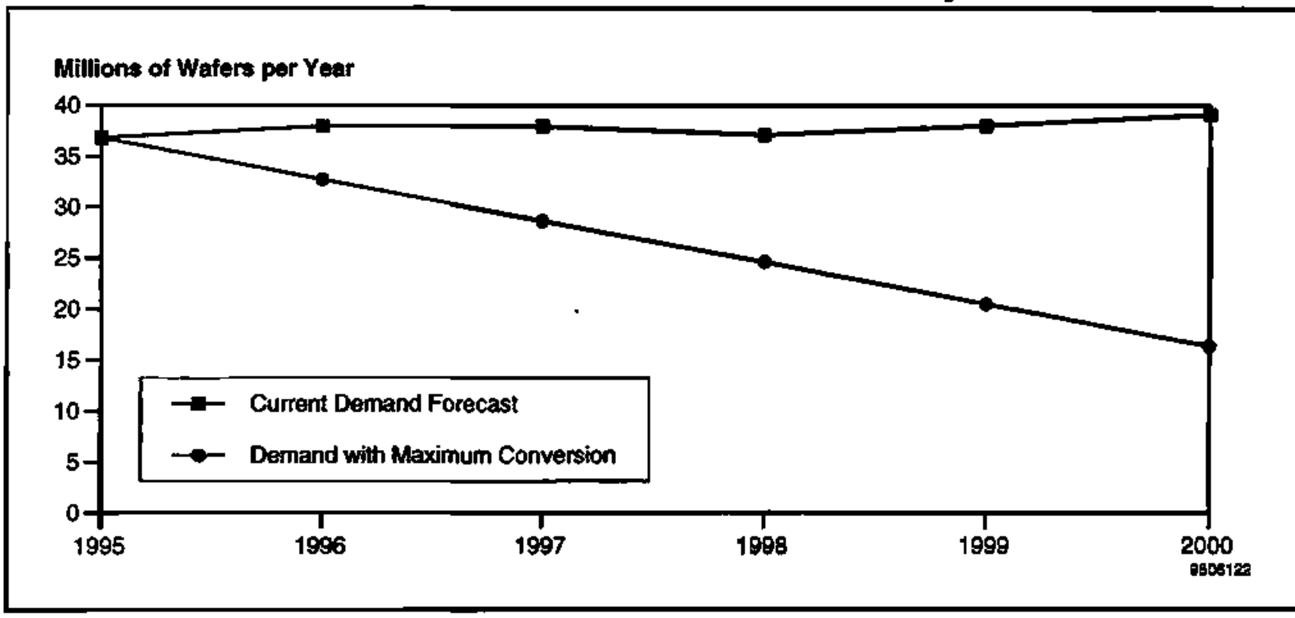
Given these estimates, the demand for 100mm wafers could fall from the current 37 million wafers to about 16.4 million by 2000, as shown in Figure 5-1.

Conversion of 125mm Fabs

As with 100mm fabs, conversion in Europe has started and is expected to be aggressive as semiconductor production moves to leading-edge products. We could expect that as much as two-thirds of European capacity will convert to 150mm wafers or be mothballed. North American conversion could also be on the order of two-thirds of capacity. It should be noted that this is heavily influenced by the actions of Motorola and AT&T, both of which have captive silicon operations, as well as Harris, Delco, and Texas Instruments.

Japan is really the major 125mm consumer, and customer loyalty can again be expected to play a role in keeping this conversion figure low. Further,

Figure 5-1
Forecast Window for 100mm Wafer Demand, 1995-2000 (Wafers per Year)



Source: Dataquest (November 1995)

some 100mm fabs in Japan will initially convert to 125mm wafers, offsetting this figure. At most, we can assume only a 30 percent conversion. In Asia/Pacific-ROW, the mixture of companies is dominated by Taiwan and Korea. Korea's Siltron supplies the local market. We expect no higher than a 30 percent conversion rate.

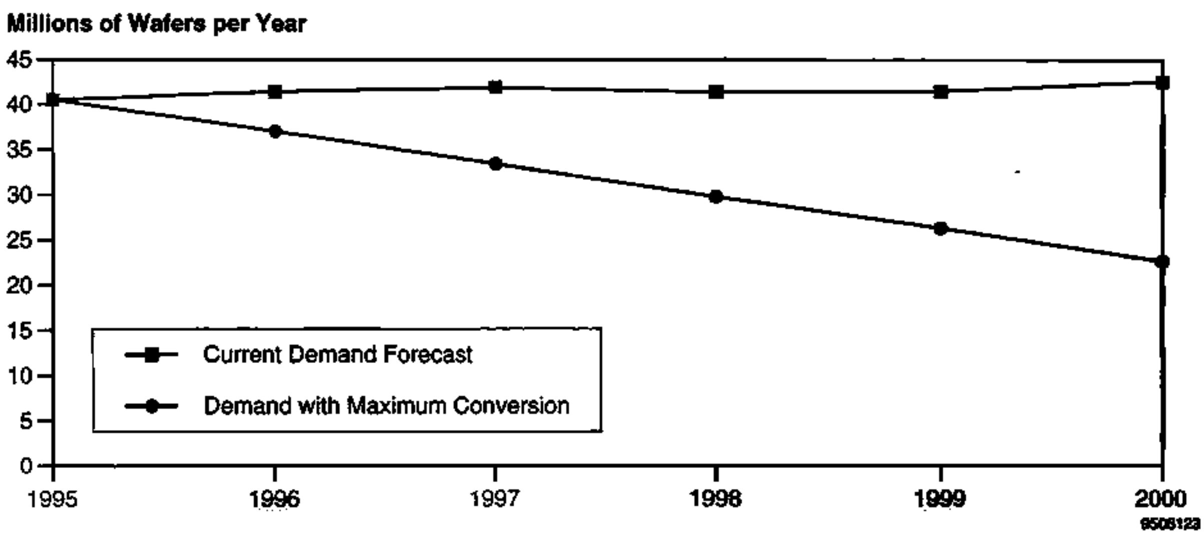
Taking these into consideration, the demand for 125mm wafers could fall from the current 41 million wafers to about 22.7 million by 2000, as shown in Figure 5-2.

The Availability of Alternative Sources

We expect the larger suppliers to phase out of 100mm and 125mm wafer supply over the next three to five years. The market will be supplied by the second tier of companies—small companies that have traditionally supplied 3-inch and some 100mm wafers but are expanding aggressively to supply 100mm and 125mm demand. Companies to watch here are Okmetic in Europe, Crysteco and Unisil in the United States, Tatung and Sino-America in Taiwan, and perhaps some in Japan, among others. There may also be new entries into the market, as well.

The companies noted have tended to occupy niche markets or have concentrated on very small wafer sizes, down to two inches in diameter. Companies that have concentrated on the smaller sizes should be able to ramp on 100mm, but 125mm could be a challenge. In most cases, these companies have been private and closely held and so may actually need some capital support from a semiconductor company to become key suppliers. Of the companies noted, Crysteco and Tatung are the most likely to be able to fill this need.

Figure 5-2
Forecast Window for 125mm Wafer Demand, 1995-2000 (Wafers per Year)



Source: Dataquest (November 1995)

We expect that these smaller companies could take between 40 and 60 percent of the 100mm and 150mm wafer market by 2000—if we assume the lower demand figures of 16.4 million for 100mm and 22.7 million for 125mm wafers.

Prices

We expect prices to go up quickly and perhaps come to within five to 10 percent of the price per square inch of 150mm wafers. We do not, however, believe this will ultimately keep the market from converting, although the transition would be slower.

Dataquest Perspective

It is clear that the demand for 100mm and 125mm wafers will be lower than we have recently forecast, primarily driven by lack of supply. We have provided two scenarios, one for each wafer size, that represent the low end of the forecast window; again, what actually happens will probably fall somewhere between the two. How much really depends on how semiconductor companies react to the current situation.

Semiconductor companies are feeling the pinch for 100mm and 125mm wafer supply rather acutely at present. We believe that semiconductor companies will have to choose to either convert fabs to process 150mm wafers or to mothball them in favor of other sources of capacity.

Paying higher prices may be the short-term strategy for many, but, if conversion is too costly, investing in a smaller silicon company may prove better in the long run. Just as in the foundry market, a capital infusion as a prepayment for wafers is a viable and sometimes preferred option.

This choice of promoting local suppliers may also be a bit more reliable than going into China or the former Soviet Union. However, there is one company that intrigues us—Pillar Ltd. This is a joint venture between Ukraine and Norway, located in Ukraine. We know very little about the company, its strategy, or its capability, but it has been very aggressive recently about marketing in Europe and the United States.

One thing is certain: Regardless of the degree of the ramp-down of these smaller wafer sizes, demand for 150mm wafers will increase as conversions occur.

Chapter 6
The "Hidden" Shortage: 150mm Wafers

Clearly the demand for 150mm wafers will grow, as our current forecast depicts. There will still be new 150mm fabs built through 2000, because there are many semiconductor product areas that will not benefit from going to 200mm. Expansion capacity will be added at 150mm.

However, our current forecast for 150mm wafers factors in only one supply constraint, the availability of 200mm wafers. It assumes that demand for the smaller wafer sizes will be met. Clearly, as outlined in Chapter 5, the latter will not be the case.

There are several scenarios that must be considered and four factors that could counteract each other in determining 150mm wafer demand and supply. The first factor would increase demand, namely the demand created by fabs that convert from smaller wafer sizes to 150mm wafers. This is almost certain to happen, so we will consider it first.

The two factors that would reduce 150mm demand are reduction in the consumption of test wafers to absolute minimum levels (a minor impact) and faster ramp of 200mm wafer supply that would shift new fab demand from 150mm wafers (a larger impact).

One other factor that we will consider here is the implementation of wire saw technology for 150mm ingots. Although not yet being seriously considered, this technology could be used to yield more wafers per ingot, effectively increasing capacity and supply.

Increased Demand from Fab Conversions

In Chapter 5 we reviewed the possibility of semiconductor companies converting 100mm and 125mm fabs to process 150mm wafers. Because part of the throughput of semiconductor processing equipment is based on wafers rather than square inches, demand is transferred to the 150mm wafer market primarily in terms of slices. (It is true that some pieces of equipment process a smaller number of the larger wafers. We believe that in these few cases semiconductor companies will invest in used equipmentas a supplement to avoid creating a bottleneck in the fab.)

Table 6-1 represents a simple calculation that we used to determine the maximum demand that might be transferred to the 150mm wafer market by 2000. We believed that most companies will choose to convert rather than invest in new fabs and that the migration from 125mm to 150mm would be easier than from 100mm. It should also be noted that these conversions represent an addition to semiconductor capacity in terms of MSI, which will be another force driving conversions.

The potential increased 150mm demand is quite shocking, nearly 30 million wafers per year of added demand by 2000. While this represents a perhaps unrealistic maximum, we would like to carry this scenario out to its conclusion in order to address more fundamental questions later. We will look at the freed capacity from the supplier's perspective later, as well.

Table 6-1
Translating Converted Smaller Wafer Demand to 150mm Demand in 2000

	From 100mm Fabs	From 125mm Fabs
100mm or 125mm Wafer Fabs Converted or Mothballed (Millions of Wafers per Year)	20.6	18.3
Wafer Start Capacity Mothballed or Closed (%)	33	15
150mm Wafers Demanded from Converted Fabs (Millions of Wafers per Year)	13.7	15.6
Net Capacity Increase or Decrease at Semiconductor Companies (MSI)	+124	+79

Source: Dataquest (November 1995)

Influences Decreasing Demand

We must consider two courses of action that would reduce 150mm wafer demand—ramping 200mm wafers to create a balance (with reduced test wafer consumption as assumed in our July forecast) and reducing 150mm test wafer consumption to a bare minimum.

Factoring Out the 200mm Demand Spillover

In our July forecast, we assumed a test wafer consumption of 33 percent for 2000. We also had supply constrained at 200mm and shifted that demand into 150mm demand in terms of MSI. The value of this demand "spillover" was about 270 MSI in our July forecast, or about 9.9 million wafers in 2000. After factoring in the increase in supply since that forecast and our estimates of increased demand based on an increased semiconductor market forecast for 2000, the figure does not change appreciably but does increase to about 10.2 million wafers.

If we assume that 200mm wafers will ramp up so there is no spillover demand, then our forecast demand should be reduced by 10.2 million wafers in 2000.

Reducing Test Wafers to an Absolute Minimum

Our July forecast assumed a test wafer use rate of 12.8 percent (see Table 2-4) for 2000. If efficient use of wafers and greater use of reclaim wafers cut this to about 8 percent, we would reduce the calculated demand by about 4.4 million wafers in 2000.

Factors Increasing Supply of 150mm Wafers

Two factors could increase the supply of 150mm wafers. First, we will calculate the capacity freed through lower demand for 100mm and 125mm wafers, and, second, we will investigate the impact of wire saw technology.

Capacity Freed by Conversion from Smaller Sizes

Table 6-2 reviews the capacity freed by a reduction of demand for 100mm and 125mm wafers. When capacity is transferred among wafer sizes, we are assuming that the number of wafers per ingot is dictated by the size of the polysilicon charge in the crystal-pulling process. Therefore, the

Table 6-2
Translating Converted Smaller Wafer Supply to 150mm Supply in 2000 (Millions of Wafers)

	From 100mm Fabs	From 125mm Fabs
100mm and 125mm Wafer Fabs Converted or Mothballed	20.6	18.3
Additional Capacity Assumed Transferred to Second-Tier Companies	9.4 (114 MSI)	9.7 (185 MSI)
Smaller Wafers No Longer Being Shipped by First-Tier Companies	30.0	28.0
Production Capacity for 150mm Wafers Created	10.7	18.0
Net Capacity Increase or Decrease Shipped to Market (MSI)	-72	-40

Source: Dataquest (November 1995)

grams-per-wafer ratios used in Chapter 3 were again used here. (Some crystal pullers can be upgraded to accept larger charges and thereby increase capacity. We did not factor that addition into this analysis. We also assumed that 100 percent of pullers could be used, which may be high.)

Through the conversion process, about 28.7 million wafers of 150mm capacity have been freed. What is most interesting is that this figure is very close to the 29.3 million wafers that demand increased because of fab conversions. Only one conclusion can be drawn from this analysis: Conversion of the market from smaller sizes to 150mm wafers has zero impact on addressing supply and demand issues.

Implementation of Wire Saws for 150mm Ingots

Retrofitting existing wafer manufacturing plants is extremely difficult because the wire saw equipment consumes more floor space than ID saws. Further, the percentage of the ingot sliced at one time is smaller than desired for cost-effectiveness. These obstacles will restrict the level and timing of wire saw implementation for 150mm wafers. We will assume only a 20 percent penetration into 150mm wafer production capacity by 2000 for the wire saw.

If achieved, this would increase the supply of 150mm wafers by about 3.5 percent, or roughly 3.4 million wafers in 2000. This is significant because it represents about $300 million to $400 million of new plant investment that does not need to be built.

Comparing Supply and Demand

Table 6-3 summarizes the potential for supply and demand for 150mm wafers. This table shows a progression of assumptions and calculations that results in the creation of three possible scenarios for 150mm wafer supply versus demand. We estimate that the current silicon capacity for producing 150mm wafers is about 65 million to 70 million wafers per year.

One observation from the supply-demand summary for 150mm wafers is that more 150mm capacity is clearly required if the semiconductor and silicon markets continue along their current path. The second observation is that this capacity would be needed whether or not there is a move away

Table 6-3
Summary Top-Level Analysis of Supply and Demand for 150mm Wafers in 2000 (Millions of Wafers)

	Supply	Demand
Supply estimate for 1995; demand estimate for 2000, July forecast (Semiconductor basis of $275 billion)	68 (65-70 range)	85.5
Demand increases using a revised semiconductor basis of $330 billion.	-	10.2
Converting fabs from 100mm and 125mm creates additional 150mm wafer supply and demand.	28.7	29.3
Worst Case Scenario Total	96.7	125.0
Test wafer use is reduced to minimum.	-	-4.4
Supply is increased by wire saw implementation.	3.4	-
Middle Case Scenario Total	100.1	120.6
The 200mm ramp is fast enough, with no spillover demand.	-	-10.2
Best Case Scenario Total	100.1	110.4

Source: Dataquest (November 1995)

from 100mm or 125mm wafers. The third observation is that heavier investment in 200mm wafer capacity will ease the 150mm situation over the next five years but cannot be effective over the next three years.

The conclusion to be drawn is that the industry needs at least eight 100,000-wafer-per-month 150mm plants by 2000, possibly as many as 15.

One troubling issue with 150mm wafer demand now is that it is the "valley" where all the demand falls should there be a simple MSI demand increase driven by the underlying semiconductor market. For this reason, it is the most difficult to predict or forecast. For example, if the semiconductor demand were to be reduced by 15 percent to 20 percent in the year 2000, few new 150mm wafer plants would be required, if any.

Likely Supplier Reaction

The market dynamics are that the 150mm wafer technically goes into shortage as early as late 1996 or 1997. Fab conversions will not ease the situation—the only response that will is adding capacity somewhere. Adding capacity at 100mm or 125mm wafer sizes at an alternate supplier can effectively raise the supply for 150mm wafers by transferring part of the customer demand among suppliers.

We do expect increases in capacity from new investments, and adding this capacity is more risky than 200mm capacity. We would like to make three points regarding this risk. First, the demand for 150mm wafers will probably not soften or decline until 2003 to 2004, so a new plant may have about a seven-year life. Second, silicon wafer capacity can be added today by placing a 150mm plant "inside" a 200mm facility, with the intention of converting the capacity later— this reduces the risk of the investment.

Third, in 2003, companies will begin ramping up 300mm wafers and will want to further convert the market and production away from 150mm to

200mm wafers. As they do today, semiconductor companies will fight this, seeking alternative supply for 150mm wafers. This means that a 150mm wafer plant may have a few more than seven years of life.

Still, resistance is high to investing in new 150mm capacity or any capacity having a lifetime shorter than fifteen years. Unless prices increase dramatically or capital sharing ventures are created, capacity is not likely to be added. There is simply too much risk, both in the investment and in the semiconductor outlook beyond two to three years (in the eyes of the silicon company).

Possible Semiconductor Company Reactions

This is the potential shortage that could send semiconductor companies reeling. There is no "large" use of test wafers to reduce, as was the case with 200mm. All other markets are constrained as well, so another wafer size is not available. Use of reclaim wafers is likely to go up significantly. Companies positioned to participate in this market will do extremely well.

One possible reaction for semiconductor companies is to accelerate their plans to shrink designs, to effectively use less silicon. Some areas of the power and discrete segments could actually benefit a great deal from this strategy.

We believe semiconductor manufacturers face two possibilities, however. The first is much higher pricing. A 15 percent to 20 percent increase over the next 12 to 18 months is certainly feasible. The second is the need to contribute capital toward building 150mm capacity, with guaranteed supply contracts in return. This represents a difficult choice.

Dataquest Perspective

Dataquest believes that the semiconductor industry is getting extremely close to and even slightly beyond the limit for growing to $330 billion by 2000 with the current infrastructure.

The dynamics of the silicon supply market have created a "valley" where all incremental demand for silicon manifests itself in 150mm wafer demand. This is not a comfortable position for the industry, and it will cause a shortage of 150mm wafers during 1997, if not sooner. Prices will likely go up higher and faster than most people expect.

Silicon wafer suppliers have responded to the current tight market by allocating capacity from 100mm and 125mm wafers to 150mm wafers. While this makes short-term business sense, in the long run, the supply/demand situation remains unchanged.

Semiconductor companies will have to contribute capital for secured 150mm wafer supply, as is common now in the equally tight foundry market. This will be the only way to add the capacity required to fuel semiconductor growth while keeping the silicon company's investment risk at lower, healthier levels.

Without this, the semiconductor industry will not be able to achieve the $330 billion level forecast for 2000.

Epilogue: Some Random Thoughts and Questions

During the course of this analysis of the 150mm wafer market, we investigated an intriguing thought process. We attempted to view the market from 50,000 feet to take a look at the silicon industry's management of demand and supply for MSI among the wafer sizes. This analysis follows. It raises some interesting questions, but left us a little unsure what to do about it.

We first pondered some business strategy theory, and then went through an example to illustrate our dilemma. First, two abstract thoughts, which, upon further reflection, may seem obvious:

- When trying to manage supply in a tight market, one tries not to steer the customer toward a reaction that will direct you to supply in an undesired direction (namely, less).
- When trying to manage business profitability, one tries not to make competition do things that lower profitability for the entire industry.

Silicon wafer suppliers have responded to the current tight market by allocating capacity away from 100mm and 125mm wafers toward 150mm wafers. While it makes short-term business sense to do this, we propose that this is not the most efficient industry solution and that it violates the above principles.

Here is the example. Say that a silicon manufacturer discovers that 400 MSI of capacity must be added in five years, and that manufacturer has complete freedom in placing that demand, in terms of wafer size. What wafer size would be best? Our guess is that most manufacturers would pick 200mm, because it has the highest revenue per square inch and is the most profitable at present.

(By the way, this is exactly the problem we face as we try to construct December's forecast for 2000. The MSI demand will go up by about 400, and we will have to consider all the constraints in this report in order to construct the forecast.)

The silicon industry has chosen to restrict 100mm and 125mm wafer sizes in favor of 150mm wafers. This could cause some interesting reactions:

- Semiconductor companies are likely to react by converting fabs and, by our analysis, add about 200 MSI net of demand not on 200mm (see Table 6-1).
- Second-tier companies could respond (based on the semiconductor companies' initial action) by increasing industry capacity at 100mm and 125mm, to the tune of about 300 MSI (see Table 6-2). This is not investment to add 200mm capacity.
- The conversion process for the supply side reduces capacity by about 110 MSI (see Table 6-3), going from the smaller sizes to 150mm. The smaller the wafer, the more efficient the polysilicon use is per square inch.

- These reactions raise demand 200 MSI and capacity 190 MSI (300 MSI added at 100/125mm, less 110 MSI shortfall for 150mm).
- This scenario does not allow new 200mm capacity to be added because of the 310 MSI net imbalance at 150mm, which must be corrected by adding 150mm capacity.

To summarize, capacity is added in the industry to the tune of 500 MSI, all at a wafer size below 200mm. The customer's reaction—converting to 150mm wafers—has caused the manufacturer's supply capacity to decrease (110 MSI) and caused competitors to introduce new capacity at 100mm and 125mm, which is less profitable for the industry.

From the 50,000-foot level, it appears the most efficient way to add the 400 MSI needed would be to leave the 100mm and 125mm markets alone for a while and add capacity split between 200mm and 150mm (that is ultimately convertible to 200mm). This makes for happy customers, competition that stays away, and a more profitable product mix.

So what should silicon companies do now? Stop squeezing 100mm and 125mm supply? This would be less profitable in the short term, but would it not place the squeeze on 150mm wafers, where it belongs? Prompting capital-sharing proposals where they are really needed? Should the supply squeeze continue? This would raise prices across the board, perhaps to the level where there would be an incentive not to squeeze supply. But what about the long-term ramifications? A more unhappy customer? Competition gaining share?

We wonder what the semiconductor company would do if given the choice between either investing in upgraded or new semiconductor capacity to address being squeezed at 100mm or 125mm wafers or investing with a silicon company in the supply of 150mm wafers? The cost per fab is probably equal, but investment in 150mm plants would probably be cheaper for the combined industries (so many fabs, yet only eight to 15 wafer plants).

There is one potential flaw in this analysis— the assumption that demand for 100mm and 125mm wafers will remain strong and stable through the decade. But let's say it declines naturally instead of being forced down by supply constraints. What then? Conversions will happen as noted, and supply issues will remain as outlined in this chapter. But the key difference is that the customer is not actively searching for alternative suppliers, so the competitive introduction of capacity would not occur—still a better situation than forcing down the demand.

As you can see, we were not quite sure where to take this, or what conclusions to make, but it does generate interesting questions to consider.

Appendix A
Silicon Wafer Suppliers Worldwide

U.S. Silicon Companies

Crysteco Inc.

Founded in 1971, Crysteco Inc. of Wilmington, Ohio supplies silicon wafers to the semiconductor industry, primarily into automotive, discrete, and power applications. This $18 million company specializes in supplying arsenic-doped silicon material and concentrates on wafer diameters of 150mm or less. Crysteco is believed to have a large share of the worldwide arsenic and heavily doped substrates market. All material grown is Czochralski silicon, though Dataquest believes that Crysteco has provided some slice and polish services for float-zone ingots in the past. About 70 percent of its sales are in the United States and 20 percent in Europe, with the balance in Japan and Asia/Pacific. Besides selling wafers, the company sells a small number of single-crystal silicon ingots.

About 85 percent of Crysteco was sold early in 1995 to investors from Dayton, Ohio. A new management team is in place today, and we understand that facilities upgrades andexpansions are under way.

Epitaxy

Epitaxy is a $12 million epitaxial services company in Santa Clara, California established in 1972. Epitaxy does not grow any substrate material but purchases it from other merchant silicon manufacturers. Like several other small custom epi houses, it is pursuing niche market applications and has opted not to compete in the CMOS epi wafer market. About half of its business is in the United States, with a little over one-third in Asia/Pacific and the remaining small portion in Europe.

General Instrument—Power Semiconductor Division

The Power Semiconductor Division of General Instrument (Westbury, New York) manufactures epitaxial wafers. Most of its epi wafers are used in-house, but a small number are sold on the merchant market. Major applications for its epitaxial wafers include microwave and radio frequency discrete devices. Production volumes are extremely small.

Lawrence Semiconductor Laboratories

Lawrence Semiconductor is a small but quickly growing epitaxial service company located in Tempe, Arizona. The founder, Lamonte Lawrence, was also the founder of U.S. Semiconductor, which was acquired by Sumitomo Sitix in 1987. Revenue in 1994 is estimated to be about $7.5 million and could reach $16 million in 1995. Near the end of last year, Lawrence announced a major expansion into a new facility in Tempe, which would more than triple its current capacity. Lawrence has about 20 ASM epitaxial reactors currently operating. Lawrence's strategic strength is running high quality, technically demanding epitaxial layers, and the company has projects with SEMATECH and others to develop various technologies.

M/A-COM Semiconductor Products

M/A-COM Semiconductor Products (Burlington, Massachusetts) produces epitaxial silicon wafers for the semiconductor industry, as well as some III-V substrates. It offers epi wafers from 3 inches to 125mm in diameter. These wafers are used primarily in discrete device applications, with a small number used in CMOS processing as well. In 1985, M/A-COM produced 50 percent of its silicon substrate material and purchased 50 percent from other companies. In 1986, however, M/A-COM decided to curtail its single-crystal growth operations and now obtains all of its silicon substrate material from other merchant silicon companies. Dataquest estimates its revenue in 1994 at about $7 million.

Moore Technologies

Moore is a company with two primary businesses: the manufacture of epitaxial reactors and an epitaxial wafer deposition service. Moore's strategy is to use the two businesses synergistically to improve both the quality of the deposition and the production-worthiness of the equipment it produces. Moore recently announced a "mini-batch" 200mm epitaxial reactor that processes three wafers at a time. This productivity edge, coupled with high-quality CMOS epi depositions, is expected to place this company on a strong growth path.

Pure-Sil (Formerly Pensilco)

Pensilco is a small (just over $1 million) silicon wafer manufacturer in Bradford, Pennsylvania. It specializes in small-diameter wafers, which range from 1 inch to 100mm in diameter. It provides customized silicon wafers, especially for zener diode fabrication. The company started its silicon operations in 1958 under the name of Allegheny Electronics; the Pensilco name was adopted in 1976. Late in 1994, the company changed its name to Pure-Sil.

Spire Corporation

Spire Corporation (Bedford, Massachusetts) supplies epitaxial silicon wafers to the semiconductor industry. Spire provides 2-inch, 3-inch, and 100mm epi wafers and focuses on meeting custom epitaxial specifications for microwave devices and discretes. The company has chosen not to pursue the MOS epitaxial wafer market. Spire has supplied compound semiconductor epitaxial wafers and silicon-on-insulator (SOI) wafers, also. The company first began its efforts in SOI in 1985. In the fall of 1988, Texas Instruments signed an agreement with Spire that enables Spire to market SOI wafers produced by TI. It is unclear whether this agreement has continued—Texas Instruments' wafer operations are now under a joint venture with MEMC. Spire also manufactures MOCVD equipment for the III-V market. Spire's silicon sales are less than $2 million.

UniSil

UniSil is medium-size silicon wafer manufacturer with sales of $40 million in 1994. The Mountain View, California, company specializes in test and monitor wafers, with a recent set of expansions for 200mm wafer capacity. The company recently acquired a small company, Prosil, which is expected to increase its proportion of prime wafer revenue. UniSil's focus on low-cost production of quality test wafers, along with the increased demand for test wafers at 200mm diameters, earns it the distinction of being the fastest growing and largest purely U.S.-owned manufacturer of silicon wafers.

Virginia Semiconductor

Virginia Semiconductor, a small $4 million silicon wafer manufacturer in Fredericksburg, Virginia, specializes in small-diameter wafers (from 1 to 3 inches) and offers very thin wafers of 3-mil (0.003-inch) thickness. Founded in 1978, Virginia Semiconductor started production of float-zone and Czochralski single-crystal ingots in June 1979.

Japanese Silicon Companies

Komatsu Electronic Metals

Komatsu is the sixth-largest silicon wafer manufacturer in the world, with its $453 million in sales in 1994 accounting for 10 percent of the worldwide market. Komatsu's Hiratsuka facility produces single-crystal silicon and some polished and epitaxial wafers. The Kyushu Komatsu plant in Miyazaki produces most of the company's polished wafers. Komatsu's Nagasaki plant was opened in 1985 and initially produced epitaxial wafers. In 1989, Komatsu expanded its Nagasaki facility for the growth of single-crystal silicon ingots. Today, the Nagasaki plant produces about half of the polished 200mm and nearly all of Komatsu's epitaxial 200mm wafers. The Nagasaki facility is destined to become Komatsu's main production site in Japan. Two major projects have been announced that expand Komatsu's production outside of Japan. Komatsu is building a 200mm wafer plant in Hillsboro, Oregon. Total investment is about $450 million, and the plant is expected to produce 130,000 wafers a month at full capacity. Initial production is expected to start in late 1997. Komatsu's joint venture with Formosa Plastics is expected to produce 200mm wafers by early 1997, initially at 70,000 wafers a month, with plans to increase production to 100,000 by 1998.

Komatsu supplies both Czochralski and float-zone material to the semiconductor industry. It ranks as one of the three major float-zone suppliers in the world (Shin-Etsu Handotai and Wacker are the others). Komatsu is also a leading supplier of diffused wafers, primarily for power diode devices.

Komatsu both produces polysilicon for its own needs through Advanced Silicon Materials and purchases it from the merchant market to supplement its supply.

Komatsu Electronic Metals Silicon Plant Locations

Head Office, Technical Center, and Plant, Hiratsuka City, Kanagawa Prefecture

Nagasaki Plant, Omura City, Nagasaki Prefecture

Kyushu Komatsu Electric, Kiyotake City, Miyazaki Prefecture

Hillsboro Plant, Hillsboro, Oregon (expected production 1997)

Komatsu-Formosa Plastics Joint Venture, Taiwan (expected production 1997)

Mitsubishi Materials Silicon

Mitsubishi Metal Corporation is a multibillion-dollar, multinational corporation headquartered in Tokyo. (Mitsubishi Metal and Mitsubishi Electric Corporation, the semiconductor manufacturer, are members of the same industrial group, the Mitsubishi Group.) The silicon manufacturing subsidiary, Mitsubishi Materials Silicon, was formed from two companies: Japan Silicon (also known as JASIL or Nippon Silicon) and Siltec Corporation, which was acquired in 1986. In addition to silicon wafers, Mitsubishi Metal is a major supplier of gallium arsenide wafers to the semiconductor industry.

Mitsubishi Materials Silicon is the fifth-largest supplier of silicon and epitaxial wafers to the semiconductor industry, with worldwide sales of $475 million and market share of about 10 percent. Both the Ikuno and Noda facilities in Japan have single-crystal silicon operations and wafer production. The Noda plant produces 3-inch to 200mm wafers, and the Ikuno Plant produces 125mm to 200mm wafers. Yamagata Silicon in Yonezawa obtains ingots of single-crystal silicon from its sister plants and produces 100mm to 150mm polished wafers. Dataquest believes that Mitsubishi Materials is expanding its Yonezawa facility for the production of 200mm wafers. Epitaxial wafer activity takes place at the Noda plant for 3-inch to 150mm wafers, and the Chitose plant has 200mm epi capacity.

The U.S. operations of Mitsubishi Materials Silicon began with the acquisition of Siltec Corporation in September 1986. Siltec was founded in 1969 by Robert Lorenzini, a pioneer in the field of crystal growing. The acquisition included both Siltec Silicon and Cybeq Systems, a separate business unit manufacturing production, transport, and test equipment used in silicon production operations. The acquisition was financed 60 percent by Mitsubishi Metal, 30 percent by Mitsubishi Mining and Cement, and 10 percent by Mitsubishi Corporation. Mitsubishi Metal and Mitsubishi Mining and Cement have since merged to form Mitsubishi Materials Corporation.

Siltec began operations in Salem, Oregon, in October 1982. In mid-1985, Siltec's California silicon production facilities were relocated from Menlo Park and Mountain View and consolidated in Salem. In November 1987, Siltec announced a 60 percent phased expansion and modernization program for the Salem facility. The $30 million modernization program was completed in 1988. In February 1988, the company announced its decision to construct an epitaxial wafer facility adjacent to the Salem wafer plant. The new epi facility came on line in summer 1989.

More recently, Mitsubishi Materials announced a new 200mm wafer manufacturing facility in South Salem, Oregon (its existing facility is in North Salem). This new facility is expected to begin production in 1996. Dataquest also believes that some 150mm capacity may be included in the ramp-up for 1997.

Mitsubishi Materials Silicon obtains most of its polysilicon materials from Hi-Silicon (also known as Kojundo Silicon) and Hemlock Semiconductor. Hi-Silicon was originally formed in 1967 as a 50-50 joint venture between Mitsubishi Metal and Osaka Titanium Company (now Sumitomo Sitix). In October 1987, Osaka Titanium announced that it had sold its 50 percent position in Hi-Silicon to Mitsubishi Metal for an undisclosed sum. In addition to its interest in Hi-Silicon, Mitsubishi Metal Corporation has a 12.25 percent equity position in Dow Corning's polysilicon subsidiary, Hemlock Semiconductor.

Mitsubishi Materials Plant Locations

Ikuno Plant, Asaki District, Hyogo Prefecture

Noda Plant, Noda City, Chiba Prefecture

Yamagata Silicon, Yonezawa City, Yamagata Prefecture

Chitose Plant, Chitose City, Hokkaido Prefecture

Siltec Silicon, North Salem, Oregon

Siltec Silicon, South Salem, Oregon (expected production 1996)

Central Research Lab, Omiya City, Saitama Prefecture

Hi-Silicon, Yokkaichi City, Mie Prefecture

Nittetsu Denshi

Nittetsu Denshi is a relatively new company supplying the semiconductor industry with polished silicon wafers. The company was established as a wholly owned subsidiary of Nippon Steel in June 1985. (Nittetsu Denshi is also known as NSC Electron; NSC stands for Nippon Steel Corporation and denshi refers to electronics.)

Its silicon wafer facility is in Hikari City, Yamaguchi Prefecture. Sampling of CZ polished wafers began in the fall of 1986, with production wafers available in April 1987. Nittetsu Denshi has been focusing on 125mm and 150mm wafers, with some limited 200mm capacity, and produces exclusively with polished wafers (no epi). We believe it is in the process of adding 200mm capacity to come on line in 1996. Nippon Steel, Nittetsu Denshi's parent, is one of several Japanese steel manufacturers diversifying from a sunset industry, steel, into the sunrise industries, such as electronic materials. Sales for 1994 totaled about $106 million and for the last four years have grown at a 35 percent CAGR. In addition to financial backing, the steel maker provides its new venture with a strong background in support technologies for silicon manufacturing, such as molten materials processing, crystal growth control, and precision measurement.

Sumitomo Sitix (formerly Osaka Titanium)

Sumitomo Sitix Corporation is the third-largest supplier of silicon and epitaxial wafers worldwide, with $582 million in sales (about 13 percent market share). Sumitomo Sitix is a combination of Osaka Titanium Group and Kyushu Electronic Metals Company in Japan and U.S. Semiconductor (acquired in 1987) and Cincinnati Milacron's epitaxial wafer division (acquired in 1989). Sumitomo Sitix is a fully integrated producer of silicon, from trichlorosilane (source material for polysilicon) to the finished wafer.

In Japan, Sumitomo Sitix produces both silicon (Czochralski and float-zone) and epitaxial wafers. Most of Sumitomo Sitix's wafers are produced at the facilities in Saga Prefecture. The Imari plant, originally completed in 1984, can manufacture 125mm, 150mm, and 200mm wafers. Dataquest believes that Sumitomo Sitix is expanding 200mm wafer capacity at Imari to come on line in 1995 and 1996. The Saga plant has the only Japanese epitaxial capacity, from 100mm to 200mm wafers.

In the United States, Sumitomo Sitix has three plants. The Fremont, California, plant, procured through the acquisition of U.S. Semiconductor in December 1986, manufactures epitaxial wafers for MOS and discrete device applications. Originally built in 1984, with the founding of U.S. Semiconductor, the plant supplies the semiconductor industry with 3-inch through 150mm epi wafers. The epitaxial wafer capacity at the Fremont facility expanded in the 1987 and 1988. In December 1988, Sumitomo Sitix announced that it was negotiating to purchase the semiconductor materials division of Cincinnati Milacron, one of the largest suppliers of epitaxial wafers in the United States. The acquisition by Sumitomo Sitix was finalized in March 1989, and the semiconductor materials division of Cincinnati Milacron was renamed Cincinnati Semiconductor. Since the acquisition, Sumitomo Sitix has invested in upgrading and expanding the Maineville, Ohio, manufacturing facility. The majority of Cincinnati Milacron's epitaxial wafer production had been for discrete device applications, with a small percentage dedicated to CMOS epi wafers. Cincinnati Milacron built its own epitaxial reactors, which have not been for sale on the commercial epitaxial reactor market. Dataquest believes that the Maineville plant is currently increasing its capacity for heavily doped substrates for the discrete device market, where it holds a strong market position in the United States with Crysteco and Siltec.

The newest U.S. facility in Albuquerque, New Mexico, was announced in late 1993 and came on line near the end of 1994. The plant was built by Micron Construction Company, a subsidiary of Micron Technology of Boise, Idaho. The plant produces 200mm epitaxial wafers exclusively, for advanced CMOS applications. A large portion of the output is expected to be consumed by Intel, of which Sumitomo Sitix is a major supplier.

Sumitomo Sitix has just announced a new $400 million plant to produce 200mm wafers in Phoenix, Arizona. It is expected that this plant will come on line in late 1997 and have the capability to be expanded to 200,000 wafers a month.

In 1988, Sumitomo Sitix and Tatung, a Taiwan-based manufacturer of silicon ingots and wafers, reached an agreement for Sumitomo Sitix to supply equipment and technology to Tatung in exchange for Sumitomo Sitix using Tatung's silicon facilities as a foundry for local wafer production. However, we believe that the Tatung facility is being used as a source for ingots only.

Dataquest considers Sumitomo Sitix to be a captive producer of polysilicon. Sumitomo Sitix started research on silicon for semiconductor applications in 1957 and built its first polysilicon facility in 1960. In 1984, Sumitomo Sitix completed a new polysilicon facility in Amagasaki (which has an approximate capacity of 480 metric tons per year). Until recently, Sumitomo Sitix also had access to polysilicon capacity at Hi-Silicon in Yokkaichi City, Mie Prefecture. Hi-Silicon (also known as Kojundo Silicon) was established in 1967 as a joint venture between Mitsubishi Metal and Osaka Titanium Company in which both companies shared equally in the 1,080-metric-ton capacity of the Hi-Silicon plant. In October 1987, Osaka Titanium announced that it had sold its 50 percent position in Hi-Silicon to Mitsubishi for an undisclosed sum.

Sumitomo Sitix Plant Locations

Company Head Office and Plant, Amagasaki, Hyogo Prefecture

Saga Plant (from Kyushu Electronic Metal). Kishima District, Saga Prefecture

Imari Plant and Research Center, Imari City, Saga Prefecture

Cincinnati Semiconductor Plant, Maineville, Ohio

Fremont Plant (from U.S. Semiconductor), Fremont, California

Albuquerque Plant, Albuquerque, New Mexico

Phoenix Plant, Phoenix, Arizona (expected production 1997)

Shin-Etsu Handotai

Shin-Etsu Handotai (SEH) is the largest silicon and epitaxial wafer company in the world, with its $1.17 billion in sales accounting for just under 26 percent of the market. The company was formed as a joint venture between Shin-Etsu Chemical and Dow Corning in 1967. In 1979, Shin-Etsu Chemical acquired full ownership of Shin-Etsu Handotai. Shin-Etsu Handotai's subsidiaries and affiliates include SEH America, SEH Europe, and SEH Malaysia. SEH's world headquarters are in Tokyo, and its R&D centers are in Isobe and Shirakawa, Japan, and Vancouver, Washington. In addition to silicon products, SEH manufactures gallium arsenide and gallium phosphide through a joint venture with Furukawa Mining known as Iwaki Handotai.

Shin-Etsu Handotai is a major manufacturer of both Czochralski and float-zone material. Float-zone ingots are grown at the Saigata facility; Czochralski ingots at Isobe, Shirakawa, Takefu, and Vancouver. Shin-Etsu Handotai produces epitaxial wafers at Isobe and Vancouver. In 1988, SEH America completed an expansion of its epitaxial manufacturing capacity at the Vancouver facility. In 1988, SEH also expanded slice and polish capacity at its subsidiary in Livingston, Scotland. In third quarter of 1989, SEH announced that it will build a new facility at its silicon operations in Livingston for the production of silicon wafers used in IC device fabrication. Wafer production at Livingston had been focused on transistor and other discrete device applications.

SEH has invested heavily in 200mm wafer capacity and is considered the leader in supply of high-quality 200mm wafers for DRAM applications. The major production sites for SEH in 200mm, therefore, are in Japan and Malaysia. The Malaysia facilities are expected to support primarily Asia/Pacific demand. SEH-America has 200mm polished and epitaxial capacity in Vancouver. Dataquest expects an announcement to be forthcoming on a planned joint-venture 200mm wafer plant in Taiwan, following MEMC and Komatsu. At the time of this writing, it was unclear what the exact capacity and investment would be, and we do not know the partner or partners. Dataquest also expects further expansion in the Pacific Northwest region of the United States by 1998.

Like several of the major silicon merchant companies, Shin-Etsu Handotai's silicon manufacturing is vertically integrated, from polysilicon to polished wafers. Shin-Etsu Handotai has a 24.5 percent equity position in Hemlock Semiconductor, the Dow Corning polysilicon subsidiary, and obtains additional polysilicon from other vendors to supplement its needs.

Shin-Etsu Handotai Silicon Plant Locations

Isobe Plant and R&D Center, Annaka City, Gunma Prefecture

Nagano Plant, Koshoku City, Nagano Prefecture

Naoetsu Plant, Kubiki Town, Niigata Prefecture

Saigata Plant, Kubiki Town, Niigata Prefecture

Shirakawa Plant and R&D Center, Nishishirakawa, Fukushima Prefecture

Takefu Plant, Takefu District, Fukui Prefecture

Mimasu Plant, Gunma Town, Gunma Prefecture

SEH-Malaysia, Selangor and Salum, Malaysia

SEH-America, Vancouver, Washington

SEH-Europe, Livingston, Scotland

SEH-Taiwan (announcement expected in 1995)

Showa Denko

Showa Denko is one of the more recent entrants in the Japanese silicon market and is the smallest of the Japanese companies, with only $21 million in sales. The company began actively sampling its wafers in the third quarter of 1986. In addition to its silicon wafer operations, Showa Denko provides a broad mix of electronic materials to semiconductor manufacturers, including compound semiconductor materials (gallium arsenide, gallium phosphide, and indium phosphide) and high-purity specialty gases (such as silane, hydrogen chloride, boron trichloride, nitrogen trifluoride, and fluorocarbon etchants). Showa Denko has an R&D Center and epitaxial wafer capacity at Kawasaki, Kanagawa Prefecture. Showa Denko manufactures silicon at its Chichibu City facility in Saitama Prefecture, and single-crystal ingots of gallium arsenide are also produced at this facility. Showa Denko manufactures both Czochralski and magnetic Czochralski (MCZ) material. The company obtained its MCZ technology from Sony, a pioneer in this field. The MCZ growth method has attracted interest in the last few years because of its ability to provide very high-purity material with tight oxygen control. Showa Denko has more than a decade of experience in compound semiconductor material manufacturing and has a distribution network in electronic materials, factors that Showa Denko hopes will provide a competitive advantage.

Dataquest believes Showa Denko has aggressive plans for production of 200mm wafers later in this decade, although earliest production is expected to be 1998.

Toshiba Ceramics

Toshiba Ceramics supplies both silicon and epitaxial wafers to the semiconductor industry, with sales of $275 million (about 6 percent share) making it the seventh-largest supplier in the world. Dataquest understands that a significant majority of Toshiba Ceramics' wafer sales are to its semiconductor parent, Toshiba Corporation. However, Dataquest still considers Toshiba Ceramics to be a merchant silicon company because it actively markets and sells wafers to the merchant market in addition to supplying its semiconductor parent. Toshiba Ceramics' primary silicon growing and manufacturing facility is the Oguni Plant in the Nishiokitama District, Yamagata Prefecture. Activities at this facility include the growth of Czochralski single-crystal silicon ingots and wafer production. Toshiba Ceramics has a joint venture with Tokuyama Ceramics (Tokuyama, Yamaguchi Prefecture). This facility produces epitaxial wafers through 150mm in diameter. We believe that a high percentage of these wafers are being used in power/discrete devices. Toshiba Ceramics also has a large diffused wafer business, primarily for power diodes and bipolar transistors. Toshiba Ceramics' 200mm capacity is in its Niigata plant, and it has very aggressive expansion plans through the rest of the decade.

Toshiba Ceramics also manufactures a diverse product mix for the semiconductor industry, including ceramic materials and quartz, graphite, and silicon carbide products.

Toshiba Ceramics Silicon Plant Locations

Oguni Plant, Nishiokitama District, Yamagata Prefecture

Tokuyama Ceramics, Tokuyama, Yamaguchi Prefecture

Niigata Plant, Kita-Kanbara Town, Niigata Prefecture

Sekikawa Plant, Iwafune Town, Niigata Prefecture

R&D Center, Hadano City, Kanagawa Prefecture

European Silicon Companies

EPITECH

EPITECH is a small epitaxial wafer service company located in France. EPITECH concentrates on performing epitaxial depositions for power and discrete semiconductors. It is known to have 12 to 15 LPE and Gemini reactors to support production. It is estimated that EPITECH's sales in 1994 totaled about $10 million, and the company is expected to grow to over $15 million in 1995.

MEMC Electronic Materials (Hüls AG)

Hüls AG currently owns 53 percent of MEMC Electronic Materials, the second-largest silicon company in the world with $758 million in sales (including the joint venture Posco-Hüls). This was recently reduced from

100 percent through the initial public offering of common stock on the New York Stock Exchange (symbol WFR), the first such offering of a silicon wafer company. Papers filed with the Securities and Exchange Commission indicate that MEMC is incorporated in Delaware, with headquarters in St. Peters, Missouri. It is likely that Dataquest will reclassify MEMC as a United States-based company, but it is currently listed under the European Silicon Company heading.

Hüls AG, a diversified chemical company based in Marl, West Germany, first ventured into the silicon wafer industry in May 1987, when it was announced that its parent corporation, Veba AG of West Germany, would acquire the silicon and photoresist operations of Dynamit Nobel AG. The acquisition, part of the divestiture of Dynamit Nobel's chemical and plastics operations, included Dynamit Nobel Silicon's facilities in Merano and Novara, Italy, and Research Triangle Park, North Carolina, as well as a New Jersey-based photoresist company, Dynamit Nobel Microelectronics (formerly Petrarch Systems). The Hüls division of Veba AG took over operating responsibility for the newly named operation, DNS Electronic Materials. By November 1988, the groundwork was laid for a second key acquisition when it was announced that Monsanto Company had signed a letter of intent concerning the sale of its silicon operations, Monsanto Electronic Materials Company, to Hüls. In April 1989, Hüls completed the acquisition and subsequently consolidated operations of the former Monsanto subsidiary with DNS Electronic Materials. In two short years, Hüls AG went from being a virtual unknown in the market to being one of the world's largest silicon wafer suppliers. Hüls' consolidated silicon operations today operate under the name of MEMC Electronic Materials.

MEMC Electronic Materials sold its share of Korsil, the South Korean joint venture of Monsanto Company and Dongbu Industrial Company. Shortly after MEMC left the joint venture, Korsil ceased operations.

The Merano facility includes a polysilicon plant with capacity of about 750 metric tons and is considered captive. Czochralski and float-zone ingots are also grown at the Merano facility. European wafer operations are located in Novara, where both silicon and epitaxial wafers are produced. Four facilities, formerly part of the Monsanto silicon operations, are now part of MEMC Electronic Materials. Both the St. Peters plant and the newer Spartanburg facility grow single-crystal silicon ingots and produce wafers; epitaxial wafers are produced in St. Peters. The Malaysian wafer facility in Kuala Lumpur and the Japanese facility in Utsonomiya obtain single-crystal silicon and etched wafers from the St. Peters and Spartanburg plants to produce polished wafers for their respective local markets.

In 1990, MEMC entered into an agreement which gave it 40 percent ownership in the joint venture Posco-Hüls in Korea. Samsung and Pohang Iron and Steel own 40 and 20 percent, respectively.

Early in 1994, MEMC completed the acquisition of Kawatec, a small silicon wafer manufacturer located in Santa Clara, California, from Kawasaki Steel. In the third quarter of 1985, NBK was purchased by Kawasaki Steel for $9.4 million. The acquisition was part of the Japanese steel maker's strategy for diversification into electronic materials. Kawasaki Steel invested nearly $70 million in this silicon venture in 1986 to upgrade to 150mm wafer capability and improve silicon wafer quality control with a Class 10 cleanroom and construction of a new 59,000-square-foot facility near the original wafer plant in 1989 to 1990, after a fire destroyed much of its growing capability. Although these investments were targeted at building a high-quality epitaxial facility to supply CMOS manufacturers, Kawatec was never able to penetrate the market very deeply. As a result, Kawasaki Steel, suffering from the Japanese recession, was anxious to divest itself of the silicon manufacturing operations. MEMC was able to pick up high-quality epitaxial equipment for a bargain.

In mid-1994, MEMC announced a joint venture with China Steel to manufacture 150mm and 200mm wafers in Taiwan. The plant will be located at the Hsinchu Science Park and investment is likely to total $150 million. The plant is expected to feed the growing demand for DRAM and foundry-related silicon requirements, for which Taiwanese semiconductor companies have set their strategy. MEMC owns a 45 percent interest in the joint venture.

During the months preceding its initial public offering in July 1995, MEMC negotiated the acquisition of two operations. MEMC purchased 85 percent of the polysilicon business of Albemarle, which is now named the Granular Polysilicon Business. This operation is still managed by Albemarle, which still owns a 15 percent interest and receives an operating fee. This business is discussed in more detail in Chapter 3 of this report.

MEMC also acquired an 80 percent interest in Texas Instruments' wafer manufacturing operation, which was the largest captive wafer operation in the world before its acquisition. The new joint venture, named MEMC Southwest, is still 20 percent owned by Texas Instruments, which is expected to get the largest proportion of wafer production from the operation. Coincidental with the establishment of the joint venture, a new $300 million 200mm wafer plant was announced at the Sherman, Texas, site. This new plant is expected to come on line during 1997. It is estimated that this operation had revenue of about $115 million in 1994, which will be included as part of MEMC sales in 1995.

MEMC Electronic Materials Silicon Plant Locations

St. Peters Plant, St. Peters, Missouri

Spartanburg Plant, Spartanburg, South Carolina

Technical Center and Plant, Merano, Italy

Novara Plant, Novara, Italy

Kuala Lumpur Plant, Kuala Lumpur, Malaysia

Utsunomiya Plant, Utsunomiya City, Tochigi Prefecture, Japan

Posco-Hüls, Korea

Taisil Joint Venture, Hsinchu, Taiwan (expected production 1996)

MEMC Southwest, Sherman, Texas (acquired from Texas Instruments in 1995)

Granular Polysilicon Business, Pasadena, Texas (acquired from Albemarle in 1995)

Closures

As a result of the consolidation of DNS Electronic Materials and the Monsanto silicon operations, three wafer facilities were closed: the Monsanto wafer operation in Milton Keynes, England, the DNS facility in Research Triangle Park, North Carolina, and the DNS facility in Spartanburg, South Carolina. Also, the activities of the DNS Electronic Materials technical center, formerly in Sunnyvale, California, were consolidated with the technical center in St. Peters, Missouri.

Okmetic

Okmetic is a relatively new silicon wafer company in Espoo, Finland. The company was founded in 1985 by Outokumpu and Nokia. Outokumpu is a diversified company that specializes in metallurgy, mining, industrial equipment manufacturing, and electronics, while Nokia has several divisions that specialize in electronics, cables, machinery, metal products, engineering, chemicals, and plastics. Okmetic's silicon manufacturing capability is based on a joint research and development program between Helsinki University of Technology and Okmetic's founders. Okmetic started silicon wafer production in 1987 and offers polished CZ wafers from 3 inches through 150mm in diameter. The company has been recently aggressive in its expansion of 100mm and 125mm wafer capacity.

Siltronix SA

Siltronix SA is small silicon wafer company located in Geneva, Switzerland. The privately held company was established in 1970. Dataquest believes that Siltronix focuses its sales and marketing efforts exclusively on the European market.

Topsil Semiconductor Materials A/S

Topsil is a merchant silicon manufacturer in Frederikssund, Denmark. Topsil produces its own polysilicon, grows float-zone single-crystal ingots, and manufactures wafers. The company pioneered the neutron transmutation doping (NTD) technique in 1974. This technique transforms silicon atoms into phosphorus by exposing a wafer to a flux of thermal neutrons. Although the technique can form only phosphorus-doped materials, its advantage is that it can provide an extremely uniform distribution of phosphorus, thus producing wafers with well-defined resistivity profiles. Recently, Topsil was granted funding by the Danish government to develop bonded SOI wafers.

Wacker-Siltronic

Wacker-Siltronic is the fourth-largest supplier of silicon and epitaxial wafers to the semiconductor industry, with an estimated $500 million in sales (11 percent share) in 1994. Wacker-Siltronic is the name used to refer to the collective silicon operations of Wacker-Chemie GmbH of West Germany, which is owned equally by Hoechst AG and Dr. Alexander Wacker Familliengesellschaft GmbH. Wacker Chemie first started its research into high-purity silicon materials in 1953 and established Wacker Chemitronic at Burghausen, West Germany, in 1968. Wacker's U.S. operations were established in 1978, as a U.S. subsidiary of the parent company.

Wacker's Burghausen facility has extensive single-crystal growth operations, both Czochralski and float-zone; wafer production, silicon and epitaxial, occurs at Burghausen. Wacker is a recognized leader in the field of float-zone silicon material. In the summer of 1988, Wacker expanded into Fairchild's vacated facility in Wasserburg, Germany. The plant in Wasserburg is used primarily for polishing and epitaxial processing of 150mm and 200mm wafers. Dataquest believes that wafer production at Wasserburg began in 1989. Recent expansion in Germany has enabled Wacker to become one of the leaders in 200mm wafer supply, along with SEH, MEMC, and Sumitomo Sitix.

In the United States, Wacker Siltronic produces silicon single-crystal ingots and wafers at its Portland, Oregon, facility. A major new plant called Fab 2 expected to be on line by mid-1996, which will produce 200mm wafers. Wacker Chemicals East Asia, established in Tokyo in 1983, serves as a marketing and sales arm for Wacker in Japan and the Pacific Rim.

Wacker Silicon Plant Locations

Wacker Siltronic, Burghausen, Germany

Wacker Siltronic, Wasserburg, Germany

Wacker Siltronic, Portland, Oregon

Rest Of World Silicon Companies

Dataquest has identified seven Asia/Pacific silicon companies— three in South Korea and four in Taiwan—that represent a growing domestic supplier base in the newly industrialized countries of the Pacific Rim. This section of our study briefly examines the activities of these six merchant silicon companies. Silicon wafer activities in Brazil and India are also discussed.

South Korea

Oriental Electronic Materials

Dataquest began covering Oriental Electronic Materials (OEM) in 1992, but sales of wafers dropped in 1993 to just over $3 million. OEM ships polished wafers from its plant in Seoul, with most of its sales into Japan. However, its Japanese partner, Semicon Nagano, filed for bankruptcy in 1993. OEM has adapted by shifting its business back to reclaimed wafers. We understand that it is trying to re-establish a distribution channel outside Korea for polished wafers.

Posco-Hüls

Posco-Hüls is a joint venture between Pohang Iron and Steel (40 percent), MEMC Electronic Materials (40 percent), and Samsung (20 percent). The joint venture has constructed a wafer plant south of Seoul, Korea, an investment of $110 million dollars. The plant was built to manufacturer 150mm and 200mm wafers. Qualification runs began in November of

1992. Posco-Hüls has been very aggressive in expanding production recently, particularly in 200mm wafers, and its largest customer is believed to be Samsung.

Posco-Hüls is considered a Korean company based on the 60 percent ownership by Korean interests.

Siltron

In October 1985, Siltec announced the licensing of its silicon technology to Lucky Advanced Materials, of South Korea. LAMI agreed to pay Siltec $4 million plus royalties for the technology. The LAMI silicon facility, located in Gumi, began production in February 1987. The LAMI plant has both single-crystal silicon growth and wafer production operations. Lucky changed its name to Siltron in September 1991. Siltron is one of the largest silicon suppliers in the region and the largest purely Asian-owned company with sales of $90 million in 1994. The company has been growing at a 36 percent CAGR over the last four years.

Taiwan

Five silicon wafer companies are located in Taiwan, including Taisil (the MEMC joint venture) and the Komatsu-Formosa Plastics joint venture, neither yet producing wafers. The other three are Hermes Epitaxy, Sino-America, and Tatung Company. Hermes Epitaxy is an epitaxial wafer service company, and Sino-America produces single-crystal ingots and CZ wafers. Both companies have wafer facilities in Hsinchu. Tatung Company is a large, diversified electronics firm; its silicon manufacturing facility is located in Taipei. In 1988, Sumitomo Sitix and Tatung agreed that Sumitomo Sitix would supply equipment and technology to Tatung in exchange for the use of Tatung's silicon facilities as a foundry for local wafer production. To date, however, we believe that the Tatung facility is being used as a source for ingots only.

Taiwan is the current hot spot for investing in joint ventures. With its explosion of semiconductor fabs, many companies are announcing or planning joint ventures.

Brazil

Heliodinamica of Sao Paolo, Brazil, began production of silicon wafers for semiconductor device fabrication in 1988. The solar energy company originally manufactured silicon wafers for photovoltaic applications but now has expanded its capability to service the Brazilian microelectronics industry. The crystal growth and wafer technology employed by Heliodinamica was developed in Brazil.

India

Metkem Silicon in Mettur, India, manufactures polysilicon and has plans to produce silicon wafers for semiconductor device fabrication. Another plan for polysilicon production in India was dropped by the government in late 1987—the national silicon factory project. That project, which was planned to have a capacity of 200 metric tons per year, was being developed in conjunction with Hemlock Semiconductor, a major U.S. polysilicon manufacturer.

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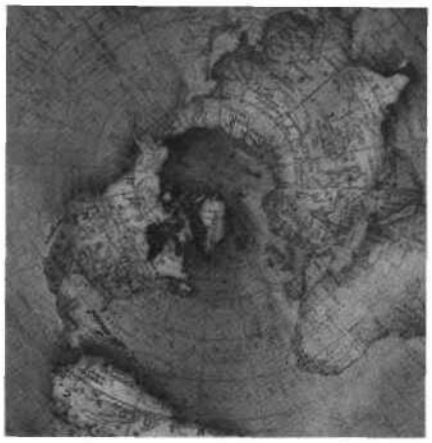

Dataquest

Dedicated Foundries

Focus Report

Program: Semiconductor Equipment, Manufacturing, and Materials Worldwide
Product Code: SEMM-WW-FR-9501
Publication Date: May 15, 1995
Filing: Focus Studies

Dedicated Foundries

Focus Report

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Table of Contents

List of Figures

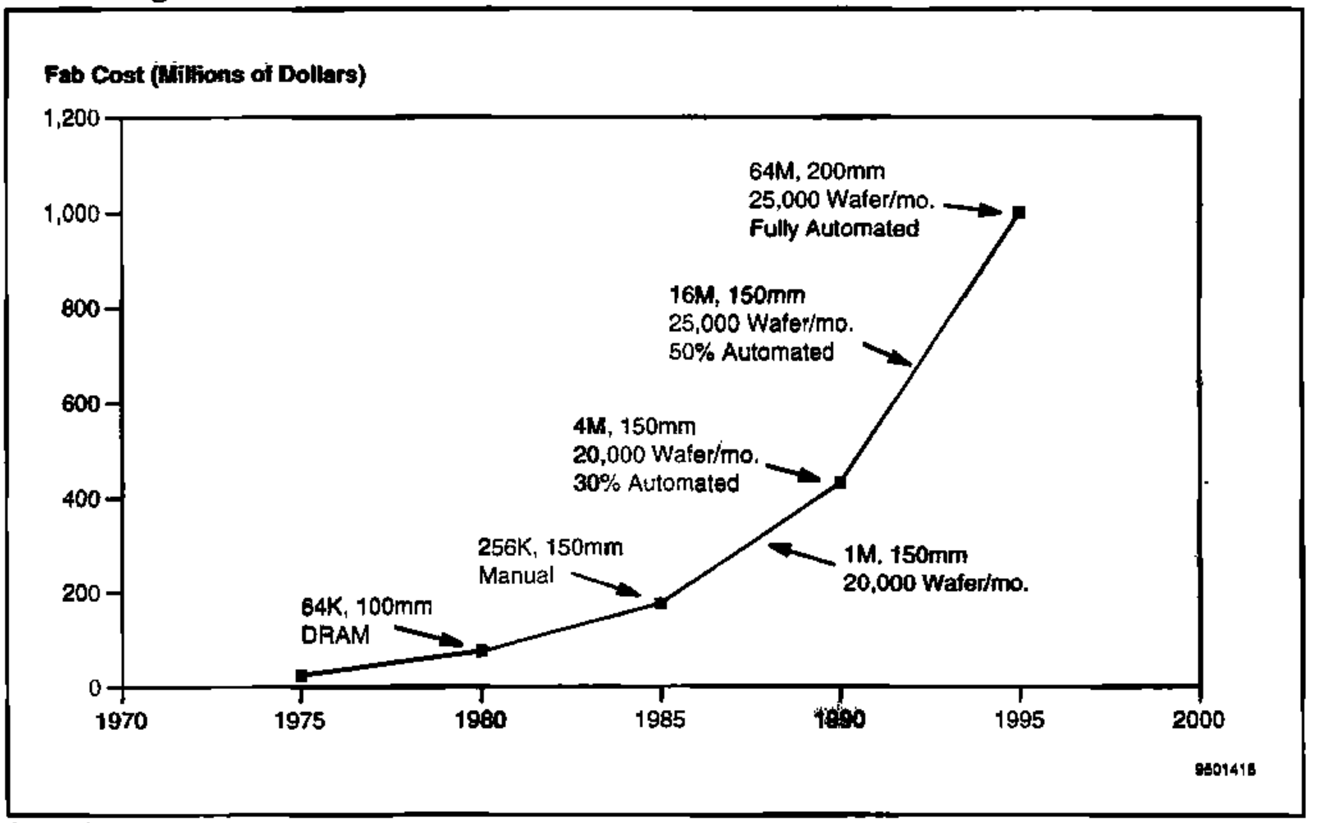
List of Tables

Chapter 1
Foundry Manufacturing

The New Economics of Semiconductor Manufacturing

The single most important factor that has profoundly altered the economics of the semiconductor manufacturing industry arguably is the continual escalation of the cost of building a fab, coupled with the cost associated with the development of the next generation of process technology. Figure 1-1 shows the rate at which the cost of a new fab has risen over the past 20 years. The cost of a new fab has increased by more than 4.5 times from 1985 to 1995, even though today's billion-dollar 8-inch fab has a silicon-area processing capability that is about 2.2 times that of a 1985 6-inch facility.

Figure 1-1
The Rising Cost of New Fabs

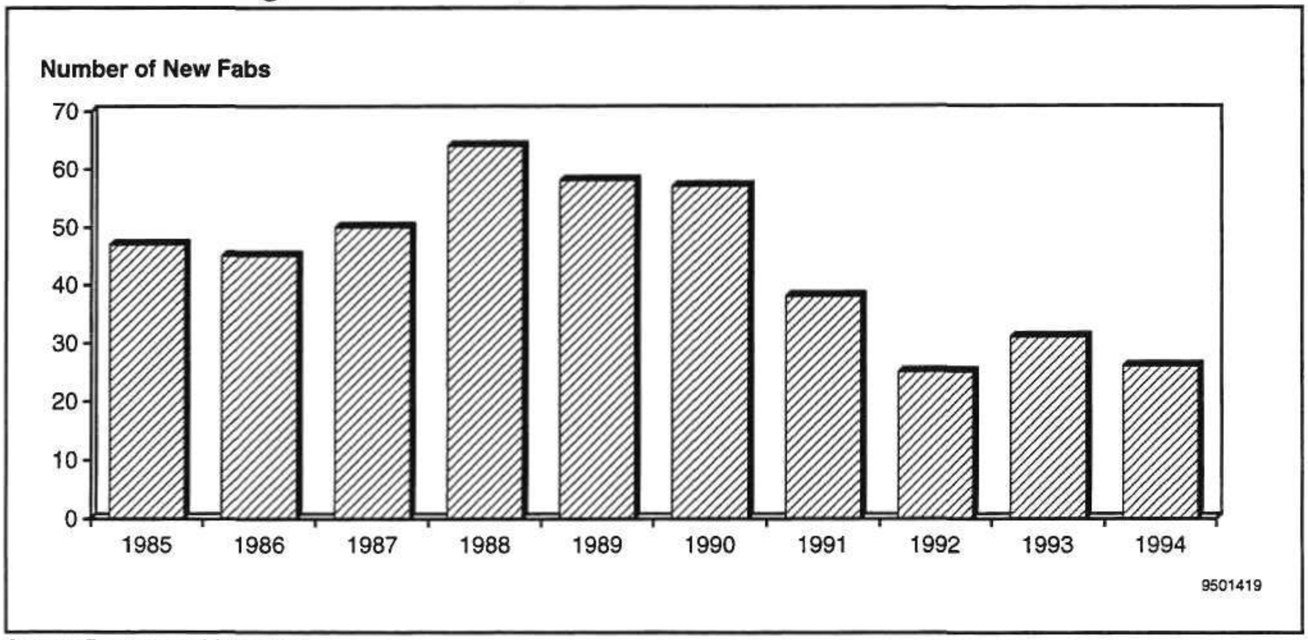


Source: Texas Instruments

This new economics of fab costs has had profound implications for the industry. The number of new fabs built has decreased dramatically. Figure 1-2 shows the number of new fabs that have come into production in the past 10 years. The average number of new fabs per year has declined from 53 in the pre-1991 era to about 30 a year in the 1990s. The staggering cost of a new fab today has forced companies to engage in thorough and cautious planning in their manufacturing capacity investment. As a result fewer and fewer fabs are being built. At the same time an increasing number of companies, including many of the large ones, have opted to share the capital costs of new fab investments. These include Tohoku (Motorola/Toshiba), FASL (Fujitsu AMD Semiconductor Ltd.), the Texas Instruments joint ventures (with Kobe Steel, Acer, Canon, Hewlett-Packard, and Hitachi), and most recently IBM/Philips. Shared fab investments usually mean shared fab output—arrangements that make it more likely for more efficient use of the fab capacity and ultimately fewer new fabs.

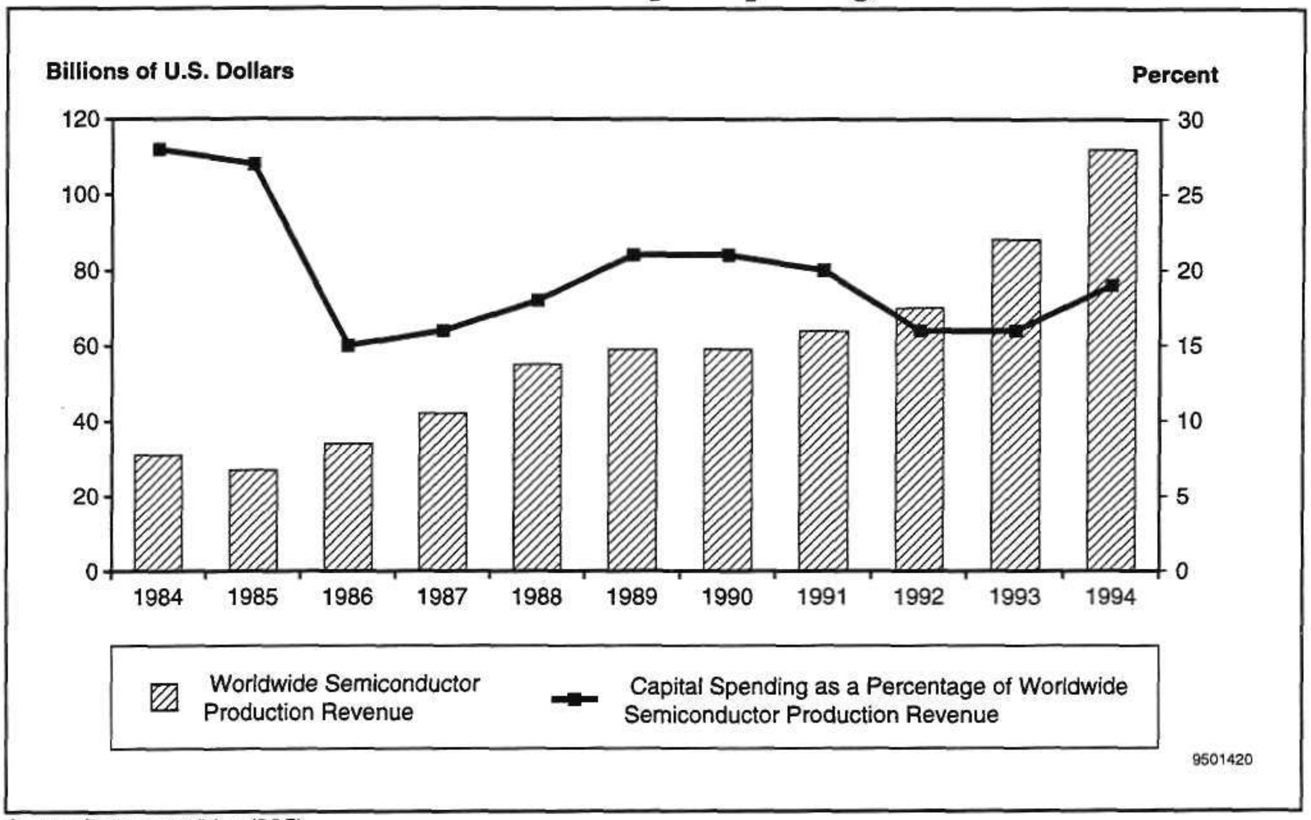
The deliberate caution in new fab investment philosophy, plus the increasingly efficient use of fabs, has caused the level of capital expenditure to lag the rapid growth of the industry. Figure 1-3 contrasts the level of capital spending as a percentage of the semiconductor production revenue with the growing levels of worldwide semiconductor production. During 1992 to 1994, when the industry ushered in the half-micron technology generation and the billion-dollar fab, the level of capital spending had not kept with the industry growth. It only began to pick up in 1994.

Figure 1-2
New Fabs Coming into Production, 1984-1994



Source: Dataquest (May 1995)

Figure 1-3
Semiconductor Production Revenue and Capital Spending



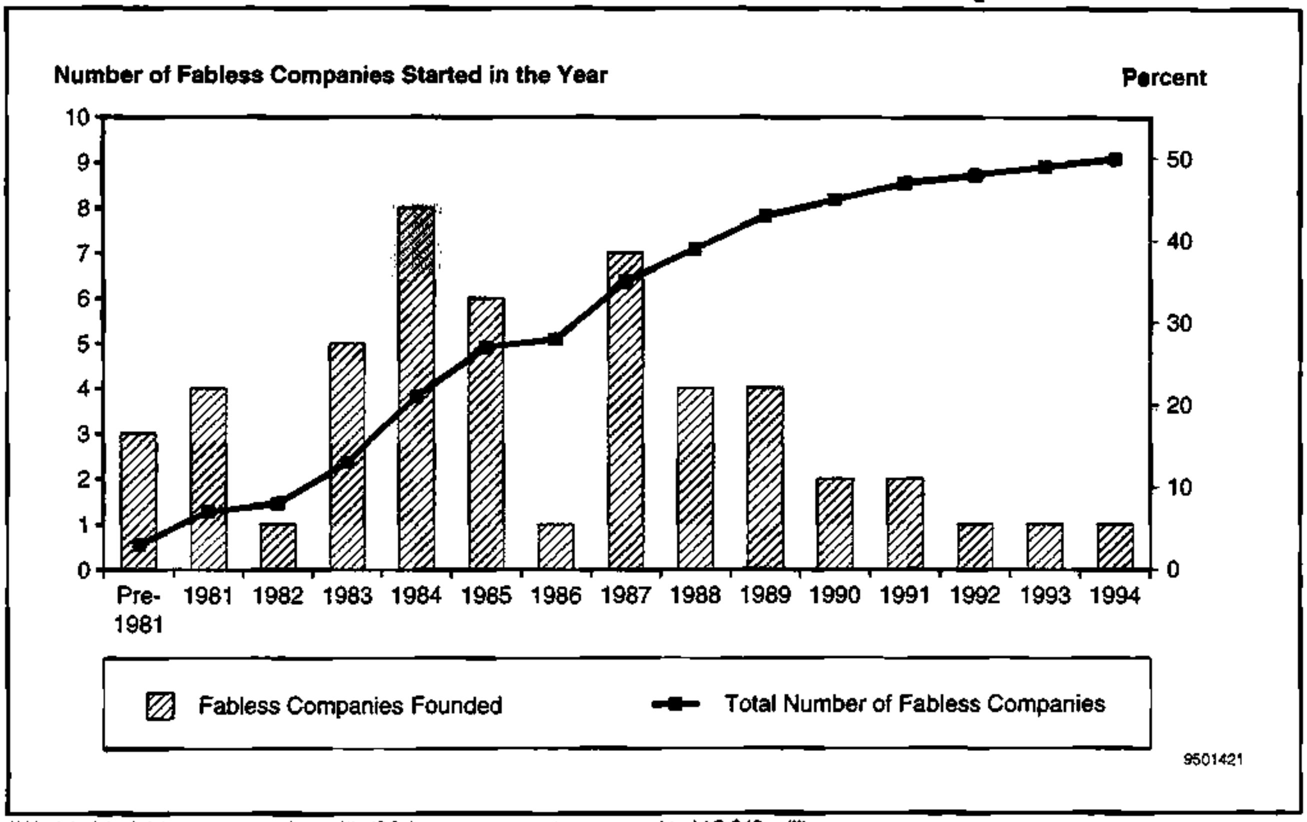
Source: Dataquest (May 1995)

The Evolution of the Fabless Companies

About 50 of the 80 or so fabless companies worldwide that Dataquest tracks reached revenue greater than U.S.$10 million in 1994. Figure 1-4 shows the years in which these 50 fabless companies were founded. The vast majority of the fabless companies were started in the 1980s; 40 percent were founded during 1983 to 1985, including the largest fabless company, Cirrus Logic, and all four major programmable logic devices (PLD) vendors, Actel, Altera, Lattice, and Xilinx. It was during this period that the so-called "fabless model" came into being. At the time no one could be sure that the fabless model would work—the pervasive feeling in the industry then, much like in the earlier days of the industry, was that a serious semiconductor company must have its own fab. The two or three years in which some of today's largest fabless companies got their start also fortunately coincided with the worst slump in the semiconductor manufacturing industry. The recession of 1984 to 1985 hit the industry hard, and as a result much of the industry capacity became idle.

Figure 1-5 shows an estimate of the semiconductor production capacity utilization (based on a model taking into account the histories of the industry's revenue growth, capital investment, and silicon consumption). Some of the excess capacity available in those years was quickly turned into foundry capacity and was more than sufficient to satisfy the modest wafer demand of the new fabless companies. The foundries that supplied the fabless companies' wafer needs during the years around 1985 mainly were vertically integrated semiconductor manufacturers in the United States, for example, Hewlett-Packard, AT&T, and NCR.

Figure 1-4
Evolution of the Fabless Model: Years in Which the Fabless* Companies Were Founded

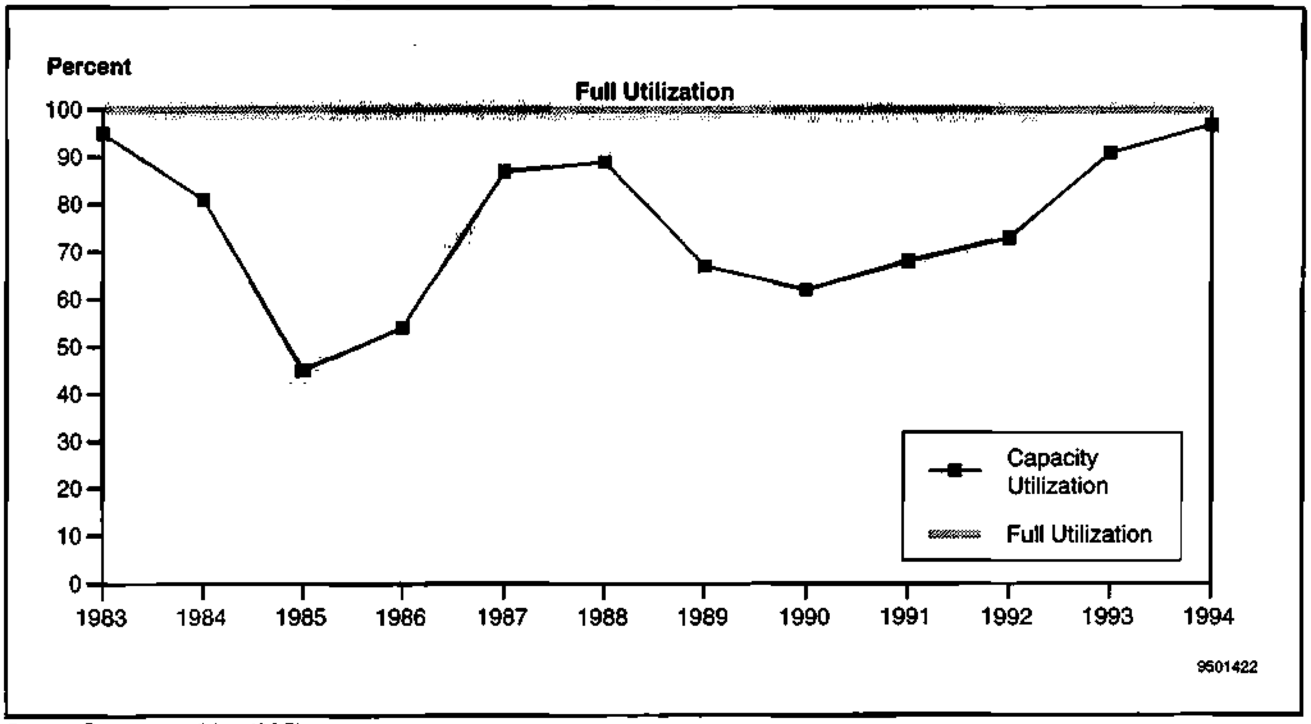


*Worldwide fabless companies with 1994 revenue greater or equal to U.S.$10 million
Source: Dataquest (May 1995)

The foundry supply picture changed in the early 1990s (1990 to 1992) when the industry again hit a slump and capacity became underutilized (see Figure 1-5). This time the capacity underutilization situation was most serious in Japan, which was mired in a deep economic recession. Some of the Japanese DRAM manufacturers began using portions of their older DRAM fab capacity for foundry and ASIC work. Examples include Toshiba, Fujitsu, and NEC. The added foundry capacity from the Japanese manufacturers helped fuel the continual growth of the fabless companies, many of which reached the U.S.$100 million revenue milestone in precisely the 1991 to 1992 time frame.

As much of the world was coming out of the recession beginning in 1993, the semiconductor industry was running full steam and reached growth rates (31.2 percent in 1993 and 28.7 percent in 1994) that nearly "maxed out" the industry fab capacity. With business booming, companies with fabs tended to their own internal production needs first. Consequently companies began ramping down their foundry capacity allocation or even exited the foundry business altogether (for example, HP). Such a situation would have adversely affected the fabless companies as they must depend on other companies to fab their products for them. But this time the fate of the fabless was again blessed. A new breed of foundry services providers emerged and came to the rescue by supplying a significant portion of the

Figure 1-5
Semiconductor Industry Production Capacity Utilization Estimate



Source: Dataquest (May 1995)

fabless companies' wafer demand. These new foundry providers are the dedicated foundries. By providing manufacturing capacity at competitive wafer prices, the dedicated foundries contributed to the fabless companies' attainment of a total revenue of U.S.$4.2 billion in 1994, a rise of 31 percent from U.S.$3.2 billion in 1993.

The Dedicated Foundries

A dedicated foundry is a semiconductor manufacturer solely committed to the manufacturing of other companies' semiconductor products. As such, a dedicated foundry does not engage in and is often prohibited by its company charter from designing or marketing IC end products of its own. Consequently a dedicated foundry is, by design, a company capable of devoting all of its resources on manufacturing technologies and services. Moreover a dedicated foundry differs from a traditional or nondedicated foundry in that it is often in a better position to ensure the customers a consistent supply of wafer capacity. This stems from the fact that the manufacturing capacity of a dedicated foundry is 100 percent allocated to customers' wafer needs, whereas a nondedicated foundry tends to take an "opportunistic" posture because its foundry capacity allocation often can be at the whim of the company's internal manufacturing needs.

The world's first dedicated foundry was founded in 1987. The company, Taiwan Semiconductor Manufacturing Company Ltd. (TSMC), has become the world's largest foundry and one of the most profitable ventures of all semiconductor companies in the five years since the operation of its first fab. TSMC typifies a full-service foundry provider that offers a "total manufacturing solution" that includes maskmaking, wafer processing, wafer probe, testing and packaging, and even an ASIC service. Another full-service provider is Chartered Semiconductor in Singapore, which has also become an important player in the foundry industry. Tower Semiconductor (Israel) and Orbit Semiconductor (Sunnyvale, California) are two foundries that, despite their smaller capacities, have grown impressively in the past few years. Newport Wafer Fab of Scotland, a company with a rich history (SGS-Thomson/Inmos), is making plans to propel itself into the big league of global foundry manufacturing. SubMicron Technology (Bangkok, Thailand) is poised to enter the foundry business in a big way when its U.S.$800 million fab goes into production in 1996.

These are the six dedicated foundries in the world of semiconductor manufacturing that Dataquest has identified. Chapter 2 presents profiles of these six companies.

Chapter 2
Company Profiles

Taiwan Semiconductor Manufacturing Company Ltd.

Corporate Staff

Location	Hsinchu, Taiwan
Chairman, CEO	Morris Chang
President	Donald W. Brooks
President, TSMC USA	John Luke
Vice President, Operations	F.C. Tseng
Senior Director, Corporate Marketing and Sales; Vice President, Finance	Gary Tseng
Estimated 1994 Revenue	U.S.$740 million
Fiscal Year-End	December 31
Employees	About 2,700
Founded	1987

Corporate Overview

TSMC was established in 1987 as a joint venture between the Taiwanese government and N.V. Philips GmbH (NVPG). TSMC is the first semiconductor company with a foundry-only company charter. The company added an ASIC CAD service in 1991. As the largest semiconductor producer in Taiwan, TSMC operates four 6-inch wafer fab modules with a combined monthly capacity of 90,000 wafers (6-inch equivalent). Current technologies range from 0.5-micron to 2.0-micron CMOS processes with triple-layer metal and double-poly. In addition to ownership of Taiwan Mask Corporation (TMC), TSMC has an in-house maskmaking capability that allows the company to serve a larger customer base. TSMC also offers test support (wafer probe and final testing) as well as assembly service to afford customers a complete range of final product forms. As a result of the company's successful September 1994 initial public offering (IPO) of 400,600 common shares, TSMC's current ownership comprises Philips' 40.0 percent share and the Executive Yuan Development Fund's (the Taiwanese government) 26.5 percent. The remainder is owned by private investors.

Corporate Financials

Table 2-1 provides a financial history of TSMC.

Table 2-1
TSMC's Revenue, Net Income, R&D, and Capital Spending, 1991-1994 (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995
Revenue	163	250	489	740	NA
Net Income	19	44	168	289	NA
R&D	3.0	4.6	7.0	NA	NA
R&D as a Percentage of Revenue	1.9	1.7	1.5	NA	NA
Capital Spending	160	100	140	300	530
Capital Spending as a Percentage of Revenue	101.0	37.0	30.0	40.5	NA

NA = Not available
Source: TSMC Annual Report, Dataquest (May 1995)

The salient features of TSMC's financial profile define the character of a dedicated foundry: low R&D expenditure and high capital spending. Average R&D and capital spending for the semiconductor industry in 1994 were 14 percent and 19.4 percent, respectively. Only Goldstar and Hyundai, in their ambitious pursuit of DRAM production leadership, and Chartered Semiconductor outspent TSMC in capital spending as a percentage of revenue, in 1994.

Fab Information

Table 2-2 provides an overview of TSMC's manufacturing capacities and technology capabilities. Table 2-3 shows TSMC's total capacity plan and year-to-year change.

Table 2-2
TSMC's Fabrication Facilities, Capacities, and Technologies

Fab	Geometry Current (µm)	Geometry Ultimate (µm)	Year of Production Start	Wafer Size (mm)	Capacity Current (Wafers/Month)	Capacity Ultimate (Wafers/Month)
Fab 1	1.0	0.8	1988	150	19,000	19,000
Fab 2A	0.8	0.6	1990	150	34,000	38,000
Fab 2B	0.6	0.5	1992	150	29,000	38,000
Fab 2C	0.8	0.6	1994	150	7,000	7,000
Fab 3	0.5	0.35	1995	200	-	30,000

Source: Dataquest (May 1995)

Table 2-3
TSMC's Total Capacity Plan and Year-to-Year Change (6-Inch Wafer Equivalent)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Capacity (K)	124	176	276	406	665	943	1,137	1,410	1,774	2,065	2,198
Year-to-Year Change (%)	-	42	57	47	64	42	21	24	26	16	6

Source: Dataquest (May 1995)

All TSMC fabs are located in the Science-Based Industrial Park in Hsinchu, Taiwan. A recent expansion in Fab 2B took the fab's capacity from 17,000 wafers per month to 29,000 wafers per month. The next stage of expansion, scheduled to be completed by March 1996, will boost 2B's capacity further to 38,000 wafers per month. Capital expenditure has been slated for the construction of Fab 3 to achieve an initial capacity of 10,000 wafers (200mm) per month by the first half of 1995. Fab 3's ultimate capacity will be 30,000 wafers per month. The fab is scheduled to be completed by March 1998.

TSMC's capital spending plan is to invest about U.S.$2 billion in the five years 1995 to 1999 to give TSMC a total capacity of nearly 183,000 wafers-per-month capacity (6-inch wafer equivalent) before the year 2000. Half of this capacity will be on 8-inch wafers and will be the recipient of the bulk of TSMC's next-five-year capital investment. Fab 3 has just been completed and will be populated with a 0.5-micron tool set extendable to 0.35-micron production. Building/shell construction has begun for a second 8-inch fab, Fab 4, and first silicon is expected to come out before the end of 1996. TSMC is planning Fab 5 and is considering locating the new fab outside of Taiwan to help serve the company's large customer base overseas. The time frame for the construction of Fab 5 has not been decided but should be consistent with the company's policy of building one new fab 18 months after the completion of the previous fab.

Figure 2-1 shows TSMC's technology road map from 1992 to 1998. Processes for TSMC's 0.8-micron technologies were developed from a 0.8-micron, one-poly, two-metal logic baseline process. The baseline process for the 0.6-micron-level technologies has been switched to a two-poly, two-metal SRAM process to allow for maximum overlap of process technologies. TSMC also has developed a salicide process for specific customers and is working with AMD to develop a 0.5-micron, three-level metal process with chemical-mechanical polishing (CMP). TSMC is also developing a process without CMP that will be offered as a lower-cost alternative for the 0.5-micron, three-metal technology.

Foundry Philosophy

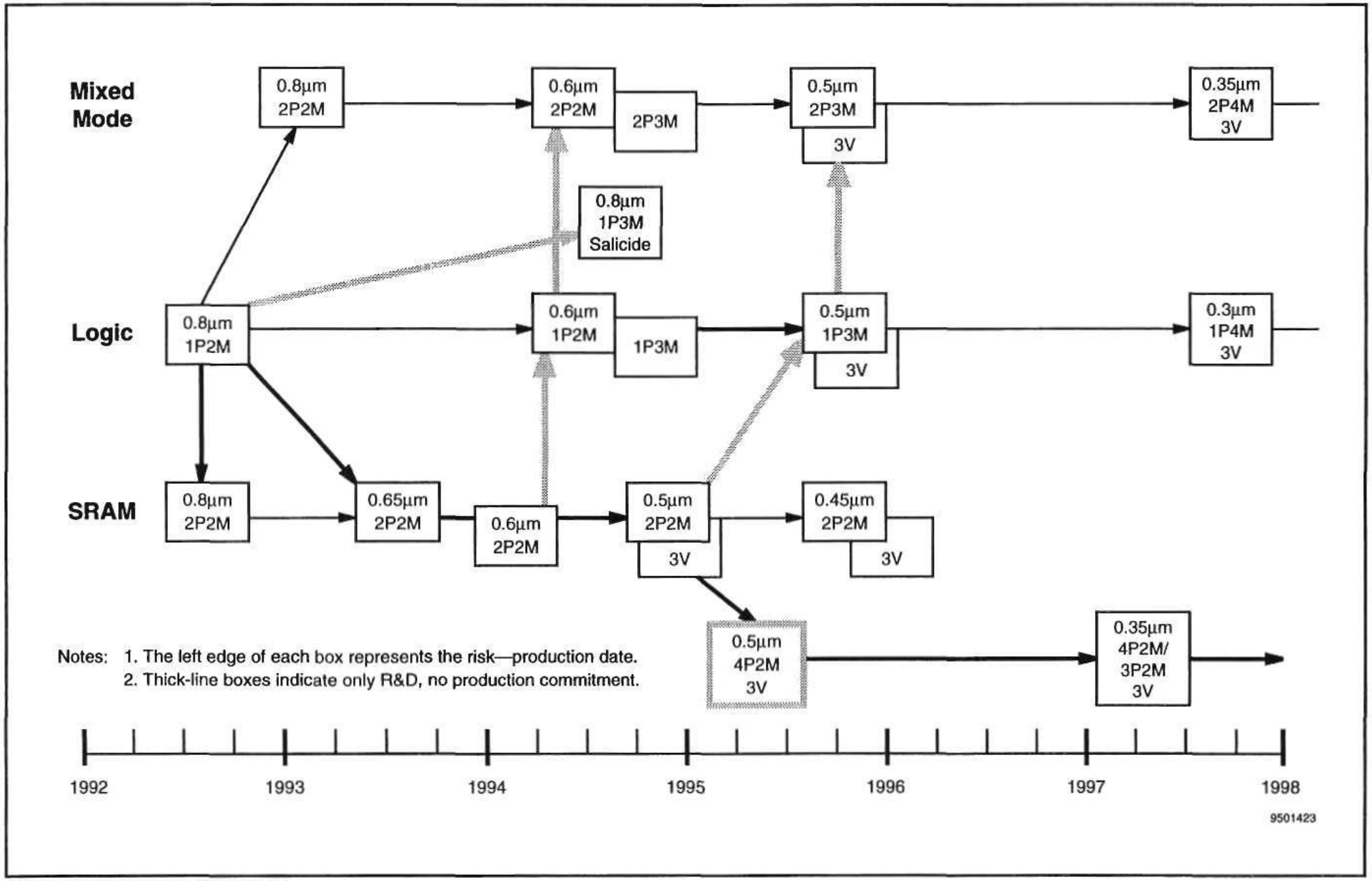
TSMC's founding missions are twofold:

- Establishment of a world-class semiconductor manufacturing enterprise through extensive and continual capital spending and training of processing engineers

- Providing ample and modest-cost fabrication capacity to the world's vibrant circuit design industry

Indeed, TSMC's founding philosophy embodied many of the elements of a government-sponsored industrial policy. Realizing that semiconductor manufacturing is a tremendously capital-intensive industry, the Taiwanese government, together with NVPG, provided the bulk of the large capital TSMC needed to get a head start. As a result, TSMC began commercial production in 1988, just one year after its founding—a phenomenal rate considering that, in the days of TSMC's founding, Taiwan had little semiconductor industry and few trained semiconductor processing personnel. Government subsidies in the form of tax breaks also helped. TSMC, like all IC companies in Taiwan, is exempt from income tax

Figure 2-1
TSMC's Technology Road Map



Source: TSMC, Dataquest (May 1995)

payment on income from operation of the first five years of each new fab—a significant boost on its bottom line. TSMC's net income as a percentage of revenue for 1993 and 1994 was 30 percent and 39 percent, respectively. These earning performances are among the highest in the global semiconductor industry.

TSMC's submicron technologies are obtained in part through technical licensing and assistance agreements with the Industrial Technology Research Institute (Hsinchu, Taiwan) and NVPG. These arrangements, at modest costs to TSMC, free the company from devoting sizable valuable resources to R&D and allow it to still be on par with advanced processing technology. TSMC's foundry charter also helps in directing the company's R&D focus on solely manufacturing and process technologies, as it chooses not to delve into the more expensive development of circuits designs. TSMC's R&D expense was only a scant 1.5 percent of revenue in 1993, compared to the 14 percent of revenue spent, on average, by the semiconductor manufacturing industry.

TSMC's future looks bright, given that it is in an ideal position where all parties benefit. Large capacity plus a comfortable profit margin will enable TSMC to continue to offer competitive prices on its foundry services. As a result TSMC has been and will continue to run at or near capacity. The year 1994 saw a successful IPO of 400,600 TSMC shares that quickly went from an initial sales price of NT$90 to the NT$150 to NT$170 range in a few months. Investor confidence in TSMC attests to the increasing endorsement of TSMC's foundry-only business model in the thriving semiconductor industry.

Chartered Semiconductor Manufacturing Pte. Ltd.

Corporate Staff

Location	Singapore
President	Tan Bock Seng
Vice President, Finance	Ong Peck Choo
Vice President, Operation	Mike Hunter (Fab I), Chris Chi (Fab II)
Vice President, Business Development and Logistics	Choong Chan Yong
Vice President, Sales and Marketing	Steve Della Rocchetta
Vice President, Engineering	Dr. C.C. Wei
Estimated Fiscal 1994 Revenue	U.S.$175 million
Fiscal Year-End	December 31
Employees	1,080 worldwide
Founded	November 1987

Corporate Overview

Chartered Semiconductor Manufacturing Pte. Ltd. (CSM) was established in November 1987 as a joint venture of Singapore Technologies Venture (STV), Sierra Semiconductor Corporation, and National Semiconductor Corporation. Operation began in 1989 in CSM's Fab I, which served as a captive foundry. National sold its ownership to STV and Sierra in 1991. CSM launched its foundry strategy in May 1991 and became a dedicated semiconductor foundry. In the following year STV increased its ownership in CSM to 99.4 percent. By 1993, STV, now the Singapore Technologies Holding Pte. Ltd., became the sole owner of CSM. CSM provides wafer processing, parametric, functional, and final test services. Customers' designs can be converted into physical layouts using CSM's design rules and third-party conversion tools. CSM subcontracts out assembly and mask-generation work.

Company Background

Table 2-4 shows CSM's revenue and capital expenditure for 1992 to 1994.

Table 2-4
CSM's Revenue, 1992-1994 (Millions of U.S. Dollars)

	1992	1993	1994	CAGR (%) 1992-1994
CSM Revenue	45*	95*	175*	97
Capital Spending	130	185	350	64
Capital Spending as a Percentage of Revenue	290	195	200	

*Dataquest estimate
Source: CSM

Fab Information

Several generations of CMOS technologies have been developed in CSM's Fab I facility since 1989, culminating in the qualification of a 0.6μm process in 1994. Table 2-5 shows CSM's existing and planned fab facilities. Table 2-6 shows CSM's projected production capacity, segmented into technologies greater than 0.6μm and less than or equal to 0.6mm.

Table 2-5
CSM's Fabrication Facilities, Capacities, and Technologies

Fab	Current Geometry (μm)	Ultimate Geometry (μm)	Year of Production Start	Wafer Size (mm)	Current Capacity (Wafers/Month)	Ultimate Capacity (Wafers/Month)
Fab I	1.0 to 0.6	1.0-0.5	1989	150	23,000	24,000
Fab II	0.6	0.6 to 0.2	Q4/95	200	-	30,000
Fab III	-	< 0.2	1997	200	-	-

Source: CSM, Dataquest (May 1995)

Table 2-6
CSM's Total Annual Capacity Plan and Year-to-Year Change
(Thousand of Wafers, 6-Inch Wafer Equivalent)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
> 0.6μm Capacity	3	17	40	73	148	200	200	200	150	150	150
≤ 0.6μm Capacity	-	-	-	-	-	32	102	277	674	744	744
Total Capacity (μm)	3	17	40	73	148	232	302	477	824	894*	894*
Year-to-Year Change in Total Capacity (%)	-	467	135	83	103	57	30	48	73	-	-

*Does not include CSM's Fab III projection
Source: Dataquest (May 1995)

Groundbreaking for CSM's Fab II took place in February 1994; equipment introduction began in the fab's production pilot line in September. In December 1994 CSM won the distinction of being the first dedicated foundry to ship 8-inch wafers to customers. The success with the 8-inch pilot production led CSM to begin full equipment introduction in the new fab. Module A of Fab II, or Fab IIA, is projected to be operational in the second half of 1995 and is the first of two modules that will have a combined 70,000-square-foot cleanroom facility with a total estimated cost of U.S.$800 million. Fab II will be equipped with minienvironment standard mechanical interface (SMIF) technology (SMIF is an implementation of the minienvironment concept that is particularly suited for the flexible manufacturing environment of a foundry operation). The second phase of Fab II, Fab IIB, is expected to begin volume production in 1996. CSM's 8-inch wafer production capacity plans calls for a ramp-up at 21,400 wafers in 1995 to 120,000 wafers in 1996, 315,000 in 1997, and a peak 355,000 wafers output in 1998. Also on the drawing board is a plan for CSM's second 8-inch fab, Fab III. Details for Fab III's construction plan are still being formulated, but Fab III is projected to begin operation in the 1997 to 1998 time frame to maintain the pace of CSM's continual capacity expansion.

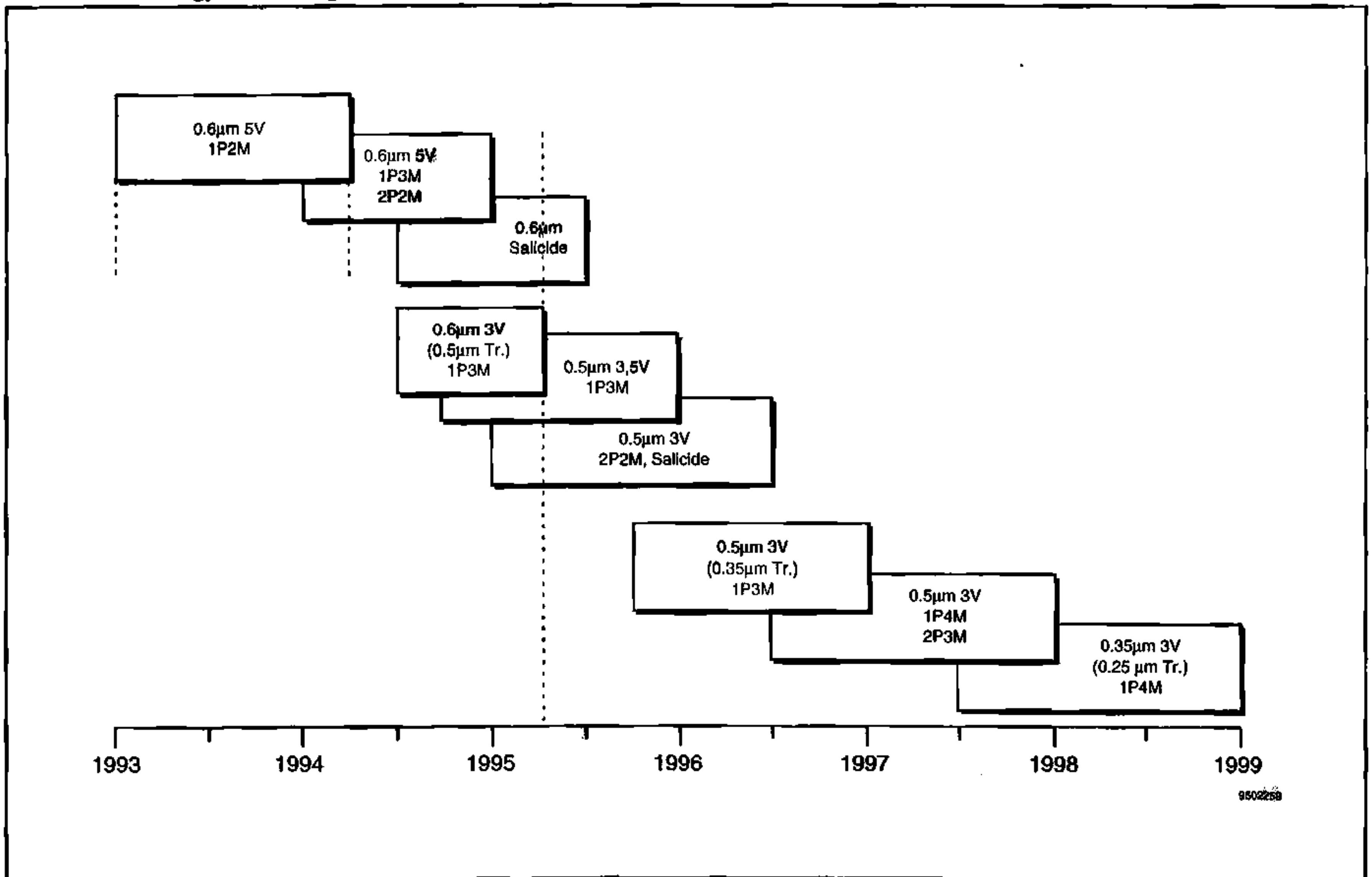
In Fab I, CSM began commercial operation with a 1.5μm CMOS technology employing an N-well process on P or P-Epi substrates. Within a year CSM introduced a 1.2μm technology using G-line steppers. By 1991 CSM achieved process capability in 0.8μm-linewidth, twin-well CMOS technology. With the introduction of I-line steppers in 1992, CSM began developing a 0.6mm process that became available in late 1993. By going from 0.8μm to 0.6μm, CSM achieved significant reduction in the die size that in some cases amounted to as much as 40 percent shrinkage in die area. CSM's production technology repertoire now includes digital logic, ROM, and SRAM processes at 0.6μm as well as analog and EEPROM/PLD processes at the 0.8μm geometry level. As shown in CSM's technology road map in Figure 2-2, CSM continues to work on advanced process development and will offer 0.5μm, three-level metal and salicide processes in 1995. Migration to still smaller geometry processes, beginning at the 0.35μm level, will start in 1996.

Foundry Philosophy

Since the launch of its foundry strategy, CSM has left circuit design work to the customers and focused entirely on the manufacturing aspect of its services. This shift in service orientation not only enabled CSM to forge a better definition of CSM's vision as a foundry, but more importantly allowed CSM to accommodate a diverse range of customers that include the fabless companies, integrated device manufacturers, and system OEM companies.

Severe shortage of fab capacity worldwide in recent years has prompted design houses to scramble for foundry capacity and, when possible, long-term, stable capacity. In response CSM has formulated an arrangement embraced by several key customers. Actel Corporation, Brooktree Corporation, Rockwell International, Alliance Semiconductor Corporation, Standard Microsystems, and LSI Logic have each taken a minority equity position in CSM since 1994. In return each investor is guaranteed capacity in CSM's Fab II. It seems that accepting equity investment by fabless companies for future capacity is a favorable method for CSM to foster long-term, close working relationships with key customers. Equity participation provides a basis for a win/win relationship whereby the customer obtains guaranteed capacity and access to the latest manufacturing technology. The foundry company has reduced capital outlays and an ensured loyal customer base. CSM has also struck up technology partnership with its customers, most notably Toshiba, which entered into a technical collaboration agreement with CSM in November 1994. Under the agreement Toshiba will provide a state-of-the-art 0.5μm process to CSM and also purchase a stake in the company. Partnership through equity participation or technology collaboration is an important theme through which CSM will work with its customers to engender a greater overlap in the mutual interests of the foundry and its customers. However, CSM also has the interest of its nonpartner customers in mind. It is working hard to maintain a balance between guaranteed capacity and future available capacity. Even with the flurry of partnership agreements involving CSM granting guaranteed capacity, CSM maintains a minimum of 70 percent of its total production capacity available for future allocation.

Figure 2-2
CSM's Technology Road Map



Source: CSM, Dataquest (May 1995)

Tower Semiconductor Ltd.

Corporate Staff

Location	Migdal Haemek, Israel
Chairman and CEO	Sanford L. Kane
Vice President and COO	Dr. Rafael M. Levin
Vice President, Technology and Business Development	Dr. Yoav Nissan-Cohen
Finance Manger	Hai Temam
Director of Manufacturing	Assaf Shavit
Director of Process and Device Engineering	Dr. Jeffrey Levy
Fiscal 1994 Revenue	U.S.$57.7 million
Fiscal Year-End	December 31
Employees	510
Founded	March 1993

Corporate Overview

Tower Semiconductor Ltd. began operation as a dedicated foundry in March 1993 by acquiring its Migdal Haemek, Israel, 6-inch wafer fabrication facility from National Semiconductor. It is run by a team of U.S. and Israeli managers with extensive experience in the semiconductor industry. Tower increased its fab capacity from 5,000 wafers per month to 10,000 wafers per month from 1993 to 1994 and migrated from 1.25/1.0μm to 1.0/0.8μm process technology. Tower successfully completed an initial public offering of 3 million shares of common stock in the United States in November 1994. Proceeds from the offering are to be used to help finance Tower's continual expansion of its manufacturing facility.

Corporate Financials

Table 2-7 shows Tower Semiconductor's revenue, net income, and R&D expenditure for 1993 to 1994.

Table 2-7
Tower Semiconductor's Financials (Millions of U.S. Dollars)

	10 Months Ended 1993	1994
Revenue	37.6	57.7
Net Income	3.7	7.8
Net Income as a Percentage of Revenue	10	13.5
R&D	0.33	0.90
R &D as a Percentage of Revenue	0.9	1.6

Source: Tower, Dataquest (May 1995)

Since the company's founding slightly more than two years ago, Tower has been profitable every quarter. By aggressively increasing manufacturing capacity and introducing higher-margin, smaller-geometry process technologies, Tower has achieved impressive revenue and income performance. In 1994, Tower's revenue increased by 54 percent over 1993 (10 months) while the company's net income more than doubled. Tower has three key customers—National Semiconductor, Motorola, and Hewlett-Packard—which consume the bulk of its wafer production. Tower entered into a new three-year contract with National Semiconductor in February 1995 that increased National's contractual wafer capacity allocation to 5,000 wafers per month, which is equal to 50 percent of Tower's current total capacity. Motorola and Tower have a rolling three-year agreement that commits Motorola to more than 3,400 wafers starts, using 1.0µm and 0.8µm processes, per month and will increase to 3,800 wafers per month by June 1997. Tower does intend to diversify its customer base and has targeted the fabless companies as the source of new and potentially higher-margin demand for its wafers. Announced fabless customers of Tower include DSP Group and Chip Express.

Tower raised U.S.$42 million in the November 1994 initial public offering. As a result of the public stock offering, 30 percent of Tower's ownership is in shares outstanding to the public; 54.2 percent of Tower is owned by Tower Semiconductor Holdings (Tower Semiconductor Holdings is 60 percent owned by the U.S.-based Data Systems and Software Inc. and 40 percent owned by The Israel Corporation, a publicly held Israel-based holding company). National Semiconductor owns 14 percent of Tower Semiconductor; the remainder, about 2.3 percent, is owned by Tower's senior management.

Manufacturing Capabilities

Tower's wafer fabrication facility's Fab 1 manufacturing capabilities are as follows:

- Process: CMOS
- Geometry (µm): 1.0, 0.8
- Wafer: 6-inch
- Capacity (Wafers/Month): 10,000
- Class: 10
- Square Feet: 31,700

Tower is investing about U.S.$100 million during 1994 and 1995 to boost its manufacturing capacity, which will reach 14,000 wafers per month at the end of 1995. The Israeli Ministry of Industry and Trade has agreed to provide capital investment grants of up to 38 percent of the costs of the expansion. Tower's plan is to increase Fab 1's capacity by 1,000 6-inch wafers per month each quarter to reach an ultimate level of 20,000 6-inch wafers per month by the end of 1997. Table 2-8 shows Tower's year-to-year change in its monthly manufacturing capacity from 1993 to 1996. Tower's capacity expansion plan beyond 1997 calls for the construction of a new 8-inch wafer facility with up to 25,000 wafers start per month.

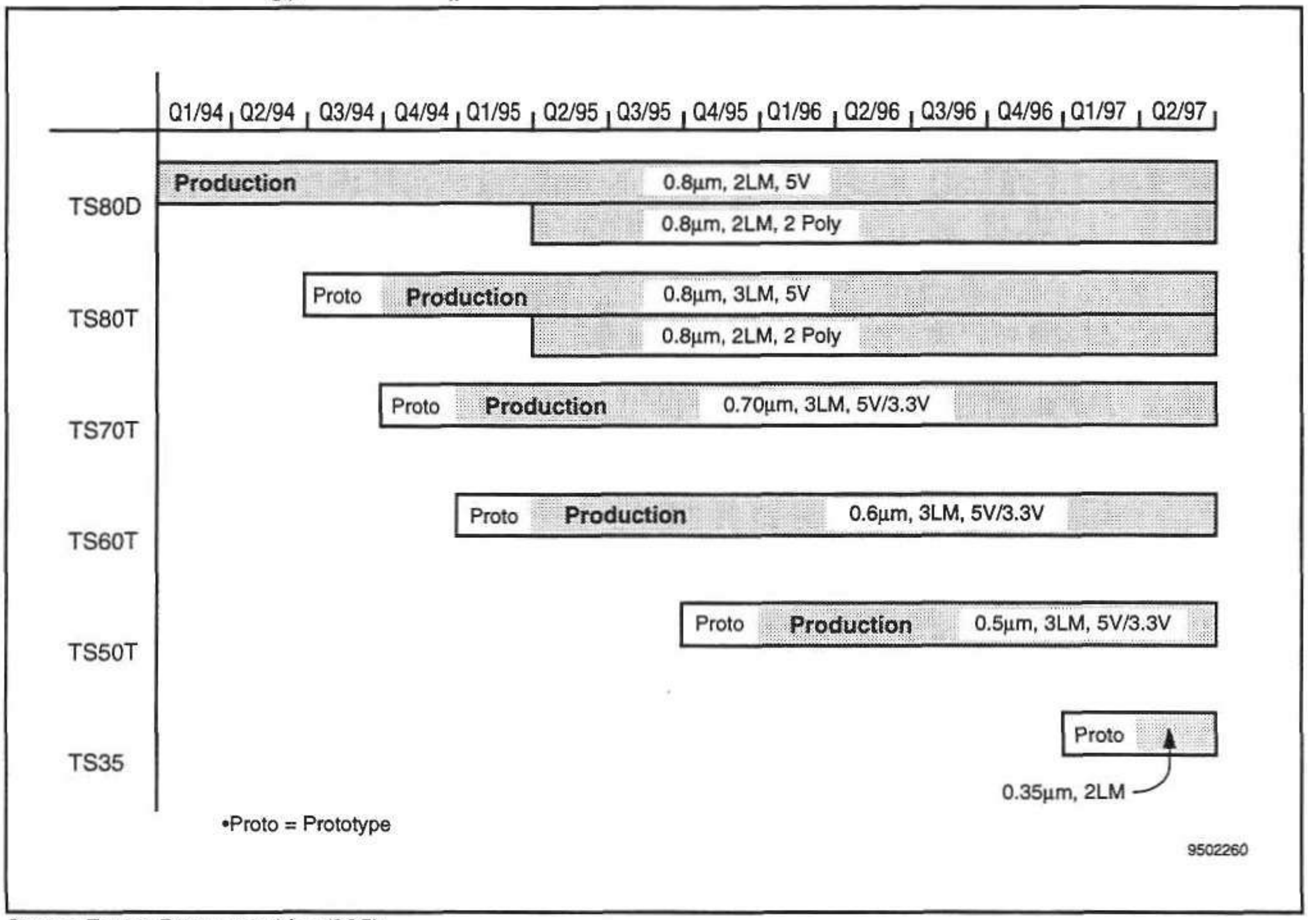
Table 2-8
Tower's Monthly Manufacturing Capacity Plan and Year-to-Year Change (6-Inch Wafer Equivalent)

	March 1995	December 1993	December 1994	December 1995	December 1996
Total Capacity	5,000	7,000	10,000	14,000	18,000
Year-to-Year Change (%)	NA	NA	43	40	29

NA = Not applicable
Source: Dataquest (May 1995)

Tower's current technological capabilities include 1.0µm to 0.8µm processes with two-level and three-level metal. Two-level poly processes are being developed and will become available during the first half of 1995. Meanwhile Tower is also keeping pace on developing smaller-linewidth processes. It expects 0.6µm and 0.5µm processes with up to three-level metal (no CMP required) to be moved into production during 1995. Looking still further into the future, Tower's process technology road map, shown in Figure 2-3, calls for the introduction of 0.35µm processes in two years, by the first half of 1997.

Figure 2-3
Tower's Technology Road Map



Source: Tower, Dataquest (May 1995)

Orbit Semiconductor Inc.

Corporate Staff

Location	Sunnyvale, California
President and CEO	Gary Kennedy
Executive Vice President, Technology	Steve Kam
Executive Vice President, Finance	Joseph Wai
Vice President, Software Engineering	George W. Lewicki
Vice President, Product Engineering	Zahid Ansari
Vice President, Operation	Fernando A. Bettencourt
Estimated Fiscal 1994 Revenue	U.S.$43.5 million
Fiscal Year-End	December 31
Employees	180
Founded	1985

Corporate Overview

Orbit Semiconductor Inc. was founded in 1985 and since then has been a semiconductor contract manufacturer. Orbit grew quickly from 1986 to 1989, but its growth stalled from 1989 to 1992. In November 1991 Messrs. Kennedy, Kam, and Wai, who had been with Orbit since 1985, acquired the company in a management buyout. The new owners began to position Orbit as a provider of semiconductor design, manufacturing, and engineering support services for ASIC development and production. While continuing its contract manufacturing programs, Orbit began in 1993 offering its ASIC services through its ENCORE! program, which provides the conversion of customers' netlist circuit designs into Orbit gate arrays. As a result Orbit has grown dramatically in the past two years (1993 and 1994). Orbit successfully completed an IPO in November 1994, raising U.S.$17 million to help finance its planned facility expansions.

Corporate Financials

Table 2-9 shows Orbit's revenue, net income, and R&D expenses from 1989 to 1994.

Table 2-9
Orbit's Financial History 1989-1994 (Millions of U.S. Dollars)

	1989	1990	1991	1992	1993	1994
Revenue	22.7	20.4	21.6	20.4	27.3	43.5
Year-to-Year Change (%)	-	-11.3	5.9	-5.9	33.8	59.3
R&D	0.60	0.31	0.43	1.12	1.23	2.34
Net Income	1.05	0.25	-2.56	0.18	1.30	4.30
Net Income as a Percentage of Revenue	-	-	-12.7	1.9	4.8	9.9

Source: Orbit

Orbit's revenue remained flat from 1989 to 1992. A significant pickup took place in 1993 after the introduction of its ENCORE! program in late 1992. ENCORE! is offered as a viable approach for reducing nonrecurring engineering (NRE) costs incurred in the prototyping of new circuit designs. ENCORE!'s contribution to Orbit's annual revenue grew from 16 percent in 1993 to 28 percent in 1994. The higher gross margin attainable from the ENCORE! program has also helped Orbit boost its net income, which has risen from 4.8 percent of revenue in 1993 to 9.9 percent of revenue in 1994. Also helping improve Orbit's financial bottom line is the company's continual emphasis on migrating to higher-margin contract manufacturing programs. These include the company's prototyping services, the "High Reliability Manufacturing Program," the Foresight program, and charge-coupled devices (CDDs) fabrication processes.

On November 22, 1994, Orbit successfully completed an IPO of 2.6 million shares of its common stock at a price of $7.50 per share, which gave the company net proceeds of about U.S.$17 million. The proceeds are to be used, in addition to general corporate purposes, to add to the company's manufacturing capacity at Sunnyvale and to fund some of the initial activities connected with Orbit's planned new fab in Israel.

Fab Information

Table 2-10 provides information on Orbit's fabrication facilities, capacities, and technologies.

Table 2-10
Orbit's Fabrication Facilities, Capacities, and Technologies

Fab	Process	Geometry (µm)	Wafer (mm)	Capacity (Wafers Month)	Class	Year of Production
Fab 1	CMOS	1.2-0.8	100	9,600	10-100	1991
Fab 1	CMOS	1.0-0.8	150	1,000	10-100	1995
Fab 2	CMOS	0.8	150	2,000	10	1996

Source: Orbit, Dataquest (May 1995)

Since 1988 Orbit has incrementally upgraded its Fab 1 facility (Sunnyvale) by adding refurbished 100-wafer processing equipment. A major expansion was completed in 1992 that doubled Orbit's production capacity. Fab 1 is rated class 10 in the lithography area and class 100 in the rest of the fab. Orbit plans to use proceeds from a recently completed IPO to install additional equipment at Fab 1 that will provide an additional capacity of 1,000 6-inch wafers per month with 0.8-micron process technology capability. Also on the drawing board is a 6-inch wafer fabrication facility with 0.8-micron production equipment to be constructed in Eilat, Israel. Qualified as an "Approved Enterprise" under Israeli laws, Orbit expects to receive U.S.$24 million in capital investment grants from the Israeli government toward the cost of building the new fab. The projected overall cost of the new fab is U.S.$64 million, which will require Orbit, in addition to using part of the proceeds from the IPO, to obtain funds from loans and the capital markets through one or more public or private financing. Completion of the new fab is expected in the third quarter of 1996. By then Orbit will have a combined production capacity of 9,600 4-inch wafers per month and 3,000 6-inch wafers per month.

Company Product Philosophy

Orbit exemplifies the case of a smaller semiconductor manufacturer that seems to have found the niche markets where its quick production turnaround, software expertise, and low-cost operation have made up for its lack of leading-edge process technology. At the heart of Orbit's strategy is a two-prong approach to moving the company's revenue sources to high-margin products and to areas where the company has competitive advantages.

The first component of the Orbit strategy clearly is its ENCORE! netlist conversion program, which uses internally developed software to convert customers' netlist circuit design of ASICs, including mask-programmable gate array (MPGA) and field-programmable gate array (FPGA) into an Orbit gate array at low NRE costs. By providing a guarantee of a quick turnaround of four to six weeks and flexible minimal volume requirement (as few as 100 pieces), Orbit's objective is provide a viable alternative to the more costly FPGA. Furthermore, compared to FPGA, ENCORE! affords the system designers with engineering flexibilities, that is, programmable power supplies, packaging options, and the ability to merge multiple designs into a single gate array. There are 12 gate array programs in ENCORE! that offer 300 to 45,000 usable gates with up to 240 I/O buffers. However, ENCORE!'s advantages over MPGA are its lower NRE cost and shorter lead time. ENCORE! cannot and does not intend to be a complete replacement of FPGA nor of MPGA, but rather serves to fill a market void created by them. Figure 2-4 shows how Orbit sees ENCORE!'s market position relative to FPGA and MPGA in terms of the unit cost, volume requirement, and time to market.

The other component of Orbit's market strategy is the company's contract manufacturing services, which tend to be low-volume but provide higher gross margins. These include the company's prototyping services, which financially guarantees on-time delivery, and the "High Reliability Manufacturing Program," which incorporates manufacturing procedures and products that meet specific standards required by medical and military applications. There also is the Foresight program, which allows customers to share space on a wafer, thereby significantly reducing the NRE costs. Orbit also supports CCD fabrication processes used in the manufacturing of imaging and analog CCD signal-processing products.

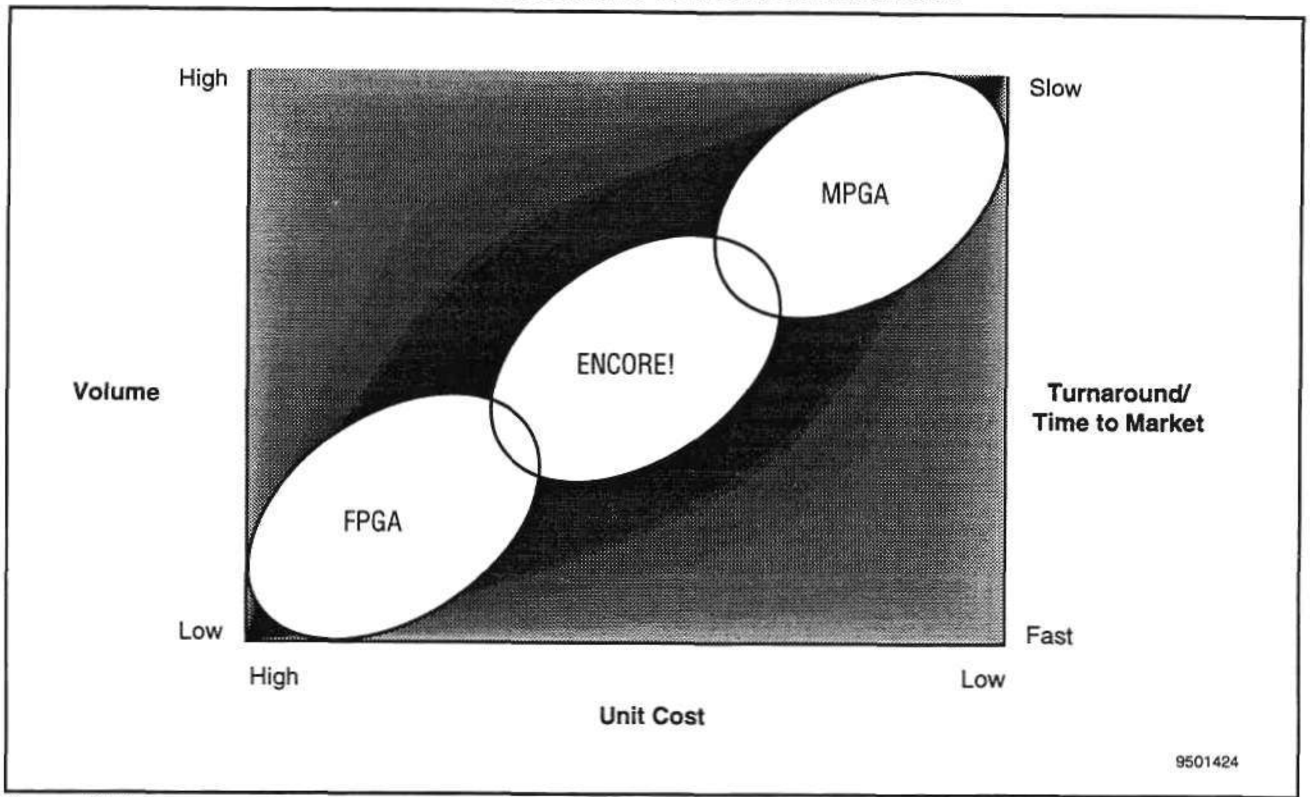
Orbit's two-prong product strategy apparently is working. By promoting the higher-margin ENCORE! program and moving its contract manufacturing services into higher-revenue products, Orbit has increased its revenue by more than 100 percent from 1992 to 1994. As shown in Table 2-11, Orbit intends to move away from low-margin contract manufacturing and reach an eventual even revenue mix balance between the ENCORE! conversion program and high-margin contract manufacturing.

Table 2-11
Orbit's Revenue Sources (Percentage of Total Revenue)

	1993	1994	Long Term
ENCORE!	16	28	50
High-Margin Contract Manufacturing	64	52	50
Low-Margin Contract Manufacturing	20	20	0

Source: Orbit (May 1995)

Figure 2-4
Orbit's ENCORE! Market Position Relative to FPGA and MPGA



Source: Orbit

Newport WAFERFAB Limited (NWL)

Corporate Statistics

Location	Newport, Wales, United Kingdom
President of QPL (Parent)	T.L. Li
CEO of Newport WAFERFAB	Steve Byars
Estimated Calendar 1994 Revenue	U.S.$24.5 million
Estimated Fiscal 1995 Revenue	U.S.$32 million
Fiscal Year-End	April 30
Employees	About 370
Founded	1993
Ownership (Private)	QPL International Holdings

Corporate Overview

NWL was created following the acquisition of a 10-year-old 100mm wafer fabrication facility in Wales by QPL International Holdings of Hong Kong (QPL) during December 1992. NWL was founded as an independent wafer foundry company in 1993.

QPL is the parent company to a group of companies providing services ranging from processing wafers to final assembly. The group of companies include NWL for wafer fabrication and probing; Total Test Systems (TTS) in Fremont, California, for probe and test; Quality Platers Ltd. for lead frames; and Advanced Semiconductor Assembly and Test Inc. (ASAT) for test and assembly. QPL represents the only dedicated service company that provides full service of semiconductor manufacturing, starting from the bare silicon wafer into the packaged chip, within a single organization.

The acquisition of the fab in Wales was beneficial for both QPL and the employees of the facility. Originally owned by Inmos Ltd., the fab came under the management of SGS-Thomson (ST) in 1989. From 1989 through 1992, ST used the Wales facility as a development center for its 0.8-micron, three-level metal technology, taking advantage of the highly skilled workforce and equipping the fab with state-of-the-art equipment. Once that process was complete, the facility no longer fit within ST's strategic focus and was earmarked for closure. QPL saw the highly technical workforce and the processing capability and agreed to purchase the facility from ST in December 1992. Thus NWL was born as a company.

A new culture and manufacturing discipline has emerged in the company in the last two years. At Inmos and under ST, the Wales facility acted primarily as a captive source for the parent company, so we believe manufacturing and cost disciplines may have been below normal in the industry. QPL has now completed a process to install effective quality management and productivity disciplines.

The result of this new business strategy and focus created a tremendously loyal and dedicated workforce, and the company is now growing rapidly and recognized as a quality supplier. A part of its mission statement clearly indicates its customer focus: "By supplying a quality manufacturing service we will provide the opportunity to release our customers' flair for design and innovation." Concrete expansion plans are in place through 1996, and being local in Europe has helped create a loyal customer base as well.

Foundry Philosophy

NWL closes its presentations with the phrase, "Making microchips you would be proud to put your name on." Their market positioning has four parts:

- NWL has no products of its own and all customers have equal status.
- NWL will either run customer processes or supply NWL processes.
- Through the QPL companies, NWL can offer the complete service of manufacturing a semiconductor chip.
- Because it is a European supplier of silicon, EC tariffs can be avoided.

Its manufacturing philosophy is centered on complete service and fast cycle times, with standards of measure through established TQM programs.

Characteristics of the Fab

The Wales fab has 48,000 square feet of cleanroom in a 95,000-square-foot facility. NWL has a capacity of 15,000 100mm wafers per month, with about one-third of that capacity at 0.7 microns. The remainder is targeted at 1.0 to 1.2 microns.

The fab is operating at capacity, and aggressive expansion plans are under way. All planned expansion will be for 0.7-micron capacity. Planned expansion will take the total capacity to 23,000 wafers per month by the end of 1995, and a planned conversion to 150mm for the entire fab will take place in 1996. This amounts to about a 50 percent growth in square-inch capacity of silicon per year for the next two years. NWL's opinion is that there is sufficient demand to fill this capacity as soon as it becomes available.

Financial Statistics

NWL is a private company, so information on specific financial statistics are not readily available. However, Dataquest estimates that 1994 revenue was about $24.5 million.Capital spending in 1994 is not available, but Dataquest estimates that the company has invested more than $23 million in its facility since acquisition two years ago.

NWL's fiscal year ends April 30. The current fiscal year, ending April 1995, should see estimated revenue of $32 million, up from $15 million in fiscal year 1994.

Outlook

NWL has made a tremendous transition in business focus and manufacturing strategy with adeptness and success. As a key foundry in Europe, NWL plays a seed role in establishing a new standard for world-class and cost-effective manufacturing. NWL's success could be a cornerstone for establishing Europe as a significant semiconductor manufacturing center.

SubMicron Technology

Corporate Staff

Location	Bangkok, Thailand
Chairman	Charn Uswachoke
President	Glen Posseley
Director, Engineering	Ray Vasquez
Director, Operation	Jim Lewis
Factory Program Manager	Dr. James Burnett
Factory Program Manager	Doug Elder
Director, Corporate Services	Jack Woodward
Director, Marketing and Sales	Jorge E. Carbo
Founded	1994
Projected Start of Manufacturing	1996

Corporate Overview

SubMicron Technology is a new dedicated semiconductor foundry based in Thailand and fully funded by local Thai investors. Majority share of SubMicron is owned by Chairman Charn Uswachoke, with his bankers and financiers holding an additional 20 percent of the company. SubMicron signed a baht 19.25 billion ($771.9 million) loan-syndication agreement in February 1995 with 23 Thai banks and financial institutions that included Bangkok Bank PCL as the lead lender. SubMicron also plans an initial public offering on the Thailand Stock Exchange late this year. The Thai prime minister's cabinet granted approval of SubMicron's new fab in February 1995.

Fab Information

Groundbreaking for SubMicron's 8-inch facility is scheduled to take place in May 1995, six months after the official launch of the SubMicron project. Equipment installation in the new fab is scheduled to begin in fall 1996, with process qualification soon to follow. Onset of production ramp-up according to this time line is expected to take place in December 1996. Table 2-12 shows SubMicron's wafer manufacturing ramp-up schedule. Production will begin at the 0.65µm level and migrate to 0.5µm in the fourth quarter of 1997. SubMicron's production equipment will be capable of two technology generations—0.5µm and 0.35µm—which will, as shown in the company's toolset manufacturing technology plan (see Table 2-13), take the company's production capability to the year 2000.

Table 2-12
SubMicron's Wafer Manufacturing Ramp-Up Schedule (8-Inch Revenue Wafers Out)

	Q1/97	Q2/97	Q3/97	Q4/97	Q1/98	Q2/98	Q3/98	Q4/98	Q1/99	Q2/99	Q3/99	Q4/99
Fab 1	3,000	10,000	20,000	24,000	29,200	35,700	45,500	58,500	65,000	65,000	71,500	71,500

Source: SubMicron (May 1995)

Table 2-13
SubMicron's Toolset Manufacturing Technology Plan

	1997	2000	2004	2004
Feature Size (Microns)	0.5	0.35	0.25	0.18 (Development)
Chip Size (Mils per Side)	400	500	600	700

Source: SubMicron, Dataquest (May 1995)

Foundry Philosophy

Because it is the first integrated circuits manufacturer in Thailand, SubMicron will need to address the country's lack of engineers and skilled technicians in semiconductor processing. SubMicron has already put together a team of foreign (mostly U.S.) personnel to carry out the planning and the management of the new company. SubMicron also will employ expatriate engineers to staff the operation of its new fab. SubMicron's technology partner will help train Thai engineers that will comprise the bulk of SubMicron's workforce. A major U.S. IC manufacturer (identity not disclosed) will provide, through a technological partnership agreement, training to SubMicron's engineers and the process technologies with which SubMicron will begin its production. In return the partner will get a significant portion (undisclosed) of the new foundry's capacity at volume pricing.

One of SubMicron's important missions will be to provide vertical integration for its sister company, Alphatec, a major IC test and assembly house. SubMicron's goal is to feed processed wafers to Alphatec for test and assembly, in addition to providing quality, cost-competitive semiconductor manufacturing. With Alphatec located just next door, the synergy between SubMicron and Alphatec promises to cut the overall chip production time and ensure that finished parts are delivered to customers in weeks as opposed to the typical period of a few months. Moreover, SubMicron also will save from transportation and inventory costs, allowing it to pass the savings onto its customers in the form of lower wafer prices.

SubMicron's future looks bright because it has received the blessing of the Thai government, which regards the new venture as a major milestone for the country's high-technology industry. The Thai government's board of investment has granted SubMicron tax cuts, including an exemption in import tariffs on production equipment and materials.

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Focus
Studies

Semiconductor Equipment, Manufacturing, and Materials Worldwide

Focus Analysis

Integrated Circuit Manufacturing Fab Capacity— Can It Keep Pace with the Semiconductor Industry's Explosive Growth?

Abstract: *Dataquest believes the present rate of new fab construction and technology migration will turn the thriving, $110 billion industry into a $330 billion market by the year 2000.*
By Calvin Chang

A $110 Billion Industry Forges Ahead

Based on the expanding semiconductor applications market and the continual strong growth in PC consumption, Dataquest projects an increase in the semiconductor industry's long-term growth rate for the second half of the 1990s. The industry is expected to generate a compound annual growth rate (CAGR) of 20.1 percent from 1994 to 1999, a noticeable increase from the 15.3 percent CAGR between 1989 and 1994. This accelerated growth is expected to push the industry to $330 billion in sales by the year 2000, tripling the revenue achieved in 1994. (By comparison, it took the industry 10 years, from 1984 to 1994, to quadruple in size. If it continues growing at the projected 20 percent CAGR for an additional six years after the year 2000, it would experience a ninefold growth over the 12 years. That would be enough to turn the semiconductor industry into a $1 trillion market by 2006.) Figure 1 shows the projection for the worldwide semiconductor market.

New Fabs: How Many, How Much Capacity?

The anticipated increase in semiconductor consumption raises several questions: Can the industry's manufacturing capacity produce the billions of integrated circuit (IC) chip units necessary to meet the expected demand?

Dataquest

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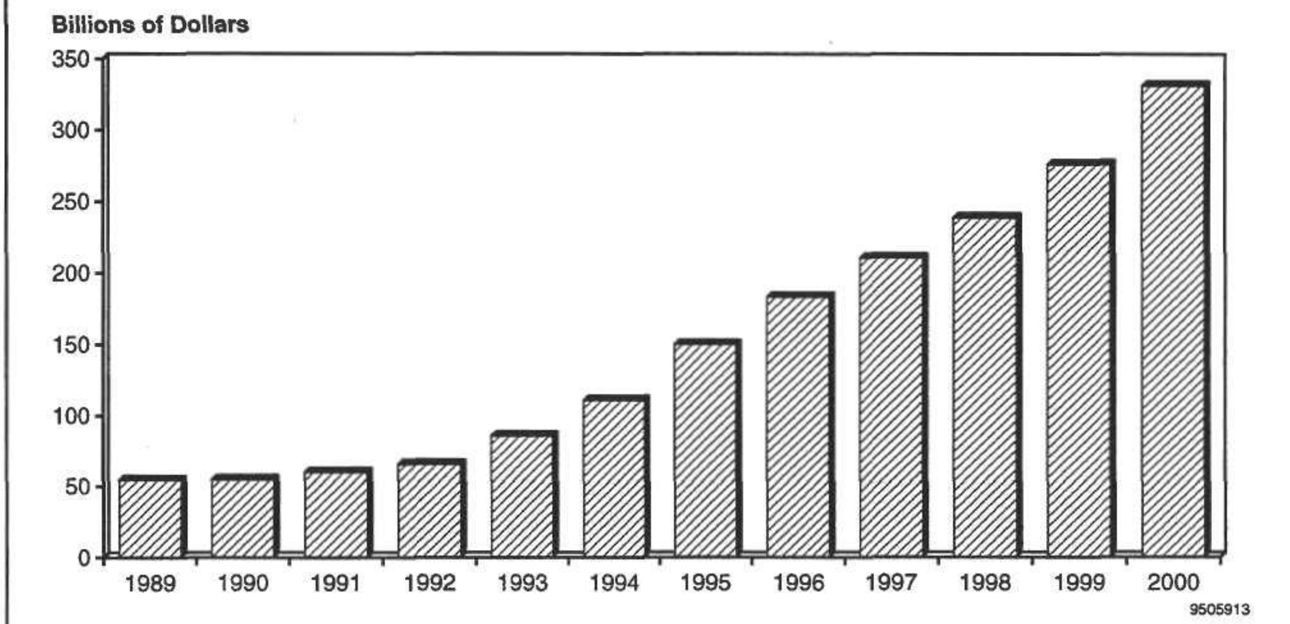
Figure 1
Worldwide Semiconductor Market, Historical and Projected (Billions of U.S. Dollars)



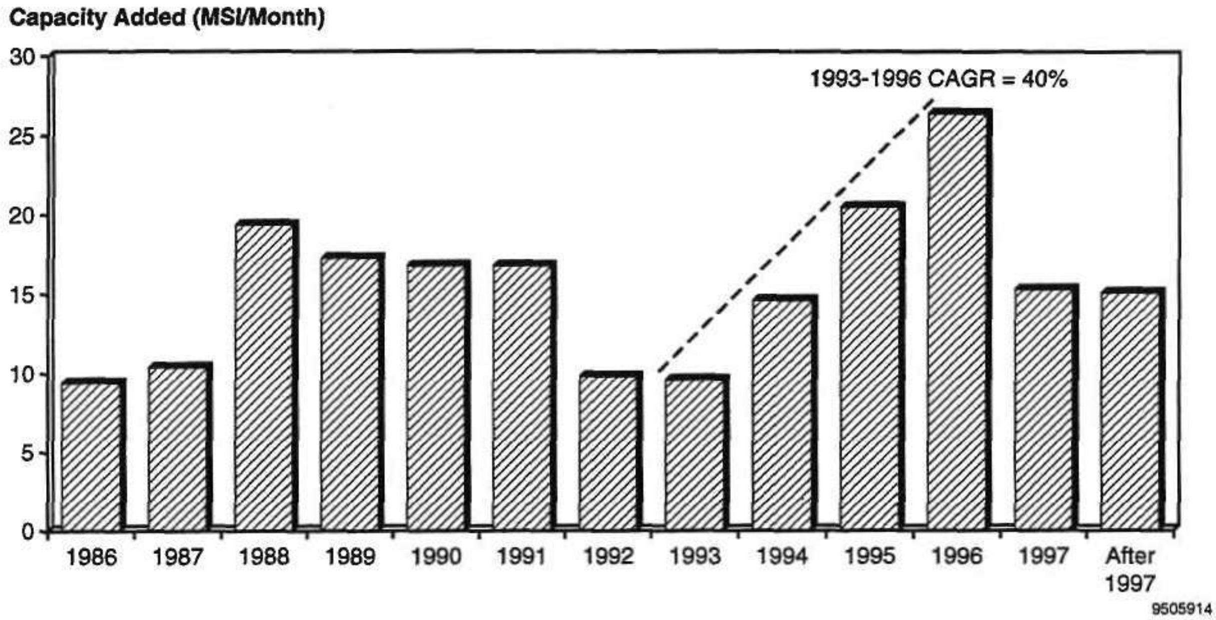
Source: Dataquest (October 1995)

Will there be enough fab capacity to allow the industry to triple in six years? Figure 2 shows the new fab capacity being added by the industry, measured in million square inches (MSIs) of silicon processing per month. Beginning in 1993, the worldwide IC manufacturing industry started rapidly adding new fab capacity, and the number of new fabs have steadily increased: 29 in 1993, 31 in 1994, 32 in 1995, and a projected 41 in 1996. Moreover, there was a migration in 1994 from 6-inch wafer size to 8 inch. That year signaled the first time the 8-inch wafer size accounted for the majority (55 percent) of the new capacity built. For 1995 and 1996, nearly 90 percent of the new fab capacity is expected to be the 8-inch wafer standard. Adoption of the 8-inch wafer size has given rise to larger fabs with ever-growing silicon processing capacity. Indeed, as shown in Figure 2, the rate at which the semiconductor industry is building new fab capacity is increasing at a CAGR of 40 percent. In 1996, 26.4 MSIs per month of new capacity is expected to be built by the industry. This is equivalent to processing 550,000 8-inch wafers per month.

The torrent of fab building has resulted in a boon for the semiconductor production equipment market. After a strong 35 percent growth in 1994, the worldwide semiconductor front-end equipment market is expected to grow by a staggering 50 percent in 1995, a growth rate not achieved since 1988.

At present, market indicators suggest a slowdown in new fab growth beginning in 1997. This perception is likely due to limited knowledge about individual companies' new fab construction plans toward the end of the decade. Information on new fabs is usually not made public until two or three years before their scheduled production dates. Dataquest will continue to monitor new fab announcements, and by end of 1996 it expects to be able to report on all new capacity coming into production by the year 2000.

Figure 2
New Semiconductor Fab Capacity Added Worldwide (MSIs per Month)



Source: Dataquest (October 1995)

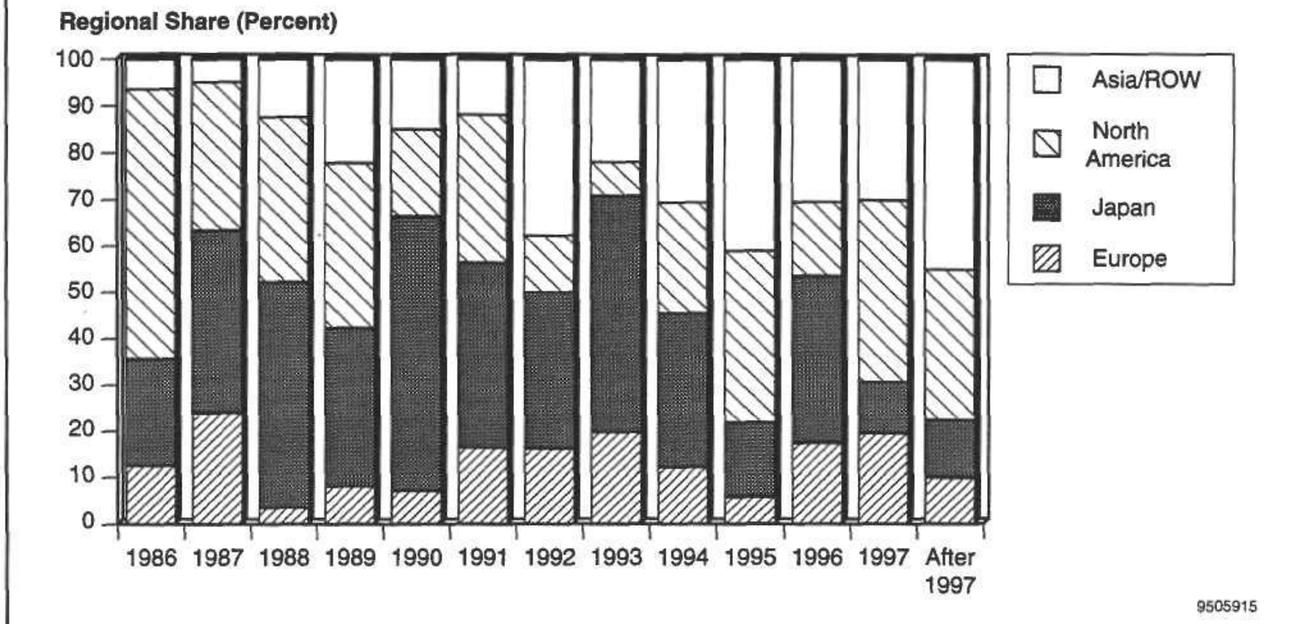
Besides the migration to the new 8-inch wafer standard, there is another important reason for the dramatic growth in new fab capacity, namely, the rise of Asia/Pacific nations as significant semiconductor manufacturing bases (see Figure 3). There are approximately 20 new fabs in Taiwan and Singapore, and there is continued production expansion in South Korea. For the next few years, the Asia/Pacific and North American regions will be the principal beneficiaries of capital investment dollars from both regional chipmakers and the Japanese. The Japanese chipmakers are shifting their capital investments from the domestic front to the primary consumption markets, namely the United States and the Asia/Pacific nations.

As a result, more than 65 percent of the industry's new fab capacity that is expected to be added from 1995 to 1998 will be in North America and the Asia/Pacific region. The Asia/Pacific region is expected to contribute 36 percent of the total new fab output, while the United States is expected to account for 29 percent. Japan and Europe will account for 21 percent and 13 percent, respectively.

The history and projection of new IC fab capacity added in the four regions of the world is shown in Figures 4 to 7.

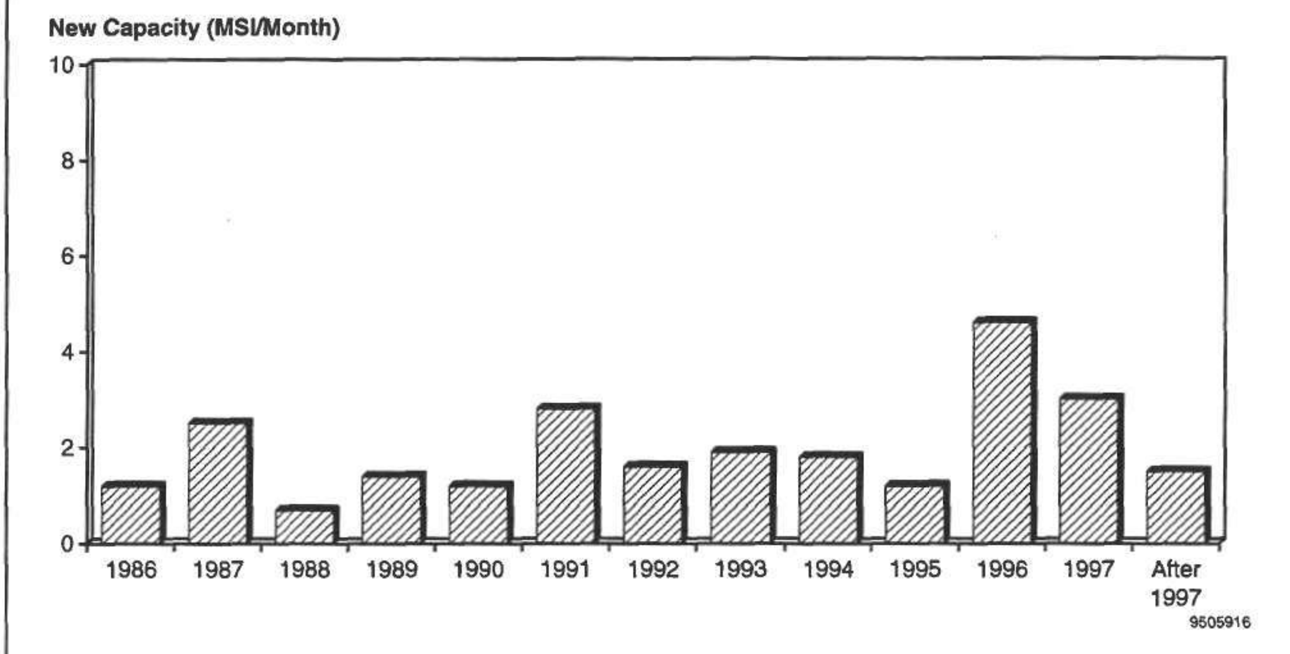
The new fabs to be built in Europe will be located in Germany, the United Kingdom, France, Italy, and the Netherlands. The new fabs in North America will be concentrated in Oregon (six) and Texas (six). Others will be located in Arizona, New Mexico, Idaho, Virginia, and Utah. Japan's investment in new capacity has lagged industry average, and it is not expected to reach its pre-1991 level until 1996. However, the post-1996 outlook for Japan as an IC-production base suggests a continual decrease in its share of the world's semiconductor manufacturing. This is largely due to Japanese chipmakers moving their IC production to regions outside of Japan.

Figure 3
Regional Distribution of New Semiconductor Fab Capacity



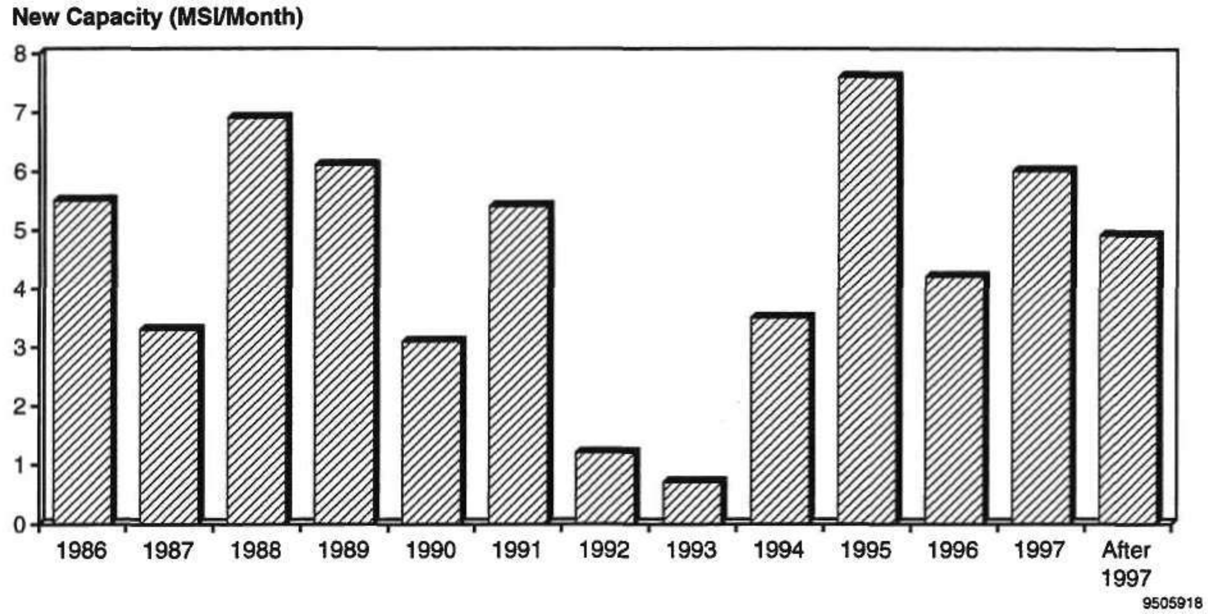
Source: Dataquest (October 1995)

Figure 4
New Semiconductor Fab Capacity Added in Europe (MSIs per Month)



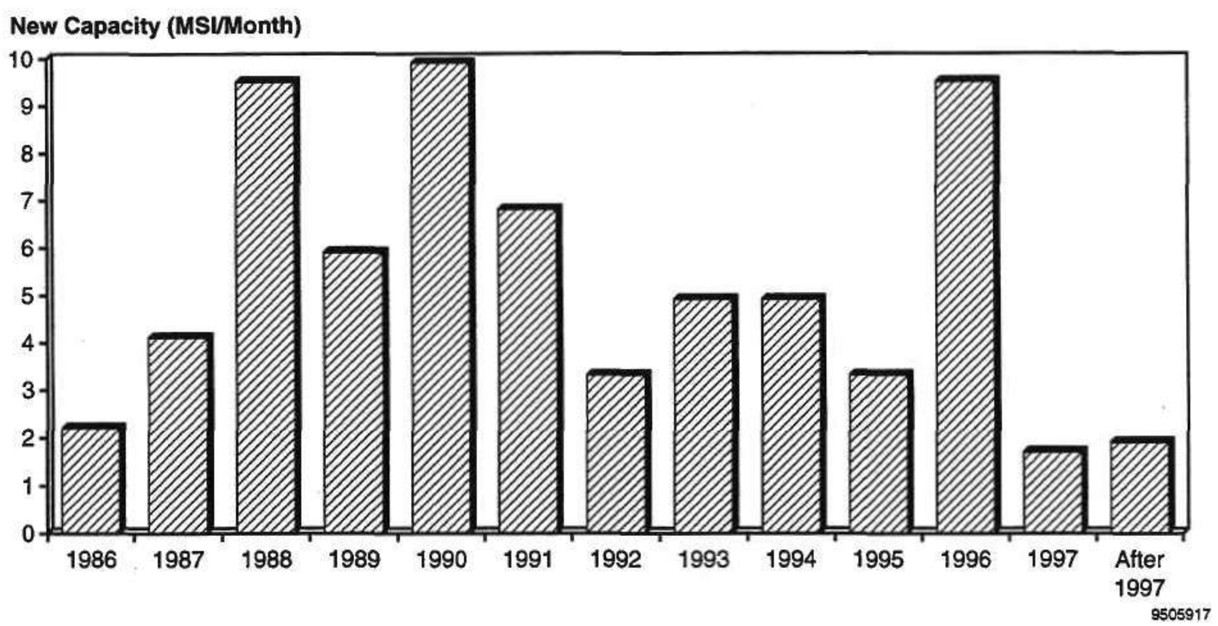
Source: Dataquest (October 1995)

Figure 5
New Semiconductor Fab Capacity Added in North America (MSIs per Month)



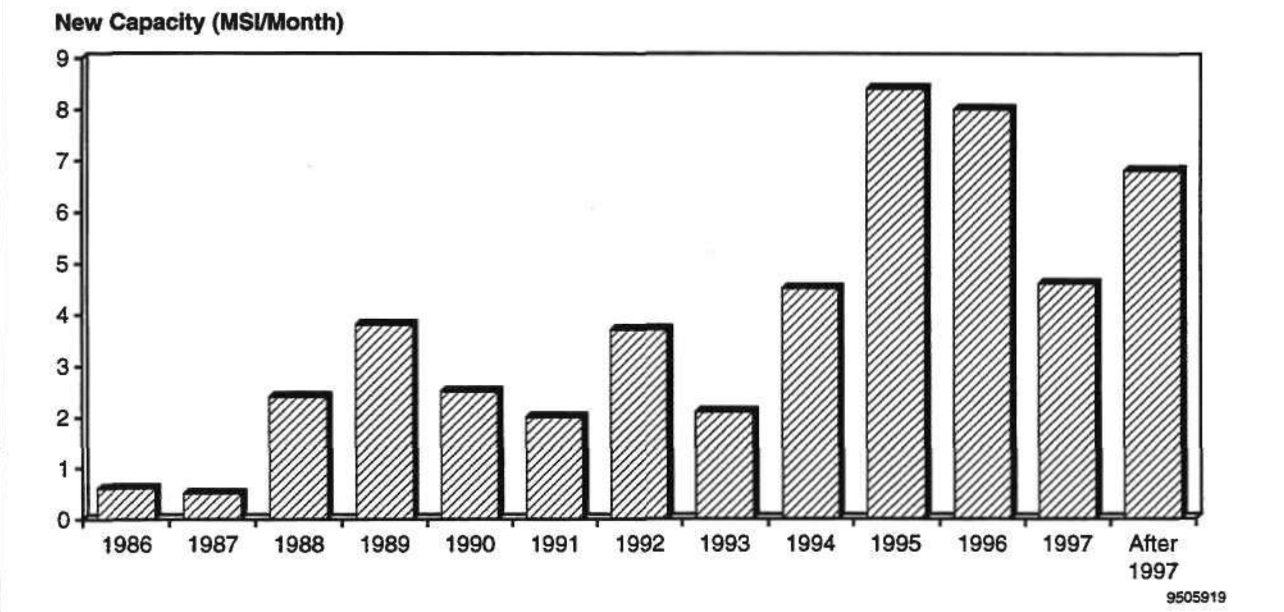
Source: Dataquest (October 1995)

Figure 6
New Semiconductor Fab Capacity Added in Japan (MSIs per Month)



Source: Dataquest (October 1995)

Figure 7
New Semiconductor Fab Capacity Added in Asia/Pacific—Rest of World (MSIs per Month)



Source: Dataquest (October 1995)

Will There Be Enough Fab Capacity?

Based on new fabs announced by October 1995, 108 new IC fabs are expected to go into production between 1995 and 1998. The combined capacity of these new fabs—in terms of total area (in MSIs) of processed wafers out per month—is 77.2 MSIs per month (926.4 MSIs annually). This is equivalent to the production of 1.6 million 8-inch wafers per month. Compared with the total industry output at the end of 1994—measured purely in terms of total wafer output (that is, linewidth geometry and metal layers not considered)—the new fabs represent an additional 35 percent new capacity being added to the industry by mid-1998. Moreover, much of the new capacity being added is leading-edge process technology: 91 percent of the new capacity will have 0.5 microns or smaller linewidth technology, making possible advanced memory such as 16/64Mb DRAM, high-end logic/ASCII, and microprocessor products.

Based on the present run rate of new-fab construction and capital-spending projections, Dataquest estimates that between 1995 and 2000 there will be a total of 160 billion-dollar-class IC fabs added to the semiconductor manufacturing industry. This figure includes the 108 new fabs announced to date. Using an average new-fab capacity of 20,000 8-inch wafers per month, the 160 new fabs will annually provide the industry with 1,860 MSIs of new IC-manufacturing capacity. Using a projected industry average for silicon-IC revenue of $120 per square inch, the new capacity will be capable of generating $223 billion worth of new semiconductor revenue. The total revenue produced by the semiconductor manufacturing industry in 1994 was $110 billion. Adding this revenue to the estimated realizable revenue by the new capacity gives credible support to the projection of a $330 billion market by the year 2000.

In the recent years, fab capacity using leading-edge technology (with line geometry ranging from 0.7 microns to 0.45 microns) has been capable of generating merchant revenue ranging from $80 (for example, DRAM) to as much as $800 (for example, Intel's high-end Pentium) per square inch of processed silicon. Table 1 shows the end-chip revenue (per square inch of processed silicon) as it varies with product type and technology. Table 1 also shows that leading-edge technology is responsible for the highest revenue productivity. Maintenance of this productivity is in turn the principal motivation for investing in new fabs. Dataquest believes the revenue-productivity structure will be maintained for the next five years with the new and more technologically advanced (0.5 microns to 0.25 microns) capacity that is being added by the industry. The industry is also continuing to adopt interconnect structures that have additional metal layers. This will help mitigate the rate of increase in die size as an ever-increasing number of transistors is being put on a chip. The continual drive toward higher packing density (higher transistor count and/or smaller die size) will be the principal reason for the maintenance of the silicon-revenue productivity.

Table 1
End-Chip Revenue Productivity Varies with Product Type and Technology (U.S. Dollars)

Revenue ($ per Square Inch)	Leading Edge	Mainstream	Trailing Edge
MPU	**300-800**	150-250	90-150
ASIC, Logic, MCU	**100-140**	80-90	50-60
DRAM	**80-100**	65-75	45-50
Power/Discrete	30-35	25	<15

Note: The highlighted area in the Leading Edge category signifies silicon-revenue productivity enabled by new fab capacity with leading-edge technology.
Source: Dataquest (October 1995)

Table 2 shows the segmentation of the new fab capacity by different product types. Memory, including DRAM, SRAM, and nonvolatile memory, receives the largest capacity investment. The recent spate of foundry fab announcements—both by existing and new-entrant foundry providers—means a significant portion of the semiconductor industry's nonmemory manufacturing capacity will be in foundry by the end of the decade. Dataquest includes product segmentation of new fab capacity figures when arriving at the projected industry average for revenue productivity. The silicon-IC revenue figure of $120 per square inch was determined by combining the data of Table 1 and Table 2.

Table 2
Segmentation of New Fab Capacity by Product Type*

Product Type	MPU	Logic, ASIC, MPR, MCU	Memory	Foundry	Others
New Fab Capacity (Percent of Total)	7	9	66	12	6

*Based on new fabs announced to date
Source: Dataquest (October 1995)

Dataquest believes the present run rate of new fab construction and technology migration will enable the industry to have sufficient manufacturing capacity to reach the $330 billion-revenue landmark by the year 2000.

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