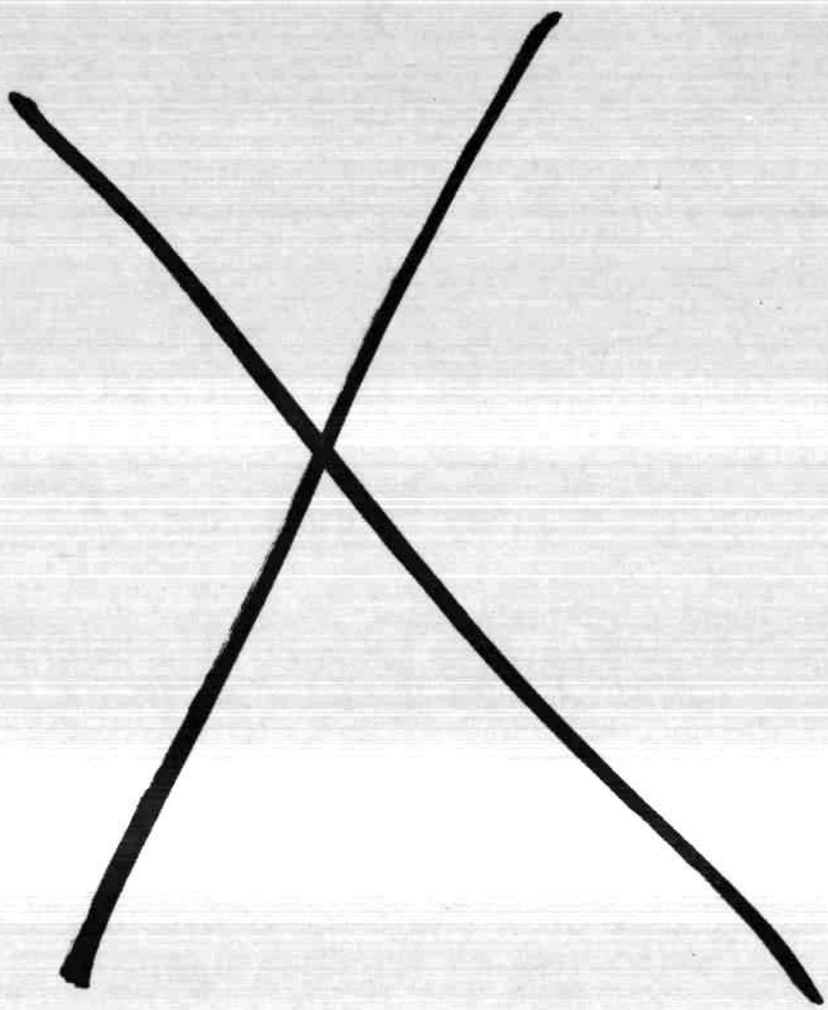


Perspective

Semiconductor Contract Manufacturing Services Worldwide

Market Analysis

Semiconductor Contract Manufacturing Wafer Pricing Trends: October 1998

Abstract: *In the third of three surveys of semiconductor contract manufacturing wafer prices conducted in 1998, Dataquest observes continuing price declines. Prices are reported for 150mm and 200mm wafers, categorized by minimum feature size and number of metal interconnect levels, as well as special process options. Results are compared with those of previous surveys dating back almost three years. Finally, a consensus view of short-term price projections is presented and discussed in relation to current supply and demand dynamics within the semiconductor foundry market.*

By James F. Hines

Foundry Wafer Prices: More Declines, but Some Firming at the Lagging Edge

Foundry-processed wafer prices declined in leading-edge technology categories and increased in some of the more mature technologies in the period from June to October 1998. The current results of Dataquest's survey of semiconductor contract manufacturing (SCM) wafer prices mark two years of pricing pressure as the industry struggles under a stubborn oversupply condition. Survey results include the following:

- Average prices for 150mm wafers ranged from $498 to $623, compared with $449 to $650 in June 1998.
- Prices for 200mm wafers, which generally represent the leading-edge technologies, averaged $870 to $2,241, compared with $917 to $2,611 in June 1998.
- Average prices for 0.25-micron wafers dropped by about 9 to 15 percent over the four-month period.

Dataquest
Program: Semiconductor Contract Manufacturing Services Worldwide
ProductCode: SCMS-WW-DP-9812
PublicationDate: February 1, 1999
Filing: Perspective
(For Cross-Technology, file in the Semiconductor Regional Markets and Manufacturing binder)

- The 0.35-micron technology category, now beginning to see higher production volumes, continues to undergo substantial price reductions, with average wafer prices falling 10 to 12 percent since June 1998.
- The lagging-edge categories experienced some price firming during the four-month period, with average wafer prices in some technologies increasing by as much as 18 percent.

The Foundry Wafer Pricing Survey

Dataquest conducts periodic surveys of the SCM market for the purpose of tracking foundry wafer pricing trends. At this time, the survey concentrates on mainstream CMOS process technologies segmented by minimum linewidth. For purposes of reporting prices, linewidth is defined as the "as-drawn" feature size, which is a more conservative measurement than the sometimes quoted "effective channel length," symbolized as L_{eff}.

The SCM wafer pricing survey completed in October is the third of three surveys planned for 1998. The previous survey was conducted in June, and the results were published in the Perspective titled "Semiconductor Contract Manufacturing Wafer Pricing Trends: June 1998" (SCMS-WW-DP-9809), dated August 31, 1998.

In October, a total of 19 companies were surveyed and reported prices paid and charged for 150mm and 200mm foundry-processed CMOS wafers. For this study, the group comprised 10 SCM users (buyers) and nine SCM suppliers (sellers), representing fabless semiconductor companies, integrated device manufacturers (IDMs), and dedicated foundries. The survey encompassed a variety of process technologies, categorized by minimum feature size and number of metal interconnect levels. Also, participants were asked to report prices for a number of special processing options, such as tungsten, chemical mechanical planarization (CMP), salicide, and epitaxial silicon. Finally, foundry users and suppliers were polled to obtain a consensus view on the expected change in wafer prices over the next four months (the interim period between surveys).

October 1998 Foundry Wafer Pricing Update

Table 1 summarizes the results of the most recent foundry wafer pricing survey, conducted in October 1998. Participants were asked to report prices paid for foundry-processed wafers delivered during October 1998, assuming CMOS, unprobed wafers with 13-to-15 mask levels, single-level poly, and no epitaxial silicon. The minimum volume requirement was set at 1,000 wafers per month. The estimated average price is the average of all prices reported or, in cases of small sample size, Dataquest's estimate of the average price. The price range shows the minimum and maximum prices reported.

Table 1
October 1998 Foundry Wafer Prices (U.S. Dollars per Wafer)

	150mm Wafer		200mm Wafer	
	Average Price	Price Range	Average Price	Price Range
1-Micron, 1P2M	505	370-700	NA	NA
1-Micron, 1P3M	541	420-750	NA	NA
0.8-Micron, 1P2M	498	300-700	NA	NA
0.8-Micron, 1P3M	522	340-750	NA	NA
0.6-Micron, 1P2M	538	370-650	870	775-935
0.6-Micron, 1P3M	559	420-670	1,035	889-1,150
0.5-Micron, 1P2M	580	470-710	1,019	900-1,280
0.5-Micron, 1P3M	623	510-780	1,090	950-1,400
0.35-Micron, 1P3M	NA	NA	1,354	1,100-1,900
0.35-Micron, 1P4M	NA	NA	1,488	1,200-2,050
0.25-Micron, 1P3M	NA	NA	2,055	1,660-2,500
0.25-Micron, 1P4M	NA	NA	2,241	1,910-2,750
0.25-Micron, 1P5M	NA	NA	2,209	1,600-3,000

Note: 1P2M = 1 polysilicon level, 2 metal levels; 1P3M = 1 polysilicon level, 3 metal levels; 1P4M = 1 polysilicon level, 4 metal levels; 1P5M = 1 polysilicon level, 5 metal levels.
NA = Not available
Source: Dataquest (December 1998)

Table 2 compares the average prices reported in October 1998 to those reported in the previous survey of June 1998. Foundry wafer prices have continued to slide during the past six months, reflecting the general overcapacity in the market that has existed since mid-1996.

How the Views of Buyers and Sellers Differ

Responses of buyers and sellers may differ in a survey of this type, and we might expect buyers to report generally lower prices than sellers, reflecting their respective biases in the ongoing negotiations between the two. Interestingly, this generalization has not always held true in past surveys of foundry wafer prices, and the current results are a case in point, as shown in Figures 1 and 2. The average reported prices of sellers are consistently higher for 200mm wafers, but 150mm wafer prices show the opposite trend.

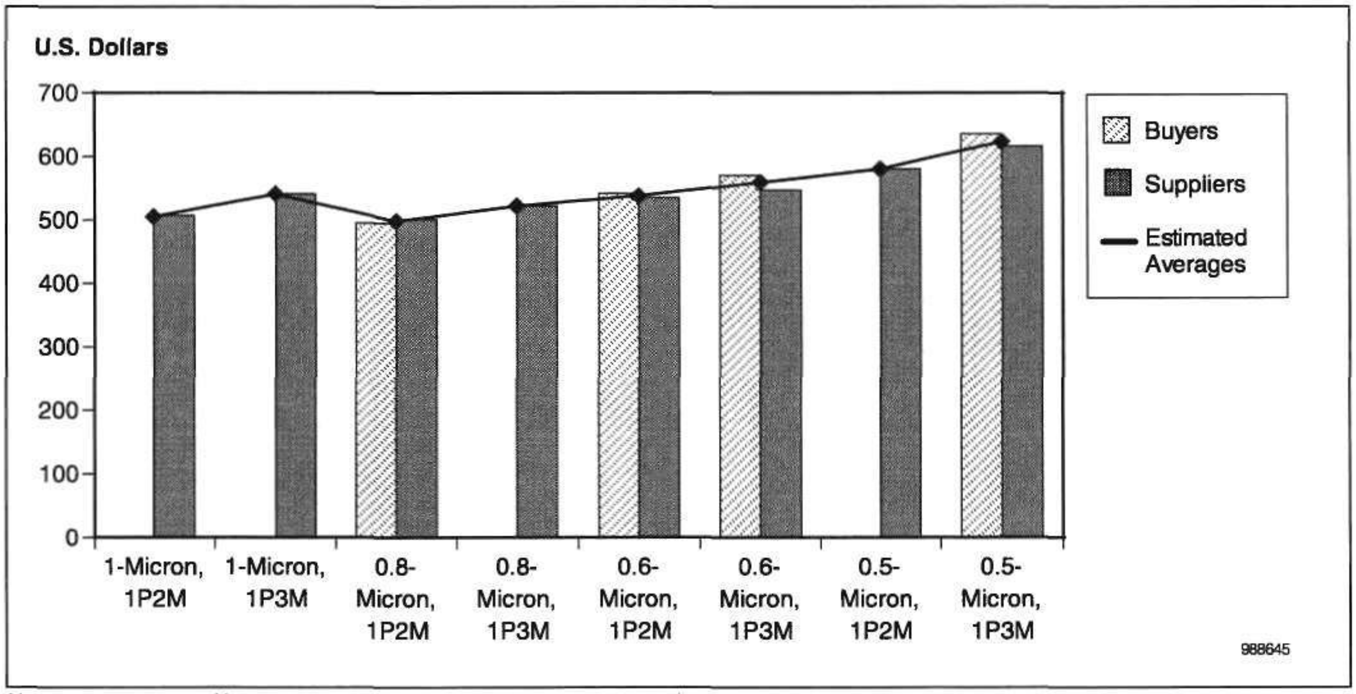
The line charts in Figures 1 and 2 represent the estimated average price for each technology category. The column charts represent the average of prices reported by buyers and sellers as separate groups. In those cases where a column is missing, the number of responses from the particular group was not sufficient to provide a statistically meaningful result.

Table 2
Change in Average Foundry Wafer Prices—June 1998 to October 1998 (U.S. Dollars per Wafer)

	150mm Wafer			200mm Wafer		
	June 1998	October 1998	Change (%)	June 1998	October 1998	Change (%)
1-Micron, 1P2M	449	505	12.4	NA	NA	NA
1-Micron, 1P3M	458	541	18.2	NA	NA	NA
0.8-Micron, 1P2M	483	498	3.2	NA	NA	NA
0.8-Micron, 1P3M	500	522	4.4	NA	NA	NA
0.6-Micron, 1P2M	549	538	-2.0	917	870	-5.1
0.6-Micron, 1P3M	576	559	-2.9	960	1,035	7.8
0.5-Micron, 1P2M	600	580	-3.3	1,093	1,019	-6.7
0.5-Micron, 1P3M	650	623	-4.1	1,195	1,090	-8.8
0.35-Micron, 1P3M	NA	NA	NA	1,511	1,354	-10.4
0.35-Micron, 1P4M	NA	NA	NA	1,686	1,488	-11.8
0.25-Micron, 1P3M	NA	NA	NA	2,267	2,055	-9.4
0.25-Micron, 1P4M	NA	NA	NA	2,444	2,241	-8.3
0.25-Micron, 1P5M	NA	NA	NA	2,611	2,209	-15.4

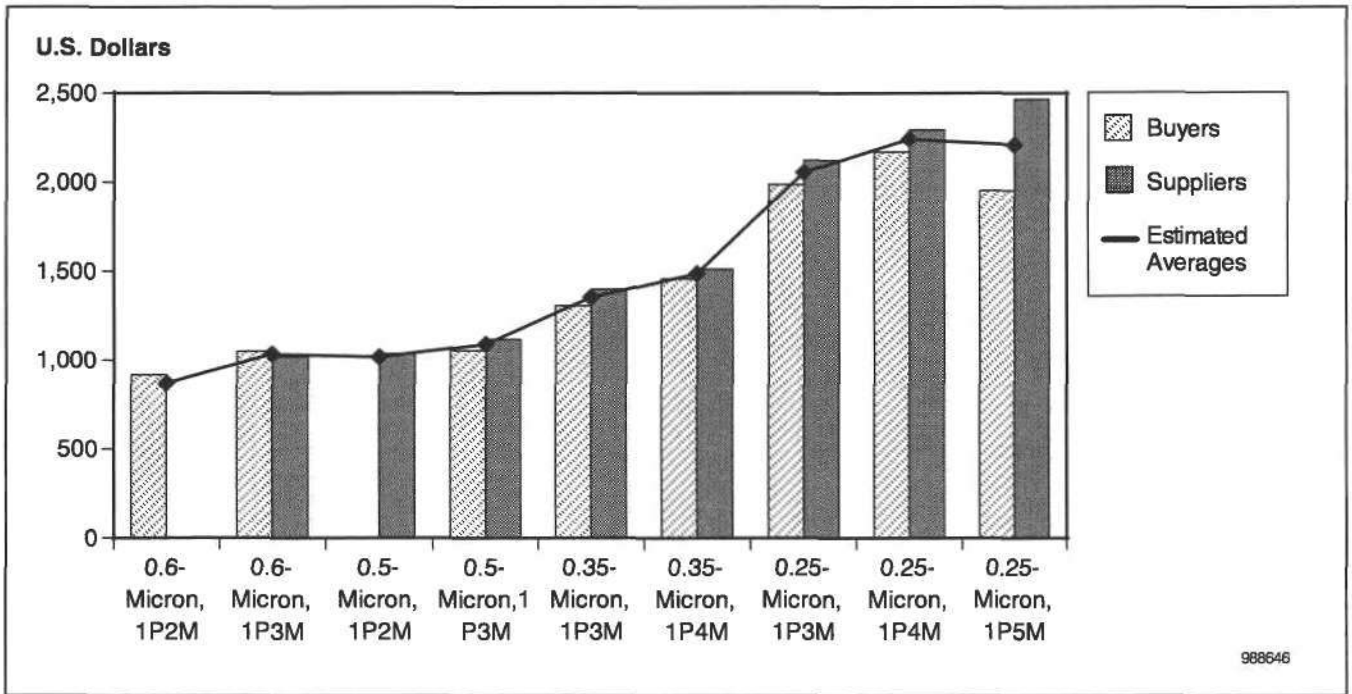
Note: 1P2M = 1 polysilicon level, 2 metal levels; 1P3M = 1 polysilicon level, 3 metal levels; 1P4M = 1 polysilicon level, 4 metal levels; 1P5M = 1 polysilicon level, 5 metal levels.
NA = Not available
Source: Dataquest (December 1998)

Figure 1
October 1998 Foundry Wafer Prices: 150mm Wafers



Note: 1P2M = 1 polysilicon level, 2 metal levels; 1P3M = 1 polysilicon level, 3 metal levels.
Source: Dataquest (December 1998)

Figure 2
October 1998 Foundry Wafer Prices: 200mm Wafers



Note: 1P2M = 1 polysilicon level, 2 metal levels; 1P3M = 1 polysilicon level, 3 metal levels; 1P4M = 1 polysilicon level, 4 metal levels; 1P5M = 1 polysilicon level, 5 metal levels.
Source: Dataquest (December 1998)

Process Option Prices

Prices for special processing options are shown in Table 3. These are processes outside of the standard process flow that normally involve an additional cost. As noted in previous reports on wafer prices, tungsten, salicide, and CMP processes are becoming standardized, at least on 200mm wafers. These processes are becoming part of the standard process flow for advanced technologies, which are predominant at the 200mm wafer size.

Table 3
October 1998 Foundry Wafer Process Option Pricing (U.S. Dollars per Wafer)

	150mm Wafer		200mm Wafer	
	Average Price	Price Range	Average Price	Price Range
Tungsten	29	23-35	38	28-50
Salicide	50	50	70	57-100
Epitaxial Silicon	55	50-65	117	75-150
CMP	51	50-52	58	50-75
Mask	52	42-60	98	75-125
Polysilicon	61	50-80	115	95-140

Source: Dataquest (December 1998)

Table 4 compares average special process option prices in this survey to the previous survey of June 1998. Like wafer prices, most process option prices decreased. Prices for tungsten decreased dramatically for 200mm wafers.

Prices for salicide decreased in both cases, as they did in the previous survey. Epitaxial silicon prices decreased for 150mm wafers and for 200mm wafers. CMP was flat for 150mm but down for 200mm. The average price for additional mask levels increased slightly for 150mm and decreased for 200mm. The price adder for additional polysilicon levels decreased in both cases.

Table 4
Change in Average Foundry Wafer Process Option Prices—June 1998 to October 1998 (U.S. Dollars per Wafer)

	150mm Wafer			200mm Wafer		
	June 1998	October 1998	Change (%)	June 1998	October 1998	Change (%)
Tungsten	30	29	-3	78	38	-104
Salicide	52	50	-4	116	70	-65
Epitaxial Silicon	63	55	-15	122	117	-4
CMP	51	51	0	88	58	-52
Mask	50	52	4	106	98	-8
Polysilicon	72	61	-17	122	115	-6

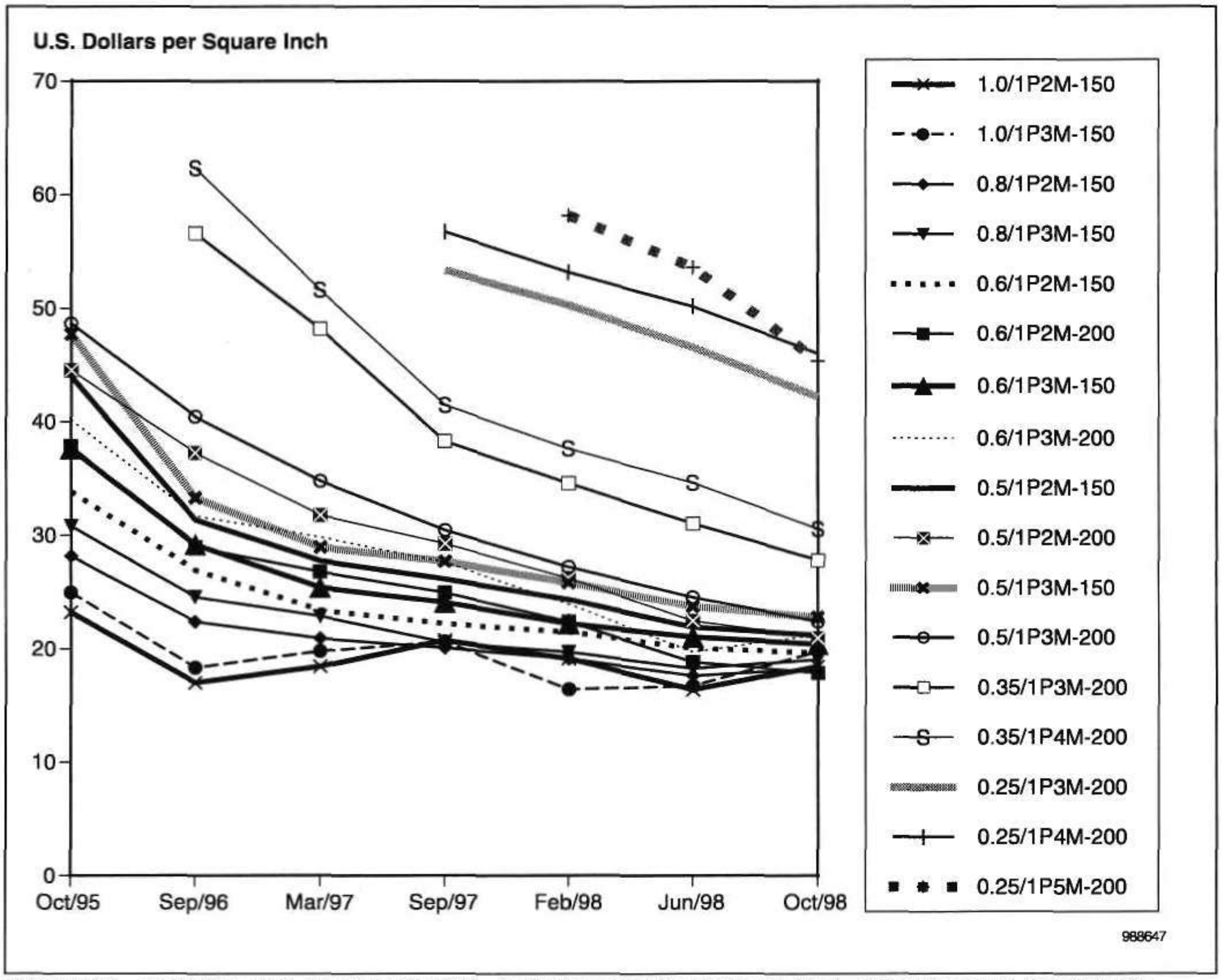
Source: Dataquest (December 1998)

Historical Foundry Wafer Pricing Trends

Figure 3 graphically displays the history of foundry wafer prices since October 1995, when Dataquest began conducting these surveys. Prices are plotted in dollars per square inch in order to normalize differences in wafer size. This chart is somewhat busy, but it provides an interesting snapshot of foundry wafer pricing trends for almost three years. Since Dataquest has been increasing the frequency of these surveys, the periods of time between divisions on the horizontal axis are not uniform, gradually shrinking from 11 months at the start to four months presently. This point should be considered when making a visual interpretation of the relative slopes of the trend lines in the chart.

The dominant trends in this history of foundry wafer prices are a general deceleration of price declines during the past 12 months and a convergence of prices for lagging-edge technologies. In our last report on foundry wafer prices, we noted that prices declined at a slower rate than had been previously observed, and we speculated that the big price drops may now be behind us. Indeed, 1997 has so far been the year in which prices fell most rapidly, especially for 0.35-micron wafers. It now looks as though the trend may continue, for although prices continue to fall, the rate of decline appears to be slowing. However, the high levels of excess foundry capacity that now exist are cause for concern and could lead to another round of competitive price cutting.

Figure 3
Historical SCM Average Price-per-Square-Inch Trends, October 1995 to October 1998



Notes: 1P2M = 1 polysilicon level, 2 metal levels; P3M = 1 polysilicon level, 3 metal levels; 1P4M = 1 polysilicon level, 4 metal levels; 1P5M = 1 polysilicon level, 5 metal levels. 150mm wafer area = 27.4 in.; 200mm wafer area = 48.7 in.
Source: Dataquest (December 1998)

Because of the faster rates of price erosion for leading-edge technologies than for lagging technologies, a convergence of prices has developed. This trend is most evident in the 0.5-micron to 1.0-micron categories, where the total price spread has narrowed to about $6 per square inch. Whereas the cost of manufacturing wafers in the leading-edge technologies of 0.35-micron and 0.25-micron is dominated by the depreciation expenses of a new fab and its associated capital equipment, the lagging technologies are manufactured in older fabs, many of which are already fully depreciated, so variable cost is the primary determinant of overall cost. The wafer prices depicted in this chart appear to be approaching a lower limit that will likely be determined by variable cost and the minimum margin that SCM suppliers are willing to accept.

The Outlook for Foundry Wafer Prices

The oversupply of foundry capacity makes it quite likely that competitive pricing pressures will persist throughout 1999. While this report is not intended to be a forecast of foundry wafer prices, we can gain some insight into the near-term outlook by polling our survey participants for their expectations of future prices.

Report Card

Each time Dataquest surveys the market for current foundry wafer prices, we also ask our survey participants to offer their predictions on how prices will change in the next scheduled survey, in this case, four months hence. In this way, a short-term consensus outlook for pricing trends is obtained. It might be instructive to compare the predictions of the June 1998 survey to actual results to calibrate the accuracy of this consensus view. Table 5 shows the latest "report card" for our survey participants.

Table 5
Comparison of June 1998 Expected Change in Foundry Wafer Prices to Actual Results (Percent)

	Buyers	Sellers	Actual
0.5-Micron	-5.0	-5.0	-5.7
0.35-Micron	-7.5	-5.0	-11.1
0.25-Micron	-7.5	-5.0	-11.0

Source: Dataquest (December 1998)

Still Lower Prices Ahead

Survey participants were asked to predict the movement of foundry wafer prices over the next four months for 0.5-, 0.35-, and 0.25-micron wafers. Table 6 summarizes the results of this polling. Prices 5 percent lower are expected by the time we survey again, in February 1999. Because these rates of decline apply to a four-month period, the corresponding annual rates of decline would be about 14 percent.

Table 6
Expected Change in Foundry Wafer Prices over Next Four Months (Percent)

Median Response	0.5 Micron	0.35 Micron	0.25 Micron
Buyers	-5	-5	NA
Sellers	-5	-5	NA
All	-5	-5	NA

NA = Not available
Source: Dataquest (December 1998)

Excess capacity has been increasing for more than a year, and Dataquest's current analysis of foundry capacity and demand points to an "acute" oversupply condition, with excess capacity in the range of 30 to 35 percent. Fab utilization rates of 70 percent or less have been reported, and dedicated foundries such as Taiwan Semiconductor Mfg. Co. (TSMC) and United

Microelectronics Corporation (UMC) announced drastic cuts in their capital spending plans in 1998 that can be expected to extend through 1999.

It is likely that the persistent oversupply in the foundry market will sustain competitive pricing pressures through this year, as SCM suppliers scramble for market share. As we have seen before, prices for the leading-edge technologies of 0.35- and 0.25-micron will be affected the most because this area is where the competition is hottest and volumes are ramping quickly. Lagging technologies will also see price pressure but to a lesser extent, and the underlying cost structure will provide some support.

Dataquest Perspective

With this latest survey, Dataquest now has over three years of history tracking foundry wafer prices. During this period, the foundry market has followed the broader semiconductor industry, going from widespread capacity shortage and stable prices to acute oversupply and tumbling prices.

With SCM demand impacted by the Asian economic slowdown and the related stagnation of the worldwide semiconductor market, and with excess foundry capacity running at 30 to 35 percent, continuing price pressure is likely in the foundry market. The greatest price declines are likely to occur in the leading-edge technology categories. Despite two years of falling prices, 0.35-micron and 0.25-micron wafers are still selling at a substantial premium to the lagging technologies, and as production volumes continue to increase there will be more opportunity for price competition.

The good news for SCM suppliers is that, because of price elasticity, lower wafer prices may stimulate demand. Foundries may benefit from a surge in demand from IDMs as wafer prices become low enough to make outsourcing wafer fabrication a truly compelling cost-reduction strategy, even for products requiring relatively advanced process technology. Thus, although the foundries followed the industry into the current semiconductor slump, they may be the first to climb out.

For More Information...

Inquiry Hotline:	+1-408-468-8423
Via e-mail:	scndinquiry@gartner.com
Via fax:	+1-408-954-1780
Dataquest Interactive:	http://www.dataquest.com

Perspective

Semiconductor Contract Manufacturing Services Worldwide

Vendor Analysis

United Microelectronics Corporation

Abstract: *Despite the sluggish market conditions that characterized the semiconductor industry in 1997, United Microelectronics Corporation (UMC) not only completed the transformation of its business model but also managed to achieve U.S.$896 million in revenue, an 8.7 percent increase over the previous year, 1996. To meet strong demand growth, UMC will invest NT$500 billion to build new fabs at the Tainan Science-Based Industrial Park in the next 10 years. This Perspective profiles a Taiwan-based semiconductor company, UMC, and its affiliate companies.*
By Jerry C. J. Yeh

Company Statistics

Chairman:	Robert H.C. Tsao
CEO of Domestic Operations:	John Hsuan
CEO of International Operations:	Donald W. Brooks
President:	H. J. Wu
Number of Employees:	2,751 (as of March 1998)
Fiscal 1997 Company Revenue:	U.S.$896 million
Fiscal 1997 Net Income:	U.S.$338 million
Total 1997 Assets	U.S.$3,035 million
Fiscal Year-End:	December 31

Dataquest
Program: Semiconductor Contract Manufacturing Services Worldwide
ProductCode: SCMS-WW-DP-9811
PublicationDate: November 30, 1998
Filing: Perspective
(For Cross-Technology, file in the Semiconductor Regional Markets and Manufacturing binder)

Corporate Values

United Microelectronics Corporation (UMC) has expressed its corporate values in the following statements:

- UMC believes that by fully utilizing its employees' talents, it can outperform all competition and maintain an outstanding corporation.
- UMC believes that its employees, despite outside factors, can determine the company's continued success based on their individual efforts.
- UMC believes that by working to benefit others, it will, in turn, benefit itself.

UMC's Long-Term Managerial Guidelines

The following statements describe UMC's long-term managerial guidelines:

- UMC respects the company as a public instrument, whose image, reputation, and credibility all employees are committed to preserve.
- By increasing productivity constantly, UMC will maximize profits and thus maintain its ability to contribute to the economic growth and well-being of the community.
- Through endless innovation and a relentless pursuit of quality, UMC will become a world leader in its field.
- UMC will take every opportunity to form beneficial alliances and always treat its partners with honesty and friendship.
- UMC will actively encourage employees to take initiative and make every effort to cultivate their talents. Furthermore, UMC will turn leadership into service rather than authority.
- UMC strives for vitality (endurance and productivity), harmony (mutual respect and cooperation), contentment (the right positions for the right people), and cheerfulness (positive attitudes), thus creating a lively, stimulating, and creative work environment.

Company Overview

The year 1997 was a key year in laying the foundations for UMC Group's turn-of-the-century expansion investment plan. During the year, UMC successfully completed the full transition of the UMC business model, continuing the process started in 1996 with the spin-off of the UMC design departments and the establishment of two independent IC design houses, Integrated Technology Express Inc. and Davicom Semiconductor Inc., in the United States. In 1997, UMC put the final touches on its restructuring program with the spin-off of its commercial product, memory, and multimedia divisions to create three new and independent design houses, Novatek Inc., AMIC Technology (Taiwan) Inc., and Mediatek Inc. With these actions, UMC committed itself fully to the dedicated foundry concept. In other accomplishments, UMC technology and process development departments further advanced UMC's process technology, entering the 0.25-

micron arena, and succeeded in developing independent advanced mask-making technology. Also, the turnkey services of the test and packaging engineering division and design support division have made it possible for foundry customers to enjoy even faster and more complete service.

Financial Accomplishments

Table 1 shows the exchange rates for U.S. dollars and the new Taiwan dollar between 1993 and 1997. Despite the slow conditions that characterized the semiconductor industry in 1997, UMC not only completed the transformation of its business model but also managed to achieve a U.S.$896 million revenue, an 8.7 percent increase over the previous year, 1996 (see Table 2). Net income for 1997 was U.S.$338 million, surpassing the previous year by 21.6 percent.

Table 1
Exchange Rates, 1993 to 1997

Year	New Taiwan Dollar per U.S. Dollar
1993	26.16
1994	26.45
1995	26.48
1996	27.46
1997	28.79
U.S. Dollar Appreciation (%), 1996 to 1997	4.81

Source: Dataquest (October 1998)

Table 2
UMC's Consolidated Balance Sheet (Millions of U.S. Dollars)

	1995	1996	1997
Net Sales Revenue	881	824	896
Cost of Revenue	286	475	632
Gross Profit	595	350	264
Net Income	508	278	338
Current Assets	743	949	1,036
Total Assets	1,808	2,426	3,035
Total Liabilities	605	733	716
Total Shareholders' Equity	1,203	1,693	2,319

Sources: UMC, Dataquest (October 1998)

UMC Group Advances in 1997 Foundry Ranking

The year 1997 was one of transition for UMC. The revenue reported in this year consisted of sales of merchant semiconductor products as well as foundry services. Dataquest has estimated that UMC's foundry revenue was U.S.$493 million in 1997. However, UMC has stated that production from the joint venture fabs (mainly USC during 1997) contributed an additional U.S.$350 million. Dataquest estimates that roughly one-third of the output of the joint venture fabs was used to support production of UMC's own merchant semiconductor products and therefore should be excluded from the total foundry number to avoid "double counting" of revenue. Taken as a whole, UMC Group foundry revenue totaled U.S.$726 million in 1997, securing a position as the No. 2 foundry in the world with market share of 13.4 percent.

UMC's Status on the Bond Issue

Table 3 shows UMC's status on the bond issue. To fund fab expansion, a resolution was passed to issue several bonds from 1994 to 1998. The 1996 domestic convertible bonds were used to help finance the expansion of Fab III and for reinvestment in other companies. The investment project will ultimately require a total of NT$17 billion. There are three funding sources for this project, as follows:

- Domestic convertible bonds (NT$6 billion)
- The company's own resources
- Other financial instruments

The two latter sources must provide NT$11 billion. According to the original schedule, UMC is expected to complete 100 percent of the expenditure by the end of 1997. But only 91.78 percent of the expenditure was actually executed. The company is running behind schedule because of its efforts to maximize efficiency in the plant construction and capacity expansion processes. UMC plans to return to the original financing schedule in the first quarter of 1998.

The 1997 Euro-convertible bonds were used to help finance the expansion of Fab III, for operating capital, and for investment in other companies. The investment project will ultimately require a total of NT$10.8 billion. The following represent three funding resources for this project:

- Euro-convertible bonds (U.S.$300 million or about NT$8.3 billion)
- The company's own resources
- Other financial instruments

The latter two sources must provide NT$2.5 billion. According to the original schedule, UMC is expected to complete all of the expenditure by the end of 1998.

Table 3
UMC's Status of the Bond Issue

	Euro-Convertible Bonds	Unsecured Convertible Bonds	Euro-Convertible Bonds	Domestic Convertible Bonds
Total Amount	U.S.$160,000,000	NT$6,000,000,000	U.S.$300,000,000	NT$15,000,000,000
Issue Price/Each	U.S.$1,000	NT$100,000	U.S.$5,000	NT$100,000
Annual Interest Payment (%)	1.25	2.5	0.25	0
Issue Period	6/1994 to 6/2004	5/1996 to 5/2006	5/1997 to 5/2004	1/1998 to 1/2008

Sources: UMC, Dataquest (October 1998)

Intercompany Holdings

UMC is like a tree that has its roots extended into various areas, including a wafer fab joint venture, an IC design house, packaging, LCD, telecommunications, venture capital, and even banking. Table 4 shows UMC's major affiliated companies and its investment shares. Basically, this information is based on UMC's financial reports, but there are many semiconductor company owners who invested in the related companies from their own pockets or another channel.

Table 4
UMC's Major Affiliated Companies and Investment Shares

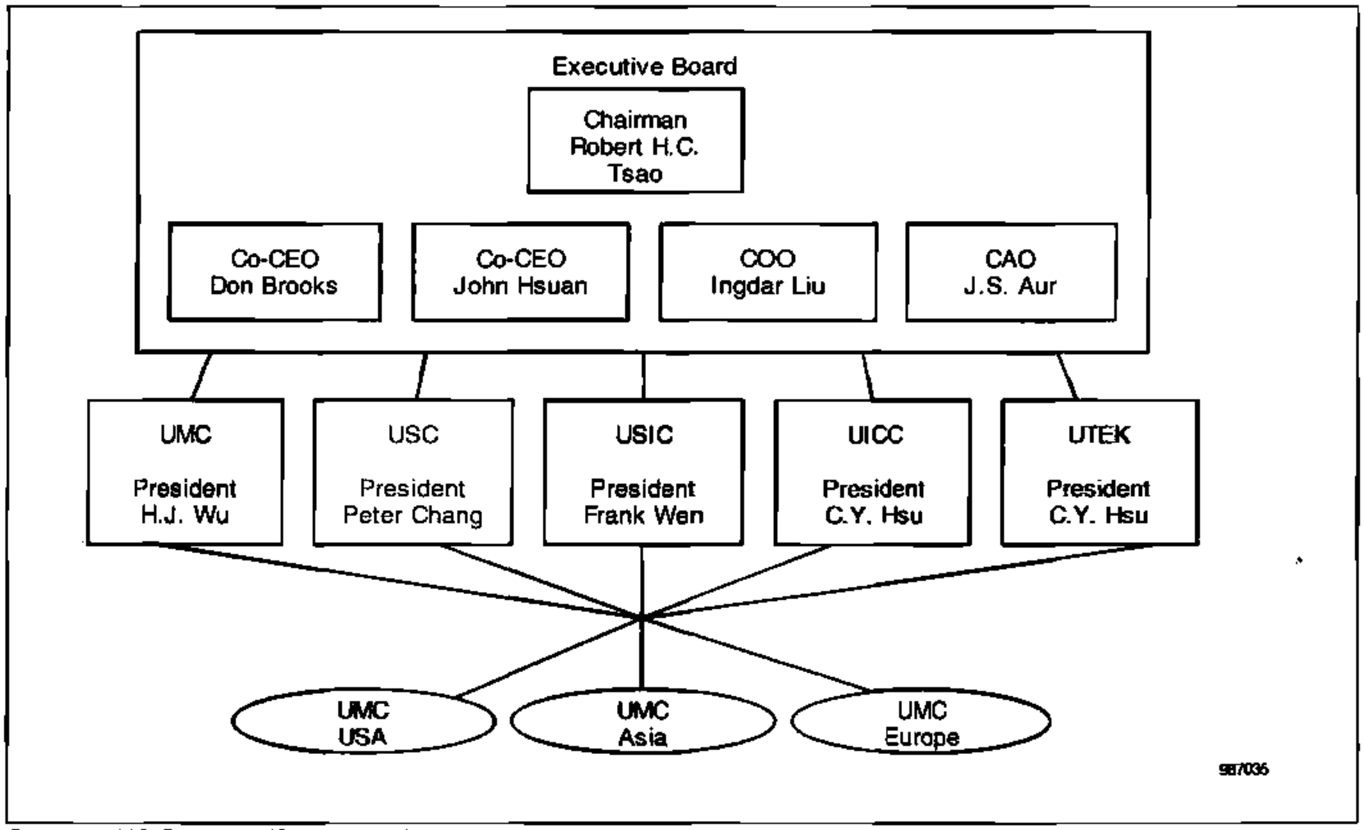
UMC-Affiliated Companies	Investment Shares (Common Stock) Number of Shares—Share Percentage	Investment in UMC (Common Stock) Number of Shares—Share Percentage
United Semiconductor Corp.	360,012,076—36.00	53,642,000—1.30
United Integrated Circuits Corp.	558,235,500—37.22	15,750,600—0.38
United Silicon Inc.	453,371,222—40.30	7,444,000—0.18
Unipac Optoelectronics Corp.	71,965,184—18.94	22,497,475—0.55
Hon Hai Precision Industry Co. Ltd.	3,116,588—0.61	16,142,206—0.39
Teco Electric & Machinery Co. Ltd.	45,475,520—4.70	136,518,808—3.32
Teco Information Systems Co. Ltd.	57,500,000—7.99	350,000—0.008
Sampo Corporation	27,178,346—3.31	38,427,028—0.933
Chiao Tung Bank	13,775,000—0.90	181,074,815—4.397
National Securities Corp.	10,168,902—1.85	750,000—0.018
UNI Securities Co. Ltd.	300,000—0.11	92,745—0.0022

Sources: UMC, Dataquest (October 1998)

UMC's Management Structure—Worldwide Operations

Figure 1 illustrates UMC's management personnel. Although UMC Group Chairman Robert Tsao's position and title remain unchanged, five new executive director positions were created. John Hsuan took the position of CEO of domestic operations; Don Brooks was named the CEO of international operations; I. D. Liu became the COO of expansion projects; Gary Tseng was appointed CFO of UMC Group; and J. S. Aur was installed as the CAO of the UMC Group. In other major changes, H. J. Wu became president of UMC, and Chris Chi, formerly a senior manager at Singapore's Chartered Semiconductor Manufacturing Pte. Ltd., joined the UMC family as senior vice president. Vice President Chi is currently in charge of operations at Fab III. Fu Tai Liou, formerly a senior manager at STMicroelectronics, joined the UMC family as the senior vice president of the technology and process development division. With the addition of United Semiconductor Corporation President Peter Chang, United Integrated Circuits Corporation President C. Y. Hsu, and USIC President Frank Wen, UMC Group has put together an impressive team to launch its NT$500 billion investment plan and earn a prominent position in the semiconductor foundry industry.

Figure 1
UMC's Management Organizational Structure



Sources: UMC, Dataquest (October 1998)

Research and Development Plans

In the area of process technology R&D in 1997, UMC's most outstanding accomplishment was the successful development of 0.25-micron logic technology and its successful qualification on a customer's product. In other areas of cutting-edge manufacturing processes, UMC smoothly ramped 0.35-micron logic, 0.3-micron SRAM, and 0.35-micron DRAM products into mass production. The development of 0.25-micron logic and 0.3-micron DRAM processes was completed, and small-scale production was launched in the first quarter of 1998. The 0.35-micron embedded DRAM process development was completed in 1997, and UMC is now manufacturing customer products that utilize this technology. Plans for 0.18-micron process technology and device qualification are in place for introduction in the first half of 1999. At the same time, the 6-inch fab pushed EPROM and flash EPROM processes into mass production; the fab also developed a 16V process and color filter process technology. The R&D department's mask-making technology was successfully qualified, and small-scale, 0.35-micron and 0.25-micron mask making are under way. On January 13, 1998, UMC held a technology symposium in California's Silicon Valley with 400 representatives from more than 50 companies attending. The outstanding results of UMC's R&D program caused quite a sensation in the U.S. semiconductor industry.

For the next 10 years, UMC has investment plans for NT$500 billion at its Tainan Science-Based Industrial Park site. UMC intends to focus on the development of 0.18-micron and 0.13-micron logic, DRAM, and SRAM manufacturing process technologies. UMC also plans to develop E-DRAM, E-flash, and multivoltage process technologies to satisfy the varied demands of foundry customers. Meanwhile, UMC will develop standard cells and intellectual property, either in cooperation with other companies or on its own, thus strengthening its customers' competitive edge by offering even more comprehensive services.

Wafer Fabrication Status and Plan

In October 1997, UMC Group was dealt a shocking blow with the fire that struck the UICC fab. Following in the footsteps of the successful first UMC Group joint venture company, USC, UICC, in the short year and a half after its founding, managed to complete fab construction and enter test production, breaking various industry speed records along the way. Tragically, just as test production had ramped up to 10,000 wafers per month and the fab was ready to enter mass production ahead of schedule, fire broke out at the fab. Fortunately, because of the unique structure and position of the UMC Group, UICC was able to guarantee capacity to its joint-venture partners and customers through cooperation with other UMC Group fabs and IC manufacturing allies in Taiwan.

Although UICC lost a year and a half of time and efforts, the fire enabled partners and customers alike to see UMC's crisis management skills in action, convincing them of UMC Group's ability to overcome whatever obstacles may lie in the future. The settlement of UICC insurance claims has also proceeded smoothly. The first payment for a sum of NT$500 million was made at the end of 1997. Total settlement should be completed by the end of 1998. To profit from this costly incident, the UMC Group has decided to invest NT$1 billion to set up a high-tech-industry-oriented firefighting department and has redoubled its efforts to improve every aspect of its industrial safety measures. The UMC Group also invited a leading risk management specialist from the Singapore insurance industry, K. W. Kong, to join its forces at the end of 1997. Table 5 shows UMC's wafer fabrication status and plan.

Dataquest Perspective

UMC was the first Taiwanese domestic IC manufacturing company to offer wafer foundry services. With nearly two decades of design and manufacturing experience, UMC has carved out an important niche on the world stage, providing comprehensive services, such as design, mask tooling, fabrication, testing, analysis, and IC packaging. In the past few years, revenue generated by foundry services has grown dramatically. In July of 1997, UMC Group announced its goal of becoming the leading name in the semiconductor foundry industry. Despite the serious setback caused by the UICC fire, UMC remains intent on accomplishing this goal.

Table 5
UMC's Wafer Fabrication Status and Plan

Fab Name	Production Start	Wafer (Inches)	CMOS Process (Microns)	Capacity, Wafer/Month (As of 9/1998)	Forecast Capacity Wafer/Month (By End of 1998)
UMC Fab 2	6/1989	6	0.8 to 0.45	48K	48K
UMC Fab 3	9/1995	8	0.5 to 0.25	28K	28K
USC	4/1996	8	0.5 to 0.25	32K	33K
USIC	5/1998	8	0.35 to 0.25	12K	15K
UTEK Fab 1	4/1991	5	1.2 to 0.7	35K	35K
UTEK Fab 2	5/1998	8	0.5 to 0.25	4K	8K
UICC	Q2/99	8	0.25 to 0.18	-	-
UMC Fab 5	Q4/99	8	0.18 to 0.15	-	-

Sources: UMC, Dataquest (October 1998)

To meet expected long-term demand growth, UMC will invest NT$500 billion to build new fabs at the Tainan Science-Based Industrial Park in the next 10 years. Fab 5, which held its groundbreaking ceremony at the end of 1997, will start mass production in 1999. Future goals will focus on the establishment of the new fabs in the Tainan Science-Based Industrial Park, specifically on construction, ramping up, the development of new foundry-related services, and the aggressive development of leading-edge process technologies with the aim of becoming the world leader in the dedicated foundry business.

Perspective

Semiconductor Contract Manufacturing Services Worldwide

Event Summary

Conference Call on Capital Spending and Wafer Fab Equipment Midyear Forecast Update: Where's the !@#?! "Up" Button?

Abstract: *Suppliers of equipment and materials to the semiconductor industry have been suffering on and off for two years now as the semiconductor industry deals with a severe case of overcapacity. Asian economies have ground to a halt, and so has semiconductor demand. Where is the "up" button in this falling elevator? What are the fundamental issues that will get the semiconductor industry and spending back on track? This document is taken from a telebriefing held by Dataquest on July 11, 1998, concurrent with the release of Dataquest's forecast update on capital spending and wafer fab equipment.*
By Clark J. Fuhs, Ronald Dornseif, James Hines, Takashi Ogawa, and Klaus Rinnen

Opening Statement

The Semiconductor Equipment, Manufacturing, and Materials Worldwide (SEMM) program tracks most aspects of the actual manufacturing of semiconductors worldwide. This document discusses the outlook and forecast for wafer fab equipment and capital spending and presents Dataquest's forecast for silicon wafers, supported by recent demand analysis tied to consumption patterns for semiconductor devices.

Forecast Overview

Our group has just released its midyear semiconductor capital spending and equipment forecast, summarized in Tables 1 and 2. Our forecast process has several cornerstones including semiconductor production by region, a worldwide database of existing and planned fabs, and independent comprehensive surveys of the equipment and semiconductor companies.

Dataquest
Program: Semiconductor Contract Manufacturing Services Worldwide
ProductCode: SCMS-WW-DP-9810
PublicationDate: September 21, 1998
Filing: Perspective
(For Cross-Technology, file in the Semiconductor Regional Markets and Manufacturing binder)

Table 1
Capital Spending Forecast, 1997 to 2003 (Millions of U.S. Dollars)

	1997	1998	1999	2000	2001	2002	2003	CAGR (%) 1997-2003
Total Capital Spending	**40,505**	**31,583**	**32,990**	**45,749**	**68,302**	**77,164**	**76,784**	**11.2**
Percentage Growth	-9.9	-22.0	4.5	38.7	49.3	13.0	-0.5	-
Percentage of Semiconductors	27.3	21.0	18.6	21.4	26.4	28.5	24.8	-
Percentage if 300mm Pilot Excluded	27.2	20.6	17.6	20.0	25.5	28.1	24.8	-
Americas	14,178	11,721	12,951	16,002	21,544	25,029	28,124	12.1
Percentage Growth	0.5	-17.3	10.5	23.6	34.6	16.2	12.4	-
Japan	7,986	5,586	6,356	9,084	13,477	14,173	12,144	7.2
Percentage Growth	-17.3	-30.0	13.8	42.9	48.4	5.2	-14.3	-
Europe, Africa, and Middle East	4,089	3,822	3,968	5,512	8,108	9,735	9,002	14.1
Percentage Growth	-18.8	-6.5	3.8	38.9	47.1	20.1	-7.5	-
Asia/Pacific	14,253	10,453	9,715	15,151	25,173	28,227	27,514	11.6
Percentage Growth	-11.7	-26.7	-7.1	55.9	66.2	12.1	-2.5	-

Source: Dataquest (July 1998)

Table 2
Wafer Fab Equipment Forecast, 1997 to 2003 (Millions of U.S. Dollars)

	1997	1998	1999	2000	2001	2002	2003	CAGR (%) 1997-2003
Total Wafer Fab Equipment	**20,171**	**16,689**	**17,179**	**23,542**	**35,266**	**39,382**	**39,258**	**11.7**
Percentage Growth	-7.0	-17.3	2.9	37.0	49.8	11.7	-0.3	
Americas	6,720	6,004	6,619	8,042	10,583	12,308	14,009	13.0
Percentage Growth	15.3	-10.7	10.2	21.5	31.6	16.3	13.8	
Japan	5,047	3,783	4,122	5,945	8,903	9,205	7,950	7.9
Percentage Growth	-22.9	-25.0	9.0	44.2	49.8	3.4	-13.6	
Europe, Africa, and Middle East	2,380	2,350	2,501	3,311	4,593	5,146	5,001	13.2
Percentage Growth	-15.4	-1.3	6.4	32.3	38.7	12.0	-2.8	
Asia/Pacific	6,024	4,552	3,936	6,244	11,187	12,724	12,298	12.6
Percentage Growth	-7.2	-24.4	-13.5	58.6	79.2	13.7	-3.3	

Source: Dataquest (July 1998)

The survey results are one input into our several forecasting models, which include analysis of trends in semiconductor production, raw silicon consumption, spending ratios, investment cycles, new fab and expansion activity, DRAM silicon consumption analysis, and semiconductor revenue per square inch.

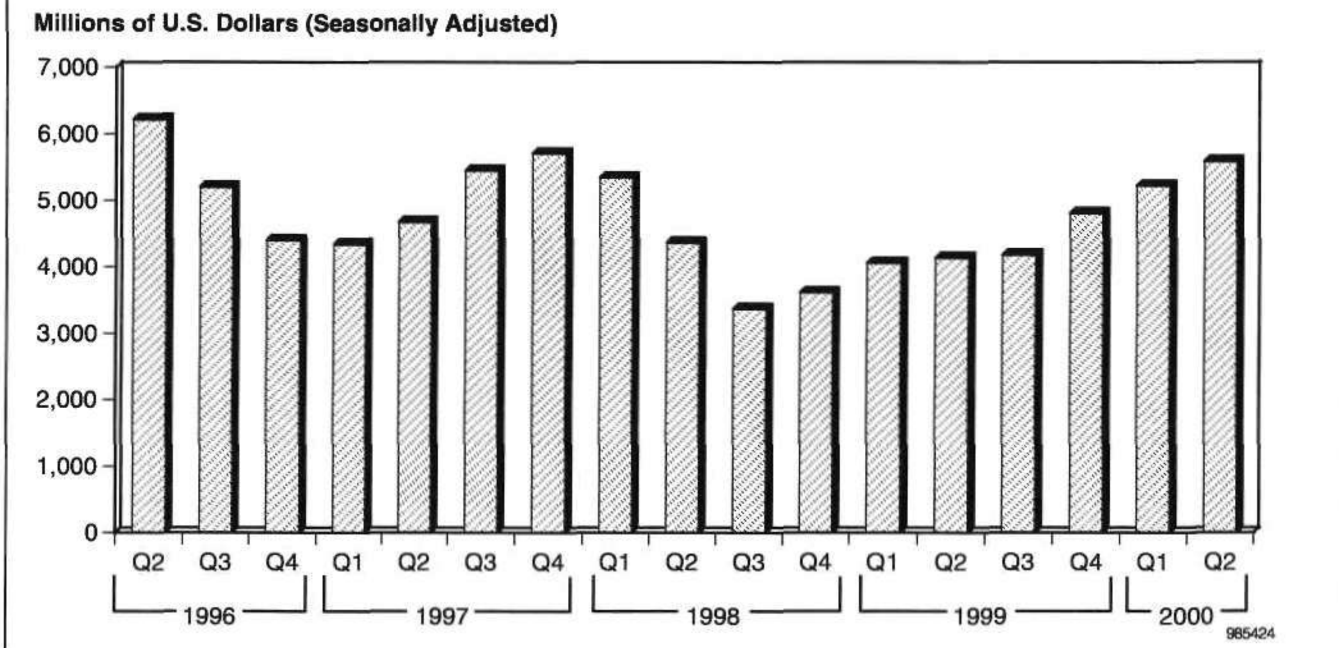
For the past 18 months, we have projected that the 1998 wafer fab equipment market would be "frustrating," calling for a "W" recovery pattern, with the second-phase downturn being caused by the fundamentals of overcapacity, and financial health eventually winning over the desire for technology.

Our forecast shows the following key points:

- Aggressive investment in 0.25-micron technology throughout 1997 contributed to the continuing overcapacity in the industry. However, the economic slowdown in Asia and Japan has made the 1998 spending environment downright ugly.
- Further, the semiconductor demand engine has stalled, essentially adding a "holding pattern" year in 1998.
- The semiconductor demand stall, coupled with the poor financial condition of the chip suppliers, will make the next 12 months an environment of "minimum investment."
- The movement to a "minimum investment" pattern in 1998 has meant a severe cut in spending levels, with a forecast 22 percent drop in capital spending and a corresponding 17 percent falloff in wafer fab equipment compared to 1997.
- The chip demand stall in 1998 actually pushes the sustained recovery into early 2000, and therefore the growth forecast for 1999 is essentially flat overall.
- But we do see a bright spot, albeit moderately in the distance. Although the next six months will be extremely difficult, and 1999 is shaping up to be a flat year, we see the first fundamental signs aligning to create a spending boom during 2000 and 2001, with a shortage in the DRAM market emerging in 2000.
- Dataquest's analysis of supply and demand in the foundry industry has been showing, for about a year, a 15 to 20 percent oversupply forecast to develop in 1998 and 1999. Unfortunately, the stall in semiconductor demand has made the forecast oversupply much more acute, now calculated to be between 30 and 40 percent.
- We had anticipated that foundry spending plans would be untouched through 1998, thinking that the supplier base would react in a way similar to the DRAM suppliers. However, the foundry suppliers are reacting much faster, since they are much more driven by profitability in their business model than the DRAM industry appears to be. Many suppliers have cut back spending from original plans for 1998, now showing only about 20 percent growth as a group. We now expect foundry investment to be cut significantly in 1999 relative to 1998 spending, perhaps by 20 to 30 percent.
- Spending on 300mm equipment has essentially been delayed a year, limited primarily to the Siemens effort in 1998, and increasing in 1999 only to the $1.2 billion level, which was about the original forecast for 1998. We now expect peak pilot line spending in the year 2000, with production ramp not really coming into play until 2002 and 2003.

Our top-line quarterly shipment forecast for wafer fab equipment is shown in Figure 1.

Figure 1
Wafer Fab Equipment Quarterly Revenue History and Forecast



Source: Dataquest (July 1998)

In the forecast "W" profile, the technology buying surge in 1997 did not quite match the second quarter 1996 peak of $6.2 billion. Dataquest is now calling for the second-leg decline to be more severe than in late 1996, with run rates 23 percent below the most recent low point of $4.3 billion in the first quarter 1997.

We are expecting a small recovery from these depressed levels starting in the fourth quarter 1998, but this recovery is expected to stall in mid-1999 as the overcapacity burden in the industry remains. A sustainable and long-term recovery is forecast for the fourth quarter of 1999 at the earliest.

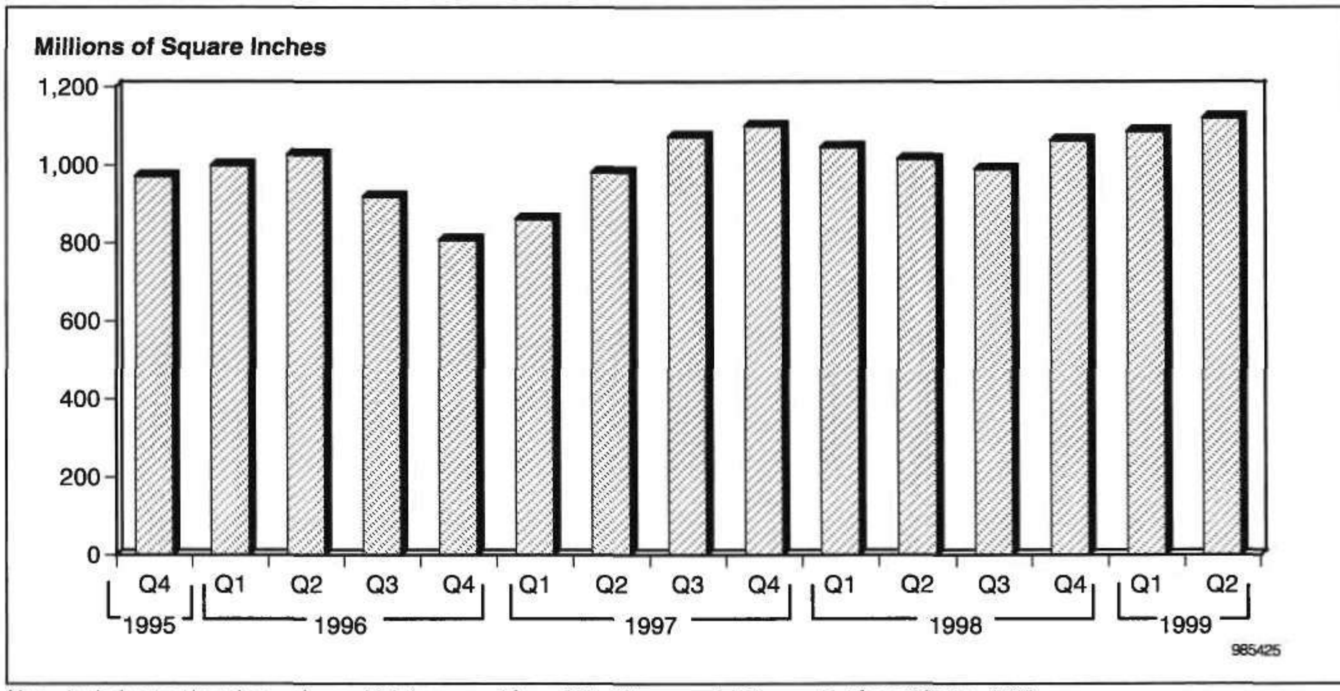
We would expect supply-and-demand dynamics to be corrected in the DRAM market by early 2000, driving a robust resumption of growth with the wafer fab equipment market growing to more than $39 billion in the year 2002, from just over $21 billion in 1997.

The current forecast sees a flat to down year in 2003. Semiconductor capital markets are cyclical, in response to profitability cycles in the chip market. Our chip market has a DRAM price decline in 2002, which we have built into a spending decline the following year.

As mentioned earlier, overcapacity remains as the constant status.

Figure 2 shows the overall silicon consumption forecast by quarter for the near term. Even though the peak shipment level in the fourth quarter 1997 exceeded the peak level in the second quarter 1996, this does not fully represent the utilization level because test and monitor wafers are included in the mix. Test wafers account for just under 24 percent of silicon shipments at the end of 1997 as opposed to about 21 percent in 1996. Silicon used for revenue wafers peaked at about the same level at both times. Many new fabs were started up during this time window and therefore represent the overcapacity.

Figure 2
Silicon Wafer Quarterly Shipment History and Forecast



Note: Includes test/monitor wafers, which increased from 20 to 24 percent of the market from 1995 to 1998
Source: Dataquest (July 1998)

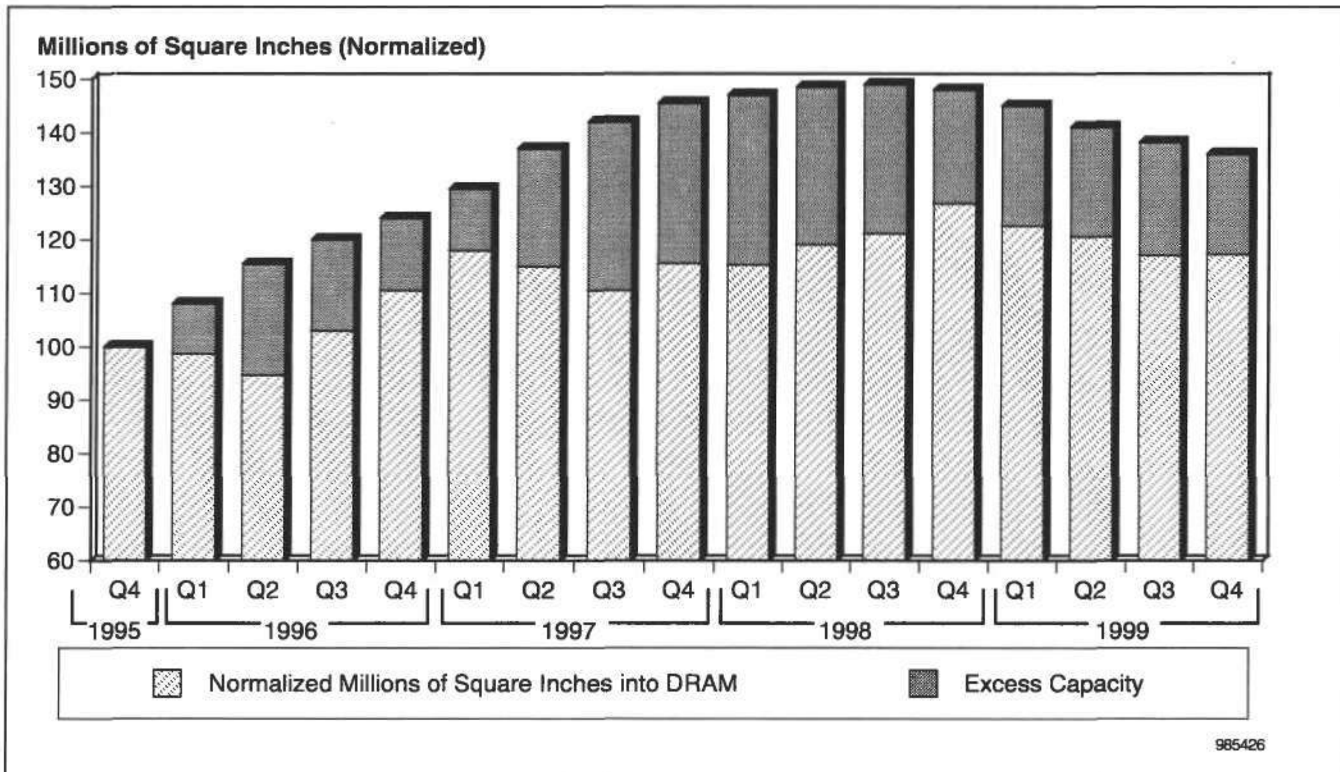
Our long term CAGR forecast for silicon has been reduced to 9.2 percent, almost four points below the semiconductor market growth.

Capacity Status: DRAM

As shown in Figure 3, in DRAM, there has been a net capacity addition in the last two years beyond the requirements for silicon area. Presently, we are estimating the overcapacity in DRAM to be between 20 and 25 percent. The darker area in Figure 3 represents the silicon area required to meet quarterly bit demand. The entire bar area represents the net capacity in the industry and therefore the lighter area represents the overcapacity.

The demand statement is based on unit shipments of various generations of DRAM per quarter, with die size and yield assumptions normalized to the fourth quarter 1995. The capacity available to process DRAM is based on an actual fab analysis and assumes migrating linewidth over time. For example, only 0.55-micron and below is considered at the end of 1995, 0.5-micron and below at year-end 1996, 0.4-micron and below at year-end 1998, and so on. The net capacity added is positive in 1997 because 23 new fabs came on line that exceeded in silicon area the amount taken out of the market because of obsolescence.

Figure 3
Silicon Consumption in DRAM: More than "Capacity Attrition" Is Needed



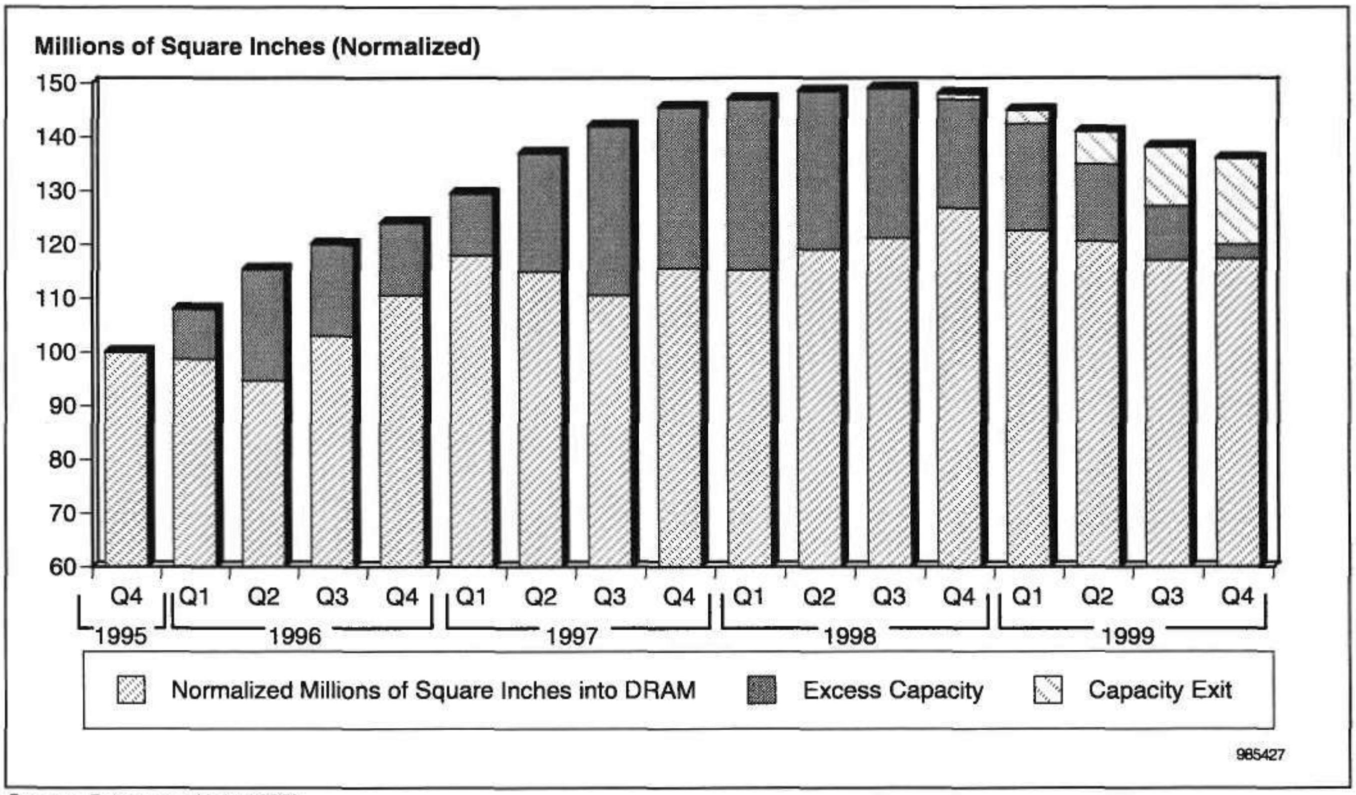
Source: Dataquest (July 1998)

As can be seen in Figure 3, the capital spending cuts will finally swing the pendulum the other way starting with the last half of this year through all of 1999. We refer to this movement as "capacity attrition."

The movement of the industry to the more silicon-efficient 64Mb density will actually reduce the silicon required in 1999 but will sustain the oversupply throughout all of that year. Our silicon demand model shows that with the forecast 60 to 70 percent bit growth rate in 1998 and 1999, about 6 to 9 percent less silicon will be required by the end of 1999 than is currently consumed.

Therefore, referring to Figure 4, we expect capacity to actively exit the market, meaning that fabs currently in commission will be closed, mothballed, or reallocated. This exit could take several forms, including companies' departure from the market, consolidation in the industry, and outright mothballing of fabs. A recent example is the net loss of the TwinStar fab in the United States, which was part of Texas Instruments' sale of its memory business to Micron Technology. This fab is being mothballed as a result of the consolidation of capacity, and the equipment is being reallocated and sold.

Figure 4
Balanced DRAM Market by End of 1999 Requires "Active Exit" of Capacity



Source: Dataquest (July 1998)

Capacity Status: Foundry

At the beginning of this year, Taiwan Semiconductor Manufacturing Corporation was reporting that its fabs were being operated at 105 percent of capacity. While some may question the calculus that produced this figure, TSMC, and foundries in general, did appear to be doing well relative to the rest of the industry, and their capital spending plans reflected an optimistic outlook. By May, TSMC was ready to admit that utilization rates had fallen below 90 percent for the first time in recent memory, and this report was cause for some concern. Now, with factory utilization continuing to slide, possibly as low as 75 percent, TSMC has announced that it will cut capital spending for the latter half of the year, and other foundries have followed suit.

Because of its position as the preeminent dedicated foundry, TSMC was the last to feel the sting of an oversupply condition that has been developing in the foundry industry for over a year. Aggressive capital spending by TSMC, United Microelectronics Corporation, and Chartered Semiconductor Manufacturing, coupled with new entrants into the foundry market such as Amkor/Anam and some integrated device manufacturing (IDM) companies, has produced a bubble of foundry capacity, much of it in leading-edge technologies, that the market simply cannot absorb in its present state of stagnation. Perhaps now is a good time for the foundries to re-evaluate expansion plans that would add capacity at the rate of 35 to 40 percent per year.

In our previous forecast, Dataquest's analysis of capacity and demand in the foundry industry projected an oversupply of 19 percent in 1998, declining slightly to 17 percent in 1999. The persistent and pervasive nature of the Asian economic slowdown, and its dampening effect on semiconductor demand, has caused this oversupply to become much more acute today. We now estimate excess foundry capacity to be in the range of 30 to 40 percent, and it is likely that the oversupply will extend to the year 2000.

There is more to this story when one looks beneath the surface of general supply-and-demand dynamics. As previously noted, much of the capacity that has been added in the foundry industry is in leading-edge technologies. The dedicated foundries, having gotten their start by supplying technology at least two generations behind the leading edge, followed their own version of Moore's Law, marching toward ever finer linewidths at a faster rate than the industry, and now have all but caught up. TSMC and UMC introduced their 0.25-micron processes to production at the end of 1997, only about six months behind Intel. By midyear 1998, 0.18-micron capacity will be available.

In characterizing the demand for foundry services, we have found that it has not moved as aggressively to the leading-edge technologies. This difference results in a technology mismatch between demand, primarily from fabless semiconductor companies, and capacity from the foundries. For example, in 1997 the "sweet spot" of fabless demand was between 0.6- and 0.5-micron, with these two categories representing a combined 60 percent of wafer demand, while 0.35-micron wafers accounted for less than 15 percent. By contrast, over 40 percent of dedicated foundry capacity was 0.35-micron capable. This year, as the sweet spot moves to 0.35-micron, the foundries are again ahead of demand, with significant capacity already ramping up at 0.25-micron.

A technology glut has emerged in the foundry market, with the greatest oversupply, in relative terms, existing in the leading-edge technologies. This observation is confirmed by trends in wafer prices, where the most severe declines can be seen in 0.35-micron, and now 0.25-micron, wafers. The foundries, in an effort to utilize capacity, are forced to load leading-edge fabs with designs based on lagging technology, resulting in lower revenue per square inch of silicon and, ultimately, suboptimal returns on assets. So, although TSMC may have proclaimed full fabs earlier this year, the fabs were probably not being fully utilized in the sense of technological capability.

The situation in the foundry market today is very dynamic and somewhat difficult to predict in the short term. The full extent of the foundries' response to the deteriorating imbalance of supply and demand is not yet known, nor are the effects of other possible outcomes such as increased demand resulting from dramatically lower wafer prices. However, the fact that the foundries have responded quickly and decisively to these new market realities can be viewed as a positive development. For while it may be painful, it will shorten the time needed to return the market to a state of balanced supply and healthy, profitable growth.

This current environment is strangely reminiscent of the 1985-to-1986 environment when the fabless industry was born and the foundry model was started. Do we see some of that again right now? It is possible that the massive overcapacity and corporate restructuring that we are seeing in the semiconductor industry could provide some of the elements needed for something of a fabless renaissance, with much design talent becoming available and ample capacity of inexpensive foundry wafers available at the leading edge. We could actually see an acceleration of the IDM demand as well, particularly as IDM companies begin to look upon the foundries as a viable source for leading-edge technology.

Where Is the Driver for Recovery?

Given this fairly dire outlook on capacity balance in the near term, we believe the situation is being set up nicely for a shortage of capacity in the year 2000 starting in the DRAM area.

Again referring to Figure 4, let's look more closely at the demand trends. Generally, demand for silicon in the DRAM market can be thought of as cyclical with a short and a longer leg. The short legs are down, namely the first half of 1996 and most of 1999, and the longer legs are up—from the third quarter 1996 through the fourth quarter 1998.

The down legs occur when transitions in DRAM densities are occurring—the movement from the 16Mb to the 64Mb density in early 1999, for example. The upward legs occur when the industry is primarily shipping one product, where the bit demand growth exceeds the shrink factor in silicon efficiency, resulting in increased demand for silicon area.

The dip in the last half of 1997 is really the result of an accelerated shrink factor having a short-term damping effect on growth. This acceleration essentially flattened the ramp for silicon demand throughout 1997 and 1998. This silicon "holiday" will be fully played out in the market by mid-1999, and any further silicon requirement increases in the future should be steeper.

Now if capacity does actively exit the market over the next 18 months, as we expect, we will be in a near-balance position, but still in slight oversupply. At the end of 1999, the transition to the 64Mb density should be complete, and the next densities not yet cost-effective in terms of cost per bit. This means that the demand for silicon should increase in 2000 and 2001 at much the same rate as in early 1997.

Because DRAM suppliers will still be unprofitable throughout all of 1999, the capital spending and capacity increase engine will be dormant. We can easily envision a shortage condition emerging sometime in 2000, spurring another capital investment cycle. This possibility has been built into our capital spending forecast. Granted this shift is still a ways off in the future, but at least we can see the fundamentals of capacity starting to align with demand.

Regional and Company Details

Coming back to the near-term outlook, let's look more closely at some tactical issues and crosscurrents to watch and monitor:

- Korean companies cut back spending in 1998 almost 70 percent in U.S. dollar terms, resulting in a total spending level of $2.0 billion compared to $7.4 billion in 1996. We are expecting, as the Korean won stabilizes, that a modest 25 to 30 percent increase in spending from this depressed level will occur in 1999. We have published before that the won exchange rate, now fairly stable at the 1,350 level, can be used as the world's report card on how the Korean companies are responding to their financial crisis. The window of 1,200 to 1,300 is considered the target range.
- Taiwanese companies' DRAM spending will be cut by 45 percent overall in U.S. dollar terms this year, at the bottom of our expected range six months ago, but foundry spending will grow only 20 percent in 1998, resulting in an overall decline in spending on the island of about 7 percent. For 1999, we are expecting DRAM spending to remain low and perhaps down, but foundry spending to be cut again, resulting in an overall island decline of roughly 20 percent.
- Japanese companies are cutting spending overall by 20 percent in yen terms. With the yen weakness, the result is a 30 percent cut in U.S. dollar terms compared to 1997. This spending cut is well below our downside scenario of six months ago. This represents the third year of spending cuts, so we are expecting some modest increase in 1999, about 10 percent, as investment in new technology will be required.
- The major U.S. and European companies are decreasing spending in 1998 by 5 to 10 percent, in response to demand issues. We are forecasting a modest recovery of 7 to 10 percent for these companies in 1999, but this recovery could be greater if the PC market shows signs of unexpected life in the second half of 1998.

In fact, we have built an upside potential scenario for spending in 1999, which is based on our optimistic semiconductor chip forecast of 8 percent growth for 1998. This optimistic forecast for 1998 is based on the possibility that the PC market will exceed our expectation for the second half. While we have a probability of only 15 percent for this scenario, we are releasing a detailed equipment segment forecast for 1999 based on the following reactions in the market:

- Intel, currently expected to increase spending levels associated with Merced sometime in the second half of 1999, will bring forward this spending plan by three to six months, based on an increase in demand.
- Because about 70 percent of the fabless companies depend on the PC market, foundry demand will be higher than currently anticipated, possibly firming plans for spending in 1999 to hold steady with 1998 levels.
- We are not expecting an effect on DRAM spending, because the stronger than expected market in 1998 may offer hope to the suppliers considering an active exit of capacity, thereby keeping supply at elevated levels.

Putting these together, the upside wafer fab equipment forecast scenario calls for just over 10 percent growth, compared to just under 3 percent in our official forecast.

In this upside scenario, as well as the forecast case, investment in advanced logic technology is expected to be favored over DRAM-sensitive technologies. More stable segments include copper-related technologies, deep-UV lithography (although at a much slower growth rate than in the past), and maskmaking equipment.

In summary, the movement to a "minimum investment" pattern in 1998 has meant a severe cut in spending levels this year. The semiconductor demand stall in 1998 actually pushes the sustained recovery into early 2000, and therefore the growth forecast for 1999 is essentially flat overall.

But we do see a bright spot, albeit moderately in the distance. We see the first fundamental signs aligning to create a spending boom during 2000 and 2001, with a shortage in the DRAM market emerging early in 2000.

We would now like to open up this briefing to your questions.

Questions and Answers

Question: I would like to get your comments on the active exit scenario you spoke of, specifically related to the scenarios of Korean rationalization that have been talked about in the market recently.

Clark Fuhs (CF): Yes, we're going to disappoint some people by not making any specific comments on companies in this forum that could possibly exit the market. The rationalization or the rotation of businesses that has been rumored in the Korean companies for some time does offer the potential for some consolidation in the capacity area. Samsung and LG Semicon, of course, are both DRAM suppliers, and they are both in the same situation. We are not sure how that would play out, frankly. There is a possibility some net capacity would exit the market, but would not be sure where it would go. Next question.

Question: Do you have a split on the stepper shipments by technology, particularly g-line and deep-UV, if that's possible? And the second question is how do you see technologies in lithography beyond deep-UV—the e-beam and X-ray lithography—coming along and affecting the market? Thank you.

Klaus Rinnen (KR): This is Klaus Rinnen. Yes, we do have splits for different stepper technologies. I do have the tables with me, so I can make specific comments on that. For 1998, we see that the overall unit level will decline by about 30 percent compared to already reduced levels of 1997. That brings the overall unit shipments down to at or below 740 units. Deep-UV will still grow at 30 percent, smaller growth when compared to the previous year of 225 percent in 1997. We expect deep-UV shipments to come in at about 401 units for 1998, with i-line declining to about 300 units, and g-line at the 35 unit level. When looking to alternative technologies, X-ray and e-beam electrolytes will have applications; however, those will be limited in the short term, and our forecast does not see these as significant until 2003 at this time.

Question: Yes, I am just trying to understand your one-year holding pattern for semiconductor demand. Does this mean that unit demand will be flat in 1998 over 1997? Can you talk a little bit about the impact of the decreasing linewidths on unit production?

CF: The unit demand is up in the first quarter. The one-year holding pattern that I refer to looks at our forecast profile over the last year in semiconductors. Dataquest was originally forecasting a 17 percent growth for 1998 last October, as were most people about a year ago. Today our forecast is essentially flat for 1998. The original forecast also represented an average growth for the chip market, and that has now been held flat for 1998. We basically have taken one year of growth out of the forecast horizon. So, when I refer to a holding pattern in the semiconductor demand, basically what I'm referring to is the fact that the 17 percent growth that we were expecting for 1998 has gone away. That is a permanent loss associated with the slower markets we see for consumer electronics and automotive markets in Asia and in the slowing PC market. So, when you look at the forecasts of a year ago or even six months ago and you look at the forecasts today relative to spending levels, we can basically push all the absolute numbers out one year and make 1998 equal to 1997 from the demand perspective.

What that has the effect of doing to the capital spending picture is that it inserts a year of minimum investment, resulting in a very severe correction in spending levels. Because with semiconductor demand on a revenue basis essentially flat, there is no motivation to add any capacity above what is needed for maintenance.

Shrinking linewidths actually affect silicon efficiency rather than unit demand. So, there really isn't an impact or much correlation between shrinks and actual unit demand of semiconductors. We are currently looking for a slight increase in unit demand for 1998 relative to 1997, but I can tell you that some of the contacts that we have in the material supplier community that particularly supply the discrete area have been signaling a little bit of weakness in the near term.

So, we are expecting the unit demand to flatten somewhat during the mid-second quarter and into the third. The second half of the year for the semiconductor market is seasonally stronger than the first half, so we do expect unit demand to recover somewhat in the second half.

Question: Yes, I was just interested in some clarity and follow-up to the question you just answered. I got confused when you were talking about revenue basis versus unit demand. Let me state what I heard, and then please correct it. I heard that 1998 to 1997 in semiconductor revenue would be flat and that as far as a unit demand, based on what you were hearing from material suppliers, you were seeing a flatness just starting. Is that correct?

CF: The revenue forecast for 1998 is flat at 1 percent growth, driven by weakness in the electronic equipment segment. Our original forecast was for 6.9 percent growth in the overall electronic equipment production forecast. That has actually been reduced for 1998 to 4.4 percent, primarily because of weakness from the consumer electronic area and a little bit in the computing side and a little bit in the automotive side. The Asian economic condition is what is creating that reduction. The consumer electronics and the automotive sector are the areas that primarily drive the unit demand for the discrete devices. So, the weakness that we are hearing from the material suppliers in the discrete area is now showing up in WSTS [World Semiconductor Trade Statistics] figures, and indeed the demand is starting to flatten a little bit. How long that is going to be the case, or how prolonged, they cannot see that right now. The discrete segment saw growth in 1997, pretty good growth in fact. That growth has flattened in the first half of 1998.

Question: Yes, you seem to imply, or at least I think I heard that the recovery for the equipment industry in 2000 and 2001 would be because of a need for capacity in DRAM. What do you see driving the need for more DRAM? What's going to be the driver at the next level up: PCs, wireless communication, automotive? What are the major drivers that you anticipate?

Jim Handy: This is Jim Handy. I run the Memories Worldwide service, and our DRAM forecast is based predominantly on PCs because they account for between 75 and 80 percent of all DRAM consumption. In general, DRAMs are consumed only in the data processing applications. There are very few other applications for DRAM. So we don't see anything in automotive like you mentioned or consumer electronics, with the exception of phone recording machines, which are really a very small consumer. However, something that happens very consistently in the DRAM business is that we do see a very strong pattern of bit growth. Bit growth tends to stay on a 67 percent per year increase, and it has been doing that since 1986. We are forecasting that continuing into the future. We see PC megabyte consumption, the number of megabytes in the average PC, increasing at a rate of about 45 percent per year, when including add-on memory sold in the aftermarket. Unit shipments of PCs increase at a rate of 15 percent per year. If you multiply that 15 percent growth times the 45 percent growth, you end up with about a 65 percent increase in the number of bits required. The only way that you are going to be able to maintain a bit growth like that is through a normal progression of densities, just following trends in Moore's Law quadrupling density every three to four years. That is going to force DRAM manufacturers to move to finer and finer line geometries and to have to continually upgrade their fabs.

Question: I was hoping you could go over what has caused a drop in capacity utilization at the foundries. What kind of products were they making before and where has that gone now that their capacity utilization has gone down so much in the past couple of months?

James Hines (JH): This is Jim Hines. I cover the semiconductor contract manufacturing market, which includes foundry. There are two causes to the overcapacity in the foundry industry. One is the increase in supply, as I mentioned in my comments. The dedicated foundries have been investing large sums of capital in new fabs for advanced technologies, and those fabs have been coming on line over the last two to three years, bringing a large amount of capacity onto the market. If you look at TSMC and UMC, they have been increasing capacity at an annual rate of 30 to 40 percent, in silicon area terms.

The other part of the equation, of course, is the demand. While those growth rates and supply could be sustainable under normal market conditions in a growing up cycle, what we are seeing now is some slowing of demand; even the fabless companies that consistently outperform the overall semiconductor industry are seeing somewhat lower rates of growth. I think they are being affected by some of the same factors that are really affecting the semiconductor market in general. In terms of product mix, I don't think we've seen any major shift there. The foundries are still making a lot of mainstream digital logic products based on CMOS processes. There are some other specialty areas that foundries participate in, but that really represents the major segment.

Question: So is the majority of the issue just too much capacity coming on quickly or is it that demand has fallen down so quickly?

JH: It is combination of both factors.

Question: Can you sort of put a number on one versus the other—50/50 or it's mostly because there is too much supply or mostly because there's lower demand?

JH: I would say that it is probably fairly equally distributed. Again, we still see some growth in silicon area terms for demand for foundry services. This year that should be at about a 10 percent growth rate while supply will be increasing closer to 25 or 30 percent on an overall basis.

Question: In the spin-on deposition numbers, what is the breakout for the low-k applications?

Ron Dornseif (RD): I haven't completed the breakdown yet on the details of the film and the applications for the deposition markets, but I'll have that probably within the week. The low-k part of deposition will start to heat up in 1999, but probably will be stronger in the year 2000 and beyond. Give me a call within the next week, and we will get that information to you.

Question: I apologize that I joined the call a little bit late. I was wondering if you were suggesting that the active exit of the DRAM market is the most likely scenario, and if not, what do you feel is the most likely scenario in the DRAM market?

CF: Yes, we believe that the active exit is the most likely scenario. This has actually historically been the case. Typically, in late stages of a DRAM oversupply, the industry does have capacity actively exiting in a number of different ways. We are not prepared, however, to offer specific forecasts on who those exiting the business may be at this time.

Question: Do you have any idea as to what time frame you might be looking on for that scenario in a little more detail?

CF: Actually, the next six quarters, as shown in Figure 4, will represent the window for this actually happening. The quantity we're talking about is roughly about six first-phase fabs, leading-edge fabs. One of those that has already been taken off the market is the TwinStar fab with the consolidation of the Texas Instruments and Micron Technology operations. It has already been determined that the fab will be mothballed and the equipment will be reallocated and sold.

Question: In Table 1, the total capital spending, is there a breakdown between what is required for maintenance versus what is expected to be new capacity?

CF: No, we have not done that kind of a breakdown, but my gut instinct is that the new capacity numbers probably represent only 30 or 40 percent of the total number and that the maintenance activities for 1998 and 1999 represent the majority, maybe a two-thirds majority. We do surveys every six months of the equipment industry, and we ask the question what percentage of the shipments are installed existing fabs versus new fabs. During peak cycles, the new fab mix is in the 60-to-70 percent range, and during the down cycles, that comes down in the 30-to-40 percent range.

Question: What does the "percentage of semiconductors" line represent in Table 1?

CF: Good point. A ratio that is closely watched is the ratio of capital spending to semiconductor revenue. We actually have represented this ratio two ways here. Let me explain the derivation of those ratios. It has been cited that on average 21 to 22 percent of semiconductor revenue should typically be invested on average in capital spending for capacity. This can theoretically be derived by doing a return on investment analysis of new fabs coming on line, and it has also been the historical average rate. The industry cycles above and below this during periods of undersupply and oversupply. The last three years, 1995 through 1997, the industry has been at a ratio of over 25 percent. So, the ratio is above average, and the conclusion could be reached that we were investing too much into the capacity in order to get return. In fact, that has been correct.

Our semiconductor forecast has been revised downward to 1 percent growth in 1998. We carried the growth rate forward from our April forecast to model capital spending, which resulted in about a $270 billion market in the year 2002 for semiconductors.

When you just take the total capital spending line and divide it by the semiconductor forecast you get the first line, which is the capital spending as a percent of the revenue. Now over the course of the next three or four years, there will be some capital spending, investment, and purchase of equipment for 300mm pilot lines. We consider this spending to be nonproductive, generating no semiconductor revenue, and therefore should not contribute to the overall calculation of the ratio. So, if we exclude the capital spending we expect on the 300mm pilot lines you get the second line, which is what we are considering to be the ratio of merit over the next several years. As you can see, the spending correction in 1998 through 2000 brings the ratio well below the 22 percent average figure, so this tells us that the forecast scenario is basically creating a condition that will trend toward eliminating the oversupply condition.

Question: I have a question on the foundry business. Do you have any idea on the breakout on the market demand for 2000 and 2001 broken down with the technology such as 0.35- and 0.25-micron?

JH: This is Jim Hines again. We are in the process of updating our forecast for foundry services, which will include a look at the different technology segments. So, I do not have that information available at this time. But if you want to follow up with me at a later time, I expect to have that work completed next week.

Question: Actually it's a follow-up to the question on capital spending. Just a clarification. The 21 to 22 percent historical level of capital spending—is that for equipment or for equipment, land, buildings and everything else to increase capacity?

CF: That's the complete ball of wax.

Question: And what fraction of that goes into equipment these days?

CF: Historically it has been somewhere between 65 and 70 percent. The front end gets the majority of it, representing on average about 50 percent of the overall capital spending number, and the back-end equipment gets somewhere between 15 and 20 percent.

Question: You have shown in Figure 2 the silicon wafer area increasing in 1999. You show DRAM silicon consumption about flat in 1998 in Figure 3. So, what is driving the increasing silicon wafer area?

CF: Good question. In Figure 2, you will also notice that the rate of increase is significantly or a little bit less than the rate of increase for 1997. What we're basically forecasting is that, based on our semiconductor chip forecast of 19 percent growth in 1999, we expect demand to pick up in fourth quarter 1998 and into 1999. So, that is a forecast of a semiconductor unit recovery. Does that answer your question?

Question: Yes, you said pickup in the fourth quarter 1998?

CF: Yes, seasonally the third quarter is a slow quarter, which picks up entering the fourth quarter. However, the fourth quarter can also be a wild card depending on inventory corrections in preparation for pricing negotiations for the following year. Usually, wafers are purchased before the actual demand comes into play. Inventories right now at the chip suppliers in raw wafers are quite low. So, we are expecting that a semiconductor unit demand seen in the third quarter will actually translate into a silicon pickup in sales into the silicon industry in the fourth quarter. This will continue as the semiconductor recovery unfolds in 1999.

I would like to make one other clarification on the silicon demand. The fourth quarter 1998 pickup also includes a 300mm element as the Siemens pilot line comes up. That has also been factored in to increase in the fourth quarter as well. The 300mm demand ramp is another extra factor that comes into play in 1999.

CF: I show that we are at the end of our hour. Thank you for participation.

Perspective

Semiconductor Contract Manufacturing Services Worldwide

Market Analysis

Semiconductor Contract Manufacturing Wafer Pricing Trends: June 1998

Abstract: *In the second of three surveys of semiconductor contract manufacturing wafer prices planned for 1998, Dataquest observes continuing price declines. Prices are reported for 150mm and 200mm wafers, categorized by minimum feature size and number of metal interconnect levels, as well as special process options. Results are compared to previous surveys, dating back almost three years. Finally, a consensus view of short-term price projections is presented and discussed in relation to current supply-and-demand dynamics within the semiconductor foundry market.*

By James F. Hines

Foundry Wafer Prices Continue Their Long Slide

In what has become a familiar story, prices for foundry-processed wafers declined across all technology categories in the period from February to June 1998. The current results of Dataquest's survey of semiconductor contract manufacturing (SCM) wafer prices mark almost two years of continuously falling prices as the industry struggles under a stubborn oversupply condition. Even the lagging-edge technologies are seeing price softness, in contrast to the results of previous surveys, in which some increases were observed.

- Average prices for 150mm wafers ranged from $449 to $650, compared to $524 to $707 in February 1998.
- Prices for 200mm wafers, which generally represent the leading-edge technologies, averaged $917 to $2,611, compared to $1,090 to $2,803 in February 1998.

Dataquest

Program: Semiconductor Contract Manufacturing Services Worldwide
ProductCode: SCMS-WW-DP-9809
PublicationDate: August 31, 1998
Filing: Perspective
(For Cross-Technology, file in the Semiconductor Regional Markets and Manufacturing binder)

- Average prices for the newly introduced 0.25-micron generation of wafers dropped by about 6 to 8 percent over the four-month period.
- The 0.35-micron technology category, now beginning to see higher production volumes, continues to undergo substantial price reductions with average wafer prices falling 8 to 10 percent since February 1998.
- The lagging-edge categories experienced fairly severe price pressure during the four-month period, with average wafer prices in some technologies dropping by 14 percent or more.

The Foundry Wafer Pricing Survey

Dataquest conducts periodic surveys of the SCM market for the purpose of tracking foundry wafer pricing trends. At this time, the survey concentrates on mainstream CMOS process technologies segmented by minimum linewidth. For purposes of reporting prices, linewidth is defined as the "as-drawn" feature size, which is a more conservative measurement than the sometimes quoted "effective channel length," symbolized as L_{eff}. Recently, Dataquest has begun soliciting inputs on BiCMOS wafer prices, but to date the response has been insufficient to allow reporting of meaningful statistics.

The SCM wafer pricing survey completed in June is the second of three surveys planned for 1998. The first was conducted in February, and the results were published in the Perspective titled "Semiconductor Contract Manufacturing Wafer Pricing Trends, Spring 1998" (SCMS-WW-DP-9803), dated April 27, 1998. The third survey is planned for October of this year.

In June, a total of 19 companies were surveyed and reported prices paid and charged for 150mm and 200mm foundry-processed CMOS wafers. For this study, the group comprised 10 SCM users (buyers) and nine SCM suppliers (sellers), representing fabless semiconductor companies, integrated device manufacturers (IDMs), and dedicated foundries. The survey encompassed a variety of process technologies, categorized by minimum feature size and number of metal interconnect levels. In addition, participants were asked to report prices for a number of special processing options, such as tungsten, chemical mechanical planarization (CMP), salicide, and epitaxial silicon. Finally, foundry users and suppliers were polled to obtain a consensus view on the expected change in wafer prices over the next four months (the interim period between surveys).

June 1998 Foundry Wafer Pricing Update

Table 1 summarizes the results of the most recent foundry wafer pricing survey, conducted in June 1998. Participants were asked to report prices paid for foundry processed wafers delivered during June 1998, assuming CMOS, unprobed wafers with 13 to 15 mask levels, single-level polysilicon, and no epitaxial silicon. The minimum volume requirement was set at 1,000 wafers per month. The estimated average price is the average of all prices reported or, in cases of small sample size, Dataquest's estimate of the average price. The price range shows the minimum and maximum prices reported.

Table 1
June 1998 Foundry Wafer Prices (U.S. Dollars per Wafer)

	150mm Wafer		200mm Wafer	
	Estimated Average Price	Price Range	Estimated Average Price	Price Range
1 micron, 1P2M	449	300-520	NA	NA
1 micron, 1P3M	458	300-545	NA	NA
0.8 micron, 1P2M	483	300-580	NA	NA
0.8 micron, 1P3M	500	300-545	NA	NA
0.6 micron, 1P2M	549	400-700	917	900-950
0.6 micron, 1P3M	576	450-680	960	1,150-1,180
0.5 micron, 1P2M	600	500-710	1,093	975-1,280
0.5 micron, 1P3M	650	525-780	1,195	1,050-1,400
0.35 micron, 1P3M	NA	NA	1,511	1,163-1,947
0.35 micron, 1P4M	NA	NA	1,686	1,288-2,106
0.25 micron, 1P3M	NA	NA	2,267	1,955-2,602
0.25 micron, 1P4M	NA	NA	2,444	2,150-2,784
0.25 micron, 1P5M	NA	NA	2,611	2,300-3,000

NA = Not available
Note: 1P2M = one polysilicon level, two metal levels; 1P3M = one polysilicon level, three metal levels; 1P4M = one polysilicon level, four metal levels; 1P5M = one polysilicon level, five metal levels
Source: Dataquest (August 1998)

Table 2 compares the average prices reported in June 1998 to those reported in the previous survey of February 1998. Foundry wafer prices have continued to slide during the past six months, reflecting the general overcapacity of the market that has existed since mid-1996.

How the Views of Buyers and Sellers Differ

Responses of buyers and sellers may differ in a survey of this type, and we might expect buyers to report generally lower prices than sellers, reflecting their respective biases in ongoing negotiations between the two groups. Interestingly, this generalization has not always held true in past surveys of foundry wafer prices, and the current results are a case in point, as shown in Figures 1 and 2. The average reported prices of sellers are consistently higher for 200mm wafers (Figure 2), but 150mm wafer prices show the opposite trend (Figure 1).

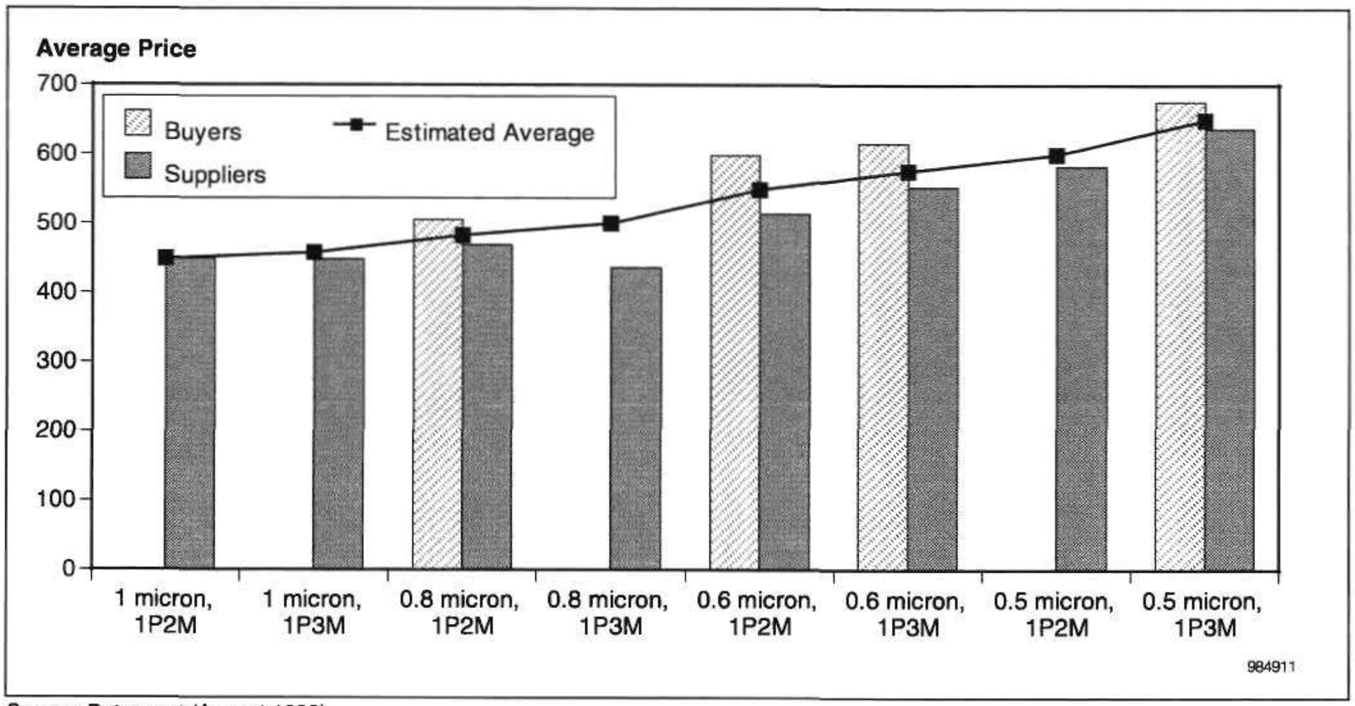
The line charts in Figures 1 and 2 represent the estimated average price for each technology category. The column charts represent the average of prices reported by buyers and sellers as separate groups. In those cases where a column is missing, the number of responses from the particular group was not sufficient to provide a statistically meaningful result.

Table 2
Change in Average Foundry Wafer Prices, February 1998 to June 1998 (U.S. Dollars per Wafer)

	150mm Wafer			200mm Wafer		
	February 1998	June 1998	Change (%)	February 1998	June 1998	Change (%)
1 micron, 1P2M	524	449	-14.2	NA	NA	NA
1 micron, 1P3M	450	458	1.8	NA	NA	NA
0.8 micron, 1P2M	527	483	-8.3	NA	NA	NA
0.8 micron, 1P3M	540	500	-7.4	NA	NA	NA
0.6 micron, 1P2M	588	549	-6.7	1,090	917	-15.9
0.6 micron, 1P3M	608	576	-5.3	1,165	960	-17.6
0.5 micron, 1P2M	667	600	-10.0	1,277	1,093	-14.4
0.5 micron, 1P3M	708	650	-8.2	1,325	1,195	-9.8
0.35 micron, 1P3M	NA	NA	NA	1,684	1,511	-10.3
0.35 micron, 1P4M	NA	NA	NA	1,833	1,686	-8.0
0.25 micron, 1P3M	NA	NA	NA	2,450	2,267	-7.5
0.25 micron, 1P4M	NA	NA	NA	2,590	2,444	-5.6
0.25 micron, 1P5M	NA	NA	NA	2,833	2,611	-7.9

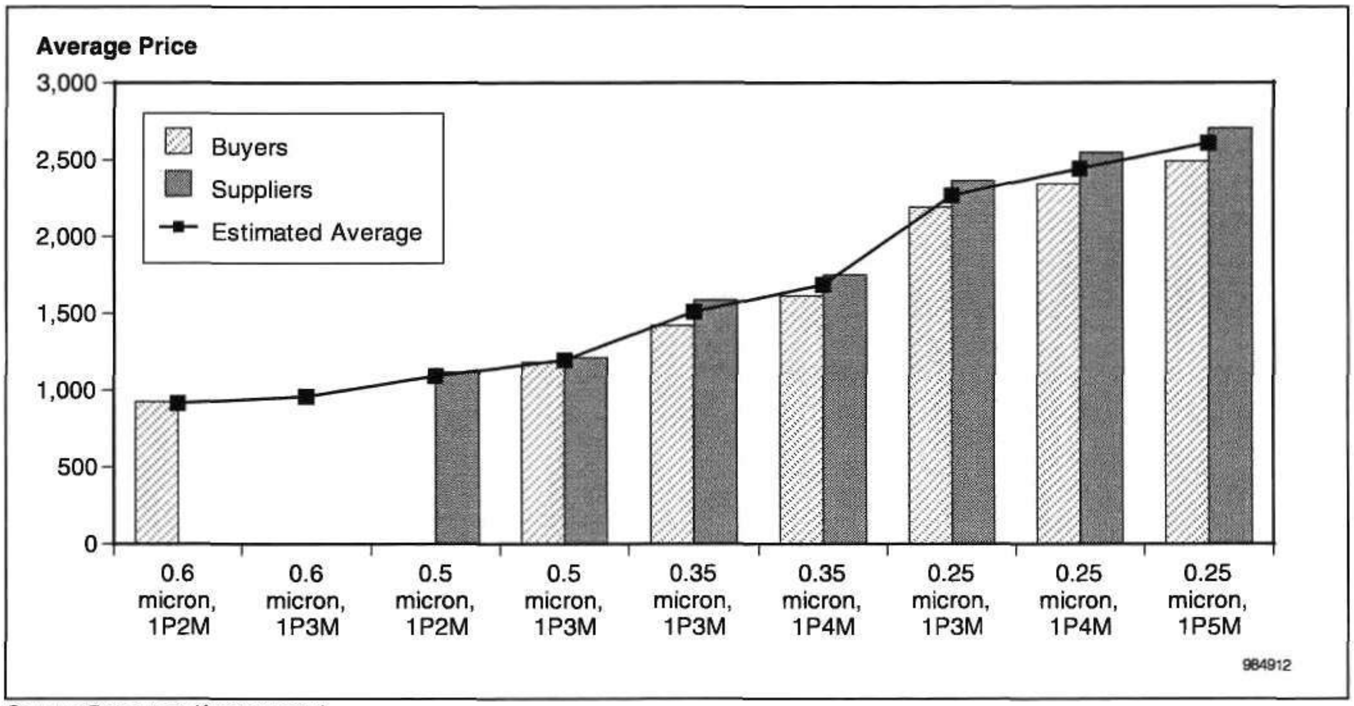
NA = Not available
Note: 1P2M = one polysilicon level, two metal levels; 1P3M = one polysilicon level, three metal levels; 1P4M = one polysilicon level, four metal levels; 1P5M = one polysilicon level, five metal levels
Source: Dataquest (August 1998)

Figure 1
June 1998 Foundry Wafer Prices: 150mm Wafers, All Process Options (U.S. Dollars per Wafer)



Source: Dataquest (August 1998)

Figure 2
June 1998 Foundry Wafer Prices: 200mm Wafers, All Process Options (U.S. Dollars per Wafer)



Source: Dataquest (August 1998)

Process Option Prices

Prices for special processing options are shown in Table 3. These are processes outside of the standard process flow that normally involve an additional cost. As noted in previous reports on wafer prices, tungsten, salicide, and CMP processes are becoming standardized, at least on 200mm wafers. These processes are becoming part of the standard process flow for advanced technologies, which are predominant at the 200mm wafer size.

Table 4 compares average special process option prices in this survey to the previous survey of February 1998. Like wafer prices, some process option prices decreased, but the results are mixed. Prices for tungsten decreased for 150mm wafers but increased slightly for 200mm wafers. Prices for salicide decreased in both cases, as they did in the previous survey. Epitaxial silicon prices increased for 150mm wafers but decreased for 200mm wafers. CMP was essentially flat. The average price for additional mask levels decreased in both cases. The price adder for additional polysilicon levels showed mixed results, increasing on 150mm wafers but remaining flat on 200mm wafers.

Table 3
February 1998 Foundry Wafer Process Option Pricing (U.S. Dollars per Wafer)

	150mm Wafer		200mm Wafer	
	Average Price	Price Range	Average Price	Price Range
Tungsten	30	25-35	35	30-40
Salicide	52	30-70	63	50-70
Epitaxial Silicon	63	50-100	144	120-150
CMP	51	50-52	58	50-75
Mask	50	30-60	96	80-100
Polysilicon	72	30-150	120	100-150

Source: Dataquest (August 1998)

Table 4
Change in Average Foundry Wafer Process Option Prices, February 1998 to June 1998 (U.S. Dollars per Wafer)

	150mm Wafer			200mm Wafer		
	February 1998	June 1998	Change (%)	February 1998	June 1998	Change (%)
Tungsten	33	30	-7.7	34	35	4.5
Salicide	62	52	-16.2	66	63	-5.3
Epitaxial Silicon	59	63	7.0	162	144	-11.1
CMP	51	51	0.0	57	58	2.0
Mask	58	50	-13.6	105	96	-8.1
Polysilicon	67	72	7.7	120	120	0

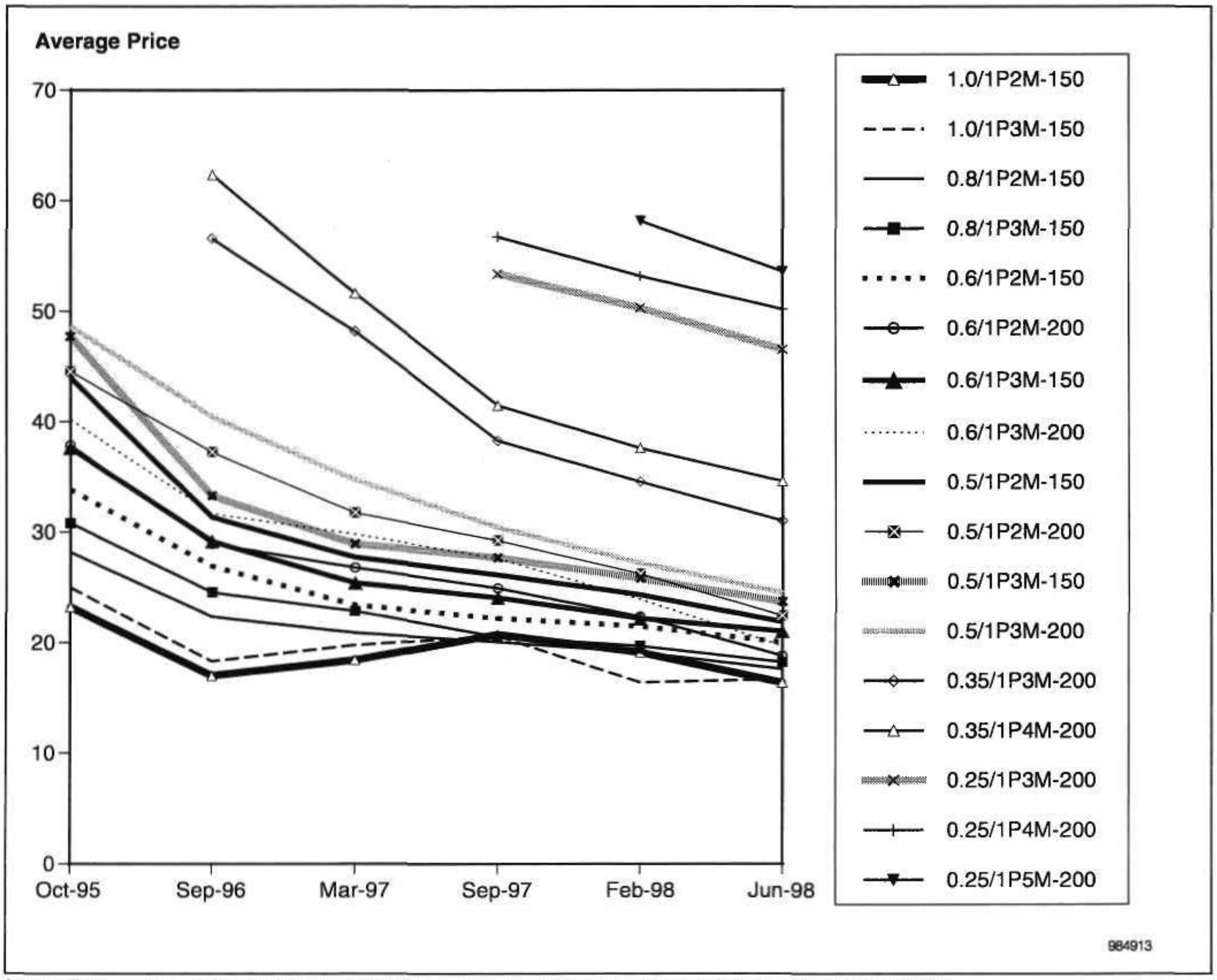
Source: Dataquest (August 1998)

Historical Foundry Wafer Pricing Trends

Figure 3 graphically displays the history of foundry wafer prices since October 1995, when Dataquest began conducting these surveys. Prices are plotted in dollars per square inch in order to normalize differences in wafer size. This chart is somewhat busy, but it provides an interesting snapshot of foundry wafer pricing trends over a period of almost three years. Since Dataquest has been increasing the frequency of these surveys, the periods of time between divisions on the horizontal axis are not uniform, gradually shrinking from 11 months at the start to four months presently. This point should be considered when making a visual interpretation of the relative slopes of the trend lines in the chart.

The dominant trends in this history of foundry wafer prices are a general deceleration of price declines during the past nine months and a convergence of prices for lagging-edge technologies. In our last report on foundry wafer prices, we noted that prices declined at a slower rate than had been previously observed, and we speculated that the big price drops may now be behind us. Indeed, 1997 has so far been the year in which prices fell most rapidly, especially for 0.35-micron wafers. It now looks as though the trend may continue, for although prices continue to fall, the rate of decline appears to be slowing. However, the high levels of excess foundry capacity that now exist are cause for concern, and this condition could lead to another round of competitive price cutting.

Figure 3
Historical SCM Average Price-per-Square-Inch Trends, October 1995 to June 1998 (U.S. Dollars)



Note: 1P2M = one polysilicon level, two metal levels;150mm wafer area = 27.4in; 200mm wafer area = 48.7in²
Source: Dataquest (August 1998)

Because of the faster rates of price erosion for leading-edge technologies than for lagging technologies, a convergence of prices has developed. This trend is most evident in the 0.5-micron to 1.0-micron categories, where the total price spread is now only about $8 per square inch. Whereas the cost of manufacturing wafers in the leading-edge technologies of 0.35 micron and 0.25 micron is dominated by the depreciation expenses of a new fab and its associated capital equipment, the lagging technologies are manufactured in older fabs, many of which are already fully depreciated, so variable cost is the primary determinant of overall cost. The wafer prices depicted in this chart appear to be approaching a lower limit that will likely be determined by variable cost and the minimum margin that SCM suppliers are willing to accept.

The Outlook for Foundry Wafer Prices: How Low Will They Go?

Everyone who participates in the SCM market, whether as a buyer or a seller, has on his or her mind the question of how low foundry wafer prices will go. Note that the question is phrased as one of magnitude, not direction. The oversupply of foundry capacity, which has actually worsened since this survey was completed, makes it quite clear that competitive pricing pressures will persist throughout the remainder of this year. Although this report is not intended to be a forecast of foundry wafer prices, we can gain some insight into the near-term outlook by polling our survey participants about their expectations for future prices.

Report Card: "B" for Sellers, "C+" for Buyers

Each time Dataquest surveys the market for current foundry wafer prices, we also ask our survey participants to offer their predictions on how prices will change in the next scheduled survey—in this case, four months hence. In this way, a short-term consensus outlook for pricing trends is obtained. It might be instructive to compare the predictions of the February 1998 survey to actual results to calibrate the accuracy of this consensus view. Table 5 shows the latest "report card" for our survey participants.

Table 5
Comparison of February 1998 Expected Change in Foundry Wafer Prices to Actual Results (Percent)

	Buyers' Expected Change	Sellers' Expected Change	Actual Results
0.5 micron	-5.0	-7.5	-10.0
0.35 micron	-7.5	-10.0	-8.6
0.25 micron	-10.0	-5.0	-6.4

Source: Dataquest (August 1998)

Still Lower Prices Ahead

Survey participants were asked to predict the movement of foundry wafer prices over the next four months for 0.5-, 0.35-, and 0.25-micron wafers. Table 6 summarizes the results of this polling. Prices 5 to 7.5 percent lower are expected by the time we survey again in October 1998. Since these rates of decline apply to a four-month period, the corresponding annual rates of decline would be about 14 to 21 percent.

It should be noted that since this poll was conducted, the oversupply in the foundry market has worsened. Excess capacity has been increasing for more than a year, and Dataquest's current analysis of foundry capacity and demand points to an "acute" oversupply condition with excess capacity in the range of 30 to 40 percent. Fab utilization rates of 70 percent or less have been reported, and dedicated foundries such as Taiwan Semiconductor Mfg. Co. and United Microelectronics Corporation have announced drastic cuts in their capital spending plans for the remainder of 1998 and 1999.

Table 6
Expected Change in Foundry Wafer Prices over the Next Four Months, Median Response (Percent)

	0.5 Micron	0.35 Micron	0.25 Micron
Buyers	-5.0	-7.5	-7.5
Sellers	-5.0	-5.0	-5.0
All	-5.0	-7.5	-7.5

Source: Dataquest (August 1998)

If Dataquest were to conduct this poll today, the consensus would probably be for prices even lower than shown in the above table. It is likely that the persistent and worsening oversupply in the foundry market will bring on another round of price-cutting as SCM suppliers scramble for market share. As we have seen before, prices for the leading-edge technologies of 0.35 and 0.25 micron will be affected the most because this area is where the competition is hottest and volumes are ramping quickly. Lagging technologies will also see price pressure, but to a lesser extent, and the underlying cost structure will provide some support.

Dataquest Perspective

With this latest survey, Dataquest now has almost three years of history tracking foundry wafer prices. During this period, the foundry market has followed the broader semiconductor industry, going from widespread capacity shortage and stable prices to acute oversupply and tumbling prices. Our last survey, in February 1998, showed prices falling at a slower rate, giving hope that the market may be entering a period of relative stability. Alas, recent news of precipitously falling utilization rates at the major dedicated foundries makes this speculation highly unlikely.

With SCM demand slowing as a result of the Asian economic slowdown and the related stagnation of the worldwide semiconductor market, and with excess foundry capacity running at 30 to 40 percent, conditions are ripe for another round of competitive price-cutting in the foundry market. The greatest price declines are likely to occur in the leading-edge technology categories. Despite two years of falling prices, 0.35-micron and 0.25-micron wafers are still selling at a substantial premium to the lagging technologies, and as production volumes continue to increase there will be more opportunity for price competition.

The good news for SCM suppliers is that, because of price elasticity, lower wafer prices are likely to stimulate demand. Low wafer prices, along with corporate restructuring among the major IDMs, could result in a renaissance of the fabless model as an army of furloughed IC designers band together to form new ventures and take advantage of an unprecedented supply of cheap foundry wafers in leading-edge technologies. Foundries may also see a surge in demand from IDMs as wafer prices become low enough to make outsourcing wafer fabrication a truly compelling cost reduction strategy.

Thus, although the foundries followed the industry into the current semiconductor slump, they may be the first to climb out.

For More Information...

Inquiry Hotline:	+1-408-468-8423
Via e-mail:	scndinquiry@dataquest.com
Via fax:	+1-408-954-1780
Dataquest Interactive:	http://www.dataquest.com

Perspective

Semiconductor Contract Manufacturing Services Worldwide

Market Analysis

Semiconductor Contract Manufacturing Wafer Pricing Trends: June 1998

Abstract: *In the second of three surveys of semiconductor contract manufacturing wafer prices planned for 1998, Dataquest observes continuing price declines. Prices are reported for 150mm and 200mm wafers, categorized by minimum feature size and number of metal interconnect levels, as well as special process options. Results are compared to previous surveys, dating back almost three years. Finally, a consensus view of short-term price projections is presented and discussed in relation to current supply-and-demand dynamics within the semiconductor foundry market.*
By James F. Hines

Foundry Wafer Prices Continue Their Long Slide

In what has become a familiar story, prices for foundry-processed wafers declined across all technology categories in the period from February to June 1998. The current results of Dataquest's survey of semiconductor contract manufacturing (SCM) wafer prices mark almost two years of continuously falling prices as the industry struggles under a stubborn oversupply condition. Even the lagging-edge technologies are seeing price softness, in contrast to the results of previous surveys, in which some increases were observed.

- Average prices for 150mm wafers ranged from $449 to $650, compared to $524 to $707 in February 1998.
- Prices for 200mm wafers, which generally represent the leading-edge technologies, averaged $917 to $2,611, compared to $1,090 to $2,803 in February 1998.

Dataquest
Program: Semiconductor Contract Manufacturing Services Worldwide
ProductCode: SCMS-WW-DP-9809
PublicationDate: August 31, 1998
Filing: Perspective
(For Cross-Technology, file in the Semiconductor Regional Markets and Manufacturing binder)

- Average prices for the newly introduced 0.25-micron generation of wafers dropped by about 6 to 8 percent over the four-month period.
- The 0.35-micron technology category, now beginning to see higher production volumes, continues to undergo substantial price reductions with average wafer prices falling 8 to 10 percent since February 1998.
- The lagging-edge categories experienced fairly severe price pressure during the four-month period, with average wafer prices in some technologies dropping by 14 percent or more.

The Foundry Wafer Pricing Survey

Dataquest conducts periodic surveys of the SCM market for the purpose of tracking foundry wafer pricing trends. At this time, the survey concentrates on mainstream CMOS process technologies segmented by minimum linewidth. For purposes of reporting prices, linewidth is defined as the "as-drawn" feature size, which is a more conservative measurement than the sometimes quoted "effective channel length," symbolized as L_{eff}. Recently, Dataquest has begun soliciting inputs on BiCMOS wafer prices, but to date the response has been insufficient to allow reporting of meaningful statistics.

The SCM wafer pricing survey completed in June is the second of three surveys planned for 1998. The first was conducted in February, and the results were published in the Perspective titled "Semiconductor Contract Manufacturing Wafer Pricing Trends, Spring 1998" (SCMS-WW-DP-9803), dated April 27, 1998. The third survey is planned for October of this year.

In June, a total of 19 companies were surveyed and reported prices paid and charged for 150mm and 200mm foundry-processed CMOS wafers. For this study, the group comprised 10 SCM users (buyers) and nine SCM suppliers (sellers), representing fabless semiconductor companies, integrated device manufacturers (IDMs), and dedicated foundries. The survey encompassed a variety of process technologies, categorized by minimum feature size and number of metal interconnect levels. In addition, participants were asked to report prices for a number of special processing options, such as tungsten, chemical mechanical planarization (CMP), salicide, and epitaxial silicon. Finally, foundry users and suppliers were polled to obtain a consensus view on the expected change in wafer prices over the next four months (the interim period between surveys).

June 1998 Foundry Wafer Pricing Update

Table 1 summarizes the results of the most recent foundry wafer pricing survey, conducted in June 1998. Participants were asked to report prices paid for foundry processed wafers delivered during June 1998, assuming CMOS, unprobed wafers with 13 to 15 mask levels, single-level polysilicon, and no epitaxial silicon. The minimum volume requirement was set at 1,000 wafers per month. The estimated average price is the average of all prices reported or, in cases of small sample size, Dataquest's estimate of the average price. The price range shows the minimum and maximum prices reported.

Table 1
June 1998 Foundry Wafer Prices (U.S. Dollars per Wafer)

	150mm Wafer		200mm Wafer	
	Estimated Average Price	Price Range	Estimated Average Price	Price Range
1 micron, 1P2M	449	300-520	NA	NA
1 micron, 1P3M	458	300-545	NA	NA
0.8 micron, 1P2M	483	300-580	NA	NA
0.8 micron, 1P3M	500	300-545	NA	NA
0.6 micron, 1P2M	549	400-700	917	900-950
0.6 micron, 1P3M	576	450-680	960	1,150-1,180
0.5 micron, 1P2M	600	500-710	1,093	975-1,280
0.5 micron, 1P3M	650	525-780	1,195	1,050-1,400
0.35 micron, 1P3M	NA	NA	1,511	1,163-1,947
0.35 micron, 1P4M	NA	NA	1,686	1,288-2,106
0.25 micron, 1P3M	NA	NA	2,267	1,955-2,602
0.25 micron, 1P4M	NA	NA	2,444	2,150-2,784
0.25 micron, 1P5M	NA	NA	2,611	2,300-3,000

NA = Not available
Note: 1P2M = one polysilicon level, two metal levels; 1P3M = one polysilicon level, three metal levels; 1P4M = one polysilicon level, four metal levels; 1P5M = one polysilicon level, five metal levels
Source: Dataquest (August 1998)

Table 2 compares the average prices reported in June 1998 to those reported in the previous survey of February 1998. Foundry wafer prices have continued to slide during the past six months, reflecting the general overcapacity of the market that has existed since mid-1996.

How the Views of Buyers and Sellers Differ

Responses of buyers and sellers may differ in a survey of this type, and we might expect buyers to report generally lower prices than sellers, reflecting their respective biases in ongoing negotiations between the two groups. Interestingly, this generalization has not always held true in past surveys of foundry wafer prices, and the current results are a case in point, as shown in Figures 1 and 2. The average reported prices of sellers are consistently higher for 200mm wafers (Figure 2), but 150mm wafer prices show the opposite trend (Figure 1).

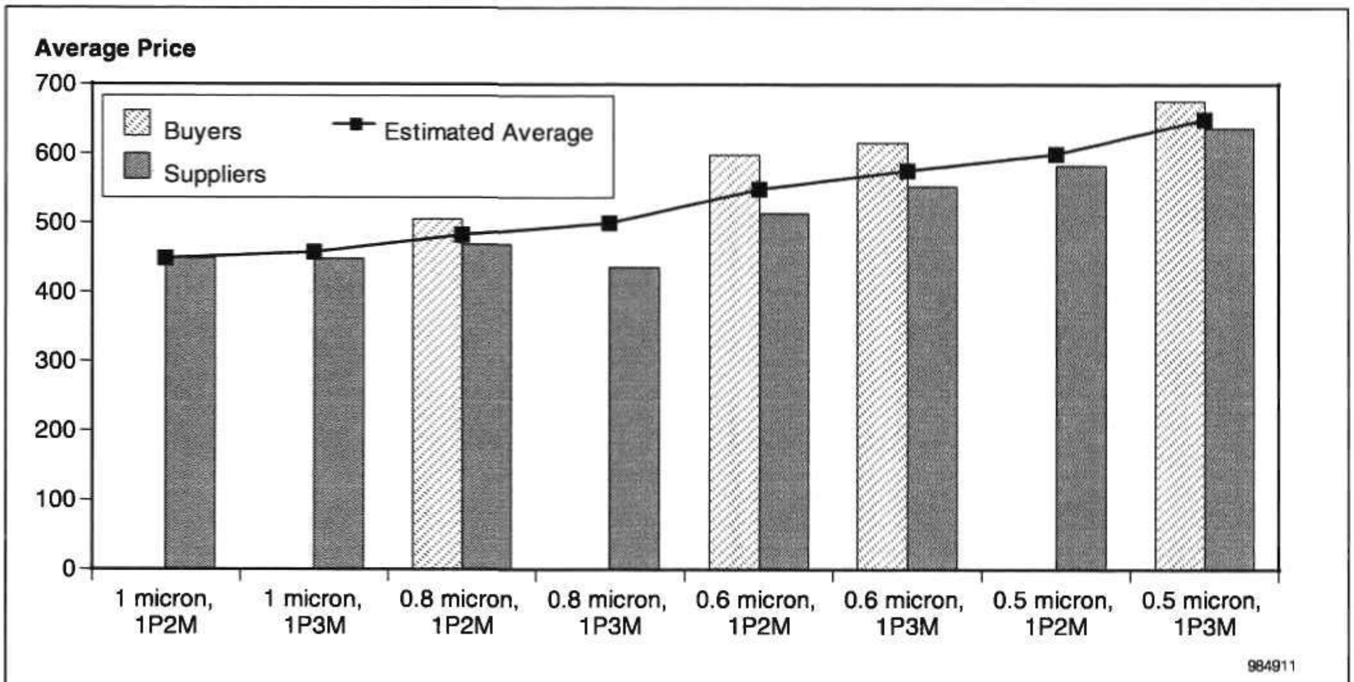
The line charts in Figures 1 and 2 represent the estimated average price for each technology category. The column charts represent the average of prices reported by buyers and sellers as separate groups. In those cases where a column is missing, the number of responses from the particular group was not sufficient to provide a statistically meaningful result.

Table 2
Change in Average Foundry Wafer Prices, February 1998 to June 1998 (U.S. Dollars per Wafer)

	150mm Wafer			200mm Wafer		
	February 1998	June 1998	Change (%)	February 1998	June 1998	Change (%)
1 micron, 1P2M	524	449	-14.2	NA	NA	NA
1 micron, 1P3M	450	458	1.8	NA	NA	NA
0.8 micron, 1P2M	527	483	-8.3	NA	NA	NA
0.8 micron, 1P3M	540	500	-7.4	NA	NA	NA
0.6 micron, 1P2M	588	549	-6.7	1,090	917	-15.9
0.6 micron, 1P3M	608	576	-5.3	1,165	960	-17.6
0.5 micron, 1P2M	667	600	-10.0	1,277	1,093	-14.4
0.5 micron, 1P3M	708	650	-8.2	1,325	1,195	-9.8
0.35 micron, 1P3M	NA	NA	NA	1,684	1,511	-10.3
0.35 micron, 1P4M	NA	NA	NA	1,833	1,686	-8.0
0.25 micron, 1P3M	NA	NA	NA	2,450	2,267	-7.5
0.25 micron, 1P4M	NA	NA	NA	2,590	2,444	-5.6
0.25 micron, 1P5M	NA	NA	NA	2,833	2,611	-7.9

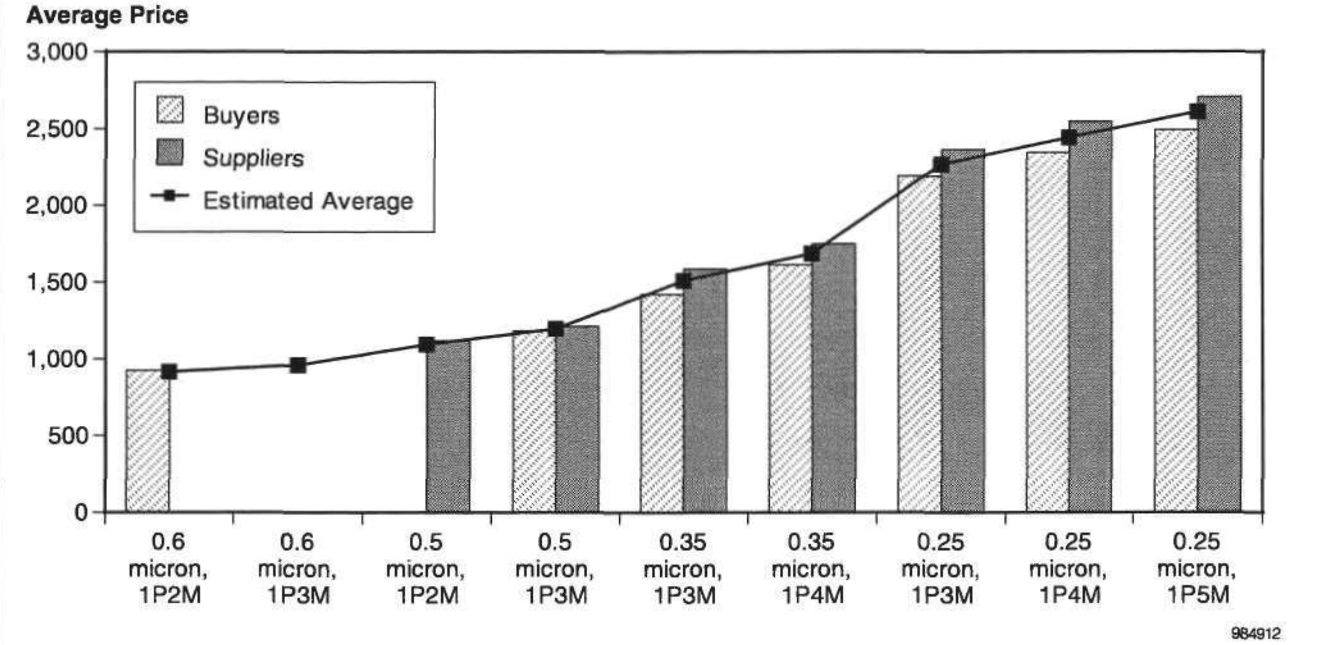
NA = Not available
Note: 1P2M = one polysilicon level, two metal levels; 1P3M = one polysilicon level, three metal levels; 1P4M = one polysilicon level, four metal levels; 1P5M = one polysilicon level, five metal levels
Source: Dataquest (August 1998)

Figure 1
June 1998 Foundry Wafer Prices: 150mm Wafers, All Process Options (U.S. Dollars per Wafer)



Source: Dataquest (August 1998)

Figure 2
June 1998 Foundry Wafer Prices: 200mm Wafers, All Process Options (U.S. Dollars per Wafer)



Source: Dataquest (August 1998)

Process Option Prices

Prices for special processing options are shown in Table 3. These are processes outside of the standard process flow that normally involve an additional cost. As noted in previous reports on wafer prices, tungsten, salicide, and CMP processes are becoming standardized, at least on 200mm wafers. These processes are becoming part of the standard process flow for advanced technologies, which are predominant at the 200mm wafer size.

Table 4 compares average special process option prices in this survey to the previous survey of February 1998. Like wafer prices, some process option prices decreased, but the results are mixed. Prices for tungsten decreased for 150mm wafers but increased slightly for 200mm wafers. Prices for salicide decreased in both cases, as they did in the previous survey. Epitaxial silicon prices increased for 150mm wafers but decreased for 200mm wafers. CMP was essentially flat. The average price for additional mask levels decreased in both cases. The price adder for additional polysilicon levels showed mixed results, increasing on 150mm wafers but remaining flat on 200mm wafers.

Table 3
February 1998 Foundry Wafer Process Option Pricing (U.S. Dollars per Wafer)

	150mm Wafer		200mm Wafer	
	Average Price	Price Range	Average Price	Price Range
Tungsten	30	25-35	35	30-40
Salicide	52	30-70	63	50-70
Epitaxial Silicon	63	50-100	144	120-150
CMP	51	50-52	58	50-75
Mask	50	30-60	96	80-100
Polysilicon	72	30-150	120	100-150

Source: Dataquest (August 1998)

Table 4
Change in Average Foundry Wafer Process Option Prices, February 1998 to June 1998 (U.S. Dollars per Wafer)

	150mm Wafer			200mm Wafer		
	February 1998	June 1998	Change (%)	February 1998	June 1998	Change (%)
Tungsten	33	30	-7.7	34	35	4.5
Salicide	62	52	-16.2	66	63	-5.3
Epitaxial Silicon	59	63	7.0	162	144	-11.1
CMP	51	51	0.0	57	58	2.0
Mask	58	50	-13.6	105	96	-8.1
Polysilicon	67	72	7.7	120	120	0

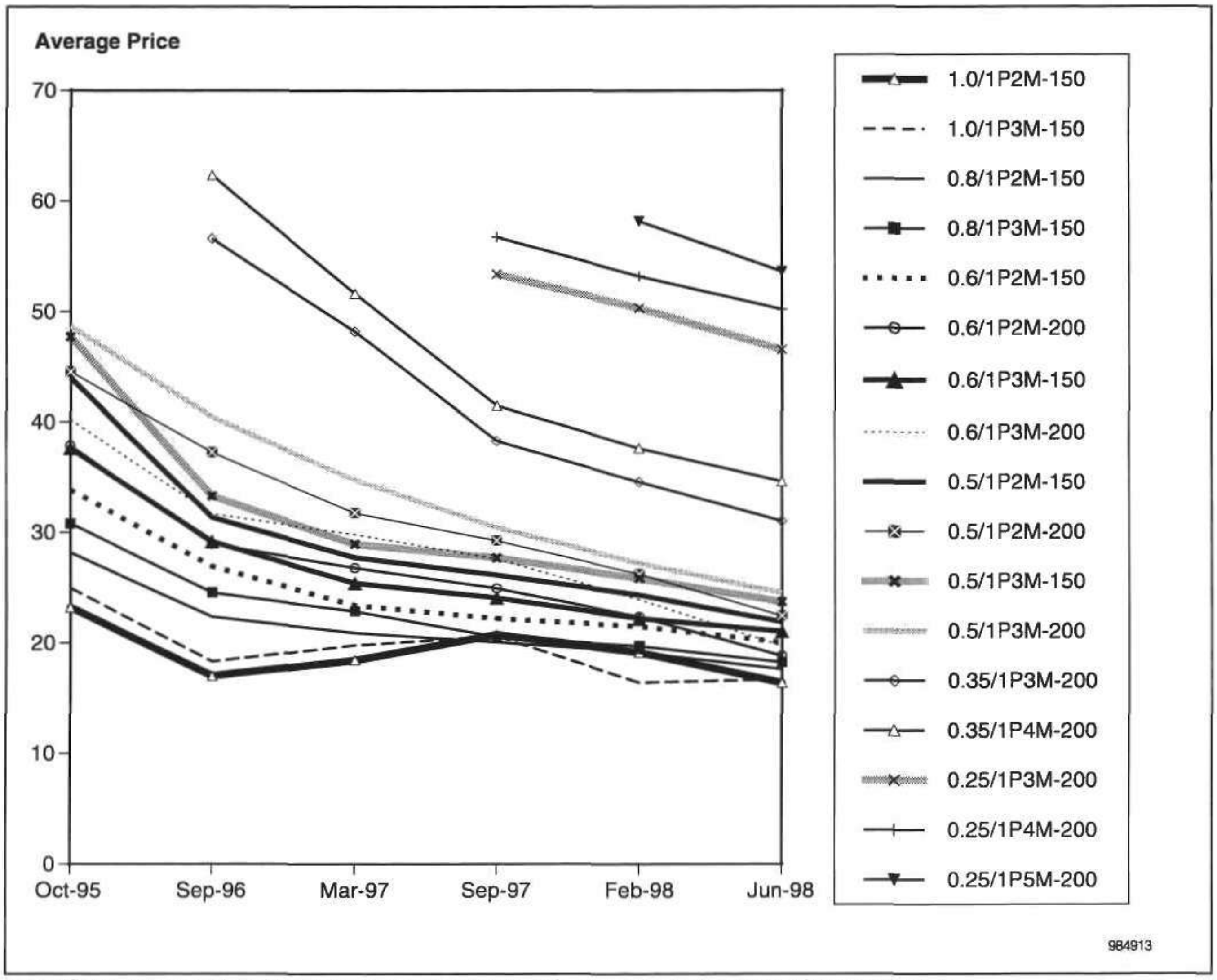
Source: Dataquest (August 1998)

Historical Foundry Wafer Pricing Trends

Figure 3 graphically displays the history of foundry wafer prices since October 1995, when Dataquest began conducting these surveys. Prices are plotted in dollars per square inch in order to normalize differences in wafer size. This chart is somewhat busy, but it provides an interesting snapshot of foundry wafer pricing trends over a period of almost three years. Since Dataquest has been increasing the frequency of these surveys, the periods of time between divisions on the horizontal axis are not uniform, gradually shrinking from 11 months at the start to four months presently. This point should be considered when making a visual interpretation of the relative slopes of the trend lines in the chart.

The dominant trends in this history of foundry wafer prices are a general deceleration of price declines during the past nine months and a convergence of prices for lagging-edge technologies. In our last report on foundry wafer prices, we noted that prices declined at a slower rate than had been previously observed, and we speculated that the big price drops may now be behind us. Indeed, 1997 has so far been the year in which prices fell most rapidly, especially for 0.35-micron wafers. It now looks as though the trend may continue, for although prices continue to fall, the rate of decline appears to be slowing. However, the high levels of excess foundry capacity that now exist are cause for concern, and this condition could lead to another round of competitive price cutting.

Figure 3
Historical SCM Average Price-per-Square-Inch Trends, October 1995 to June 1998 (U.S. Dollars)



Note: 1P2M = one polysilicon level, two metal levels;150mm wafer area = 27.4in; 200mm wafer area = 48.7in²
Source: Dataquest (August 1998)

Because of the faster rates of price erosion for leading-edge technologies than for lagging technologies, a convergence of prices has developed. This trend is most evident in the 0.5-micron to 1.0-micron categories, where the total price spread is now only about $8 per square inch. Whereas the cost of manufacturing wafers in the leading-edge technologies of 0.35 micron and 0.25 micron is dominated by the depreciation expenses of a new fab and its associated capital equipment, the lagging technologies are manufactured in older fabs, many of which are already fully depreciated, so variable cost is the primary determinant of overall cost. The wafer prices depicted in this chart appear to be approaching a lower limit that will likely be determined by variable cost and the minimum margin that SCM suppliers are willing to accept.

The Outlook for Foundry Wafer Prices: How Low Will They Go?

Everyone who participates in the SCM market, whether as a buyer or a seller, has on his or her mind the question of how low foundry wafer prices will go. Note that the question is phrased as one of magnitude, not direction. The oversupply of foundry capacity, which has actually worsened since this survey was completed, makes it quite clear that competitive pricing pressures will persist throughout the remainder of this year. Although this report is not intended to be a forecast of foundry wafer prices, we can gain some insight into the near-term outlook by polling our survey participants about their expectations for future prices.

Report Card: "B" for Sellers, "C+" for Buyers

Each time Dataquest surveys the market for current foundry wafer prices, we also ask our survey participants to offer their predictions on how prices will change in the next scheduled survey—in this case, four months hence. In this way, a short-term consensus outlook for pricing trends is obtained. It might be instructive to compare the predictions of the February 1998 survey to actual results to calibrate the accuracy of this consensus view. Table 5 shows the latest "report card" for our survey participants.

Table 5
Comparison of February 1998 Expected Change in Foundry Wafer Prices to Actual Results (Percent)

	Buyers' Expected Change	Sellers' Expected Change	Actual Results
0.5 micron	-5.0	-7.5	-10.0
0.35 micron	-7.5	-10.0	-8.6
0.25 micron	-10.0	-5.0	-6.4

Source: Dataquest (August 1998)

Still Lower Prices Ahead

Survey participants were asked to predict the movement of foundry wafer prices over the next four months for 0.5-, 0.35-, and 0.25-micron wafers. Table 6 summarizes the results of this polling. Prices 5 to 7.5 percent lower are expected by the time we survey again in October 1998. Since these rates of decline apply to a four-month period, the corresponding annual rates of decline would be about 14 to 21 percent.

It should be noted that since this poll was conducted, the oversupply in the foundry market has worsened. Excess capacity has been increasing for more than a year, and Dataquest's current analysis of foundry capacity and demand points to an "acute" oversupply condition with excess capacity in the range of 30 to 40 percent. Fab utilization rates of 70 percent or less have been reported, and dedicated foundries such as Taiwan Semiconductor Mfg. Co. and United Microelectronics Corporation have announced drastic cuts in their capital spending plans for the remainder of 1998 and 1999.

Table 6
Expected Change in Foundry Wafer Prices over the Next Four Months, Median Response (Percent)

	0.5 Micron	0.35 Micron	0.25 Micron
Buyers	-5.0	-7.5	-7.5
Sellers	-5.0	-5.0	-5.0
All	-5.0	-7.5	-7.5

Source: Dataquest (August 1998)

If Dataquest were to conduct this poll today, the consensus would probably be for prices even lower than shown in the above table. It is likely that the persistent and worsening oversupply in the foundry market will bring on another round of price-cutting as SCM suppliers scramble for market share. As we have seen before, prices for the leading-edge technologies of 0.35 and 0.25 micron will be affected the most because this area is where the competition is hottest and volumes are ramping quickly. Lagging technologies will also see price pressure, but to a lesser extent, and the underlying cost structure will provide some support.

Dataquest Perspective

With this latest survey, Dataquest now has almost three years of history tracking foundry wafer prices. During this period, the foundry market has followed the broader semiconductor industry, going from widespread capacity shortage and stable prices to acute oversupply and tumbling prices. Our last survey, in February 1998, showed prices falling at a slower rate, giving hope that the market may be entering a period of relative stability. Alas, recent news of precipitously falling utilization rates at the major dedicated foundries makes this speculation highly unlikely.

With SCM demand slowing as a result of the Asian economic slowdown and the related stagnation of the worldwide semiconductor market, and with excess foundry capacity running at 30 to 40 percent, conditions are ripe for another round of competitive price-cutting in the foundry market. The greatest price declines are likely to occur in the leading-edge technology categories. Despite two years of falling prices, 0.35-micron and 0.25-micron wafers are still selling at a substantial premium to the lagging technologies, and as production volumes continue to increase there will be more opportunity for price competition.

The good news for SCM suppliers is that, because of price elasticity, lower wafer prices are likely to stimulate demand. Low wafer prices, along with corporate restructuring among the major IDMs, could result in a renaissance of the fabless model as an army of furloughed IC designers band together to form new ventures and take advantage of an unprecedented supply of cheap foundry wafers in leading-edge technologies. Foundries may also see a surge in demand from IDMs as wafer prices become low enough to make outsourcing wafer fabrication a truly compelling cost reduction strategy.

Thus, although the foundries followed the industry into the current semiconductor slump, they may be the first to climb out.

For More Information...

Inquiry Hotline:	+1-408-468-8423
Via e-mail:	scndinquiry@dataquest.com
Via fax:	+1-408-954-1780
Dataquest Interactive:	http://www.dataquest.com

Perspective

Semiconductor Contract Manufacturing Services Worldwide

Market Analysis

SCM Market Structure Will Be Related to Chip Capacity Manufacturing Infrastructure

Abstract: *The development of the semiconductor contract manufacturing (SCM) market structure is and will continue to be directly related to the infrastructure for managing capacity generally in the semiconductor industry. In this article, we outline Dataquest's methodology for segmenting capacity and relate that methodology to Dataquest's expectations about how the foundry market will ultimately split along competitive lines.*
By Clark J. Fuhs

Background

The development of the semiconductor contract manufacturing (SCM) market structure is and will continue to be directly related to the infrastructure for managing capacity generally in the semiconductor industry. Over the last couple of years, the SCM markets that have garnered the most attention have been the leading-edge and mainstream markets, in which fabless companies and dedicated foundry suppliers have been dominant. However, this segment represents only one of four different silicon-based capacity segments of the semiconductor industry.

The Four Segments of Semiconductor Industry Capacity Infrastructure

In the early 1980s, logic and DRAM process flows were indistinguishable, and capacity in general throughout the industry was completely fungible. In order to understand how the SCM market segmentation is likely to develop, it is critical to understand how and why the semiconductor industry has segmented into four subsegments of capacity today. Each of these four subsegments has independent capacity supply-and-demand characteristics,

Dataquest

Program: Semiconductor Contract Manufacturing Services Worldwide
ProductCode: SCMS-WW-DP-9808
PublicationDate: August 24, 1998
Filing: Perspective
(For Cross-Technology, file in the Semiconductor Regional Markets and Manufacturing binder)

as well as barriers to entry or conversion that are typical. There is some interaction among the four subsegments; however, the nature of the barriers means that there is some time lag before interactive characteristics have an impact on capacity.

Leading-Edge and Mainstream Memory Capacity

When the subject of memory is raised, DRAM comes to mind first. Indeed, more than 80 percent of the industry's memory capacity is used to produce DRAM, and for at least the past 20 years, DRAM has been a key driver for process technology. In 1997, the mainstream linewidth for DRAM production was 0.4 to 0.45 micron, with leading-edge at 0.35 to 0.32 micron and new products announced at 0.25 micron. Deep-UV lithography is starting to be implemented for critical layers.

The process flow characteristics of DRAM today include three to four levels of polysilicon, but only two levels of metal. Unique to this class of capacity are the process flow and knowledge to make a storage capacitor. Process flows that are not typical include the widespread use of chemical-mechanical polish (CMP) and the process flow for creating a self-aligned silicide. Epitaxial silicon layers are also not typically used with DRAM.

The process flows included in this class of capacity for DRAM most directly match flash memory and other nonvolatile memory devices. SRAMs can also be easily built using the process flow ingredients noted for this capacity class. However, without the self-aligned silicide flow to increase speed by means of a local interconnect, the SRAMs built in this type of fab would generally be limited to the commodity or slower SRAM markets.

Memory capacity fluctuates between 30 and 50 percent of the capital spending dollar, but averages about 40 percent overall. At the end of 1997, the memory class of capacity represented about 25 percent of overall worldwide silicon consumption, and about 60 percent of capacity at below 0.5 micron.

Fabs in other capacity classes would have to add capital in order to align with leading-edge linewidths and would have to include capability for the unique storage capacitor and additional polysilicon levels in order to produce and compete effectively in the memory markets. This production market is one of the easier leading-edge areas to enter because the technology is well understood and easily purchased. Therefore, barriers to entry are essentially limited to the availability of adequate capital.

Leading-Edge and Mainstream Logic Capacity

The leading-edge and mainstream logic capacity class has perhaps the broadest range of product classes that can be manufactured. For this reason, analysis of supply and demand for individual types of products is not a practical exercise. In 1997, the mainstream linewidth for logic production was 0.45 to 0.55 micron, with leading-edge at 0.35 to 0.32 micron and new products announced at 0.25 micron. This linewidth range is nearly identical to the memory class, with the exception that the mainstream lags slightly.

Deep-UV lithography is starting to be implemented for critical layers and at 0.25 micron could represent roughly 40 to 50 percent of the mask layers.

The process flow characteristics of mainstream and leading-edge logic include two levels of polysilicon and three-to-six levels of metal. Process flows that typically exist in this class of capacity are the widespread use of CMP, the process flow for creating a self-aligned silicide, and experience with the use of epitaxial silicon layers. Trench isolation techniques and process flows are starting to be required at the 0.25-micron level. The process flow and knowledge to make a storage capacitor have not typically existed in this class of fab capacity.

Virtually any kind of advanced logic or ASIC product can be manufactured in this kind of capacity. It is the capacity generally found within the dedicated foundry market today, primarily because the customer base of fabless companies competes in this product class. SRAMs can also be built using the process flow ingredients noted for this capacity class. Because of the existence of the self-aligned silicide flow to increase speed by means of a local interconnect, the SRAMs built in this type of fab would generally be for the fast SRAM markets.

Advanced microprocessors (MPUs) also can be produced in this class of capacity. Although this representation is simplistic, from a manufacturing perspective the MPU is really a collection of memory cells and wiring. During the mid-1980s, both Intel Corporation and Motorola Incorporated migrated the memory cells to the SRAM design, away from the DRAM cell, in order to increase processing speed. The increased area for an SRAM cell is not a large concern in MPU design. What emerged from these efforts is the fast SRAM market, where Motorola has been one of the key leaders.

Leading-edge logic capacity also fluctuates between 40 and 60 percent of the capital spending dollar (depending upon the DRAM investment cycle), but in raw dollar terms is fairly stable and countercyclical, averaging about 50 percent overall. At the end of 1997, the advanced/mainstream logic class of capacity represents about 34 percent of overall worldwide silicon consumption and also about 35 percent of capacity at below 0.5 micron.

Fabs in other capacity classes would have to add capital in order to align with leading-edge linewidths, and to include capability for the unique self-aligned silicide process, as well as additional metal levels and CMP, in order to produce and compete effectively in the advanced logic markets. This production market is one of the more difficult to enter, because the technology is specialized and not easily purchased. Therefore, barriers to entry are high, but they can be hurdled if adequate capital and a technology partner or internal development are available. There is normally a significant time lag for this kind of conversion.

Lagging-Edge Technology Capacity and Product Segments

The lagging-edge capacity class also has a broad range of product classes that can be manufactured. In 1997, the mainstream linewidth for lagging product production was 0.7 to 0.9 micron (but could be as high as 1.2 micron), with leading-edge at 0.55 to 0.6 micron, and new products announced at 0.45

micron. The lithography to be employed is generally a mix of g-line and i-line.

The process flow characteristics of lagging-edge logic include one or two levels of polysilicon and two levels of metal. The process flow and knowledge to make a storage capacitor have not typically existed in this class of fab capacity. Process flows that are not typically included are any use of CMP and the process flow for creating a self-aligned silicide. Epitaxial silicon layers are also not typically used. The storage capacitor process flow could be but typically is not used in this class of capacity.

The types of products that make up the bulk of this capacity class are analog, mixed-signal analog, optoelectronics, and some low-end logic products, along with microcontrollers and older memory generations.

Lagging-edge capacity represents only 5 to 7 percent of the capital spending dollar. At the end of 1997, the lagging-edge class of capacity represents about 17 percent of overall worldwide silicon consumption, but only about 5 percent of capacity at below 0.5 micron and only the most advanced mixed signal capability.

Capacity additions are required for this class of capacity over time because the set of products is in a growing market, but the way capacity is added is quite different from the approach used for leading-edge and mainstream products. Since the revenue generated per square inch of silicon for lagging-edge products is only 35 to 50 percent of that for leading-edge and mainstream products, suppliers cannot afford to spend much on manufacturing facilities to maintain profitability. Therefore, suppliers rely heavily on the used equipment market when adding new capacity. The other way capacity is added to this segment is by means of "trickle-down" from older memory capacity, typically from the DRAM area. For example, most of the 0.5- to 0.6-micron capacity available now in Japan and Korea in this segment was producing 4Mb DRAMs in 1995.

Fabs in the leading-edge capacity classes would not have to add capital in order to migrate capacity to this segment, and thus manufacturing barriers to entry are not high. However, some product design barriers may exist, particularly in the area of analog and mixed-signal products, which may mean some delay in employing excess capacity. Also, the use of leading-edge capacity to produce lagging-edge products is not favored because the capital investment would be dramatically underutilized, producing lower revenue per square inch of product.

Senior Technology Capacity and Product Segments

The senior technology capacity class has a relatively narrow range of product classes that can be manufactured, almost all of which are in the power and discrete areas. In 1997, the mainstream linewidth for senior technology production was 1.2 to 10.0 microns, with leading-edge products at 0.9 to 1.0 micron and new products announced at 0.8 micron. The lithography to be employed is generally a mix of g-line steppers and projection aligners.

The process flow characteristics of senior technology are unique, including maybe one level of polysilicon and one level of aluminum metal on the front side, with backside metallization schemes that may include alloys of nickel or chromium. The process flow and knowledge to make a power or discrete device are very specialized, including knowledge of how to handle very heavily doped boron, arsenic, or antimony substrates, with epitaxial silicon thicknesses ranging from 10 to 250 microns. Leading-edge logic epitaxial silicon is typically 5 to 8 microns thick. Specialized deep diffusion processes are also part of the process flow.

The type of products that make up the bulk of this capacity class are bipolar power transistors, power MOSFETs, insulated gate bipolar transistors (IGBTs), power diodes, thyristors, small signal diodes, and smart power devices.

Senior technology capacity represents only 2 to 4 percent of the capital spending dollar. At the end of 1997, the senior technology class of capacity represents about 24 percent of overall worldwide silicon consumption (more than the lagging technology segment) and none of the capacity below 0.5 micron.

Capacity additions are required for this class of capacity over time, because the set of products is in a growing market, but the way capacity is added is different from the approaches used for other classes. Since the revenue generated per square inch of silicon is below even the lagging-edge capacity class, suppliers cannot afford to spend much on manufacturing facilities to maintain profitability. Therefore, the used equipment market is relied on almost exclusively for adding new capacity. Capacity additions by way of "trickle-down" are also not typical, as the process flow requirements are so vastly different. Most new capacity is added by companies that are already participating in the product markets.

Fabs in other capacity classes would have to add significant capital in order to align with capability for the unique process flow requirements, and additional equipment and specialties to produce and compete effectively in the power and discrete markets. There is also a product design barrier, which may mean some delay in employing excess capacity. Therefore the barriers to entry in this capacity class are actually quite high.

SCM Infrastructure Development Issues by Capacity Segment

SCM market segmentation is developing along the four major capacity classes, with only minimal competitive overlap. In the SCM market, each of these four subsegments is expected to have independent capacity supply-and-demand characteristics, as well as barriers to entry or conversion that are typical.

How SCM suppliers compete in these areas depends as much on the servicing needs of the varying customer types as it does on product and process technology differences. There are dedicated foundries in three of the four segments, yet these dedicated foundries do not necessarily compete with one another. Let's take a quick look at how these segments of the market are different from the customer base perspective for SCM suppliers.

Leading-Edge and Mainstream Memory Capacity

The primary customer base for the leading-edge and mainstream class of capacity are DRAM integrated device manufacturers (IDMs), and only a very small part of the customer base are fabless companies. The IDM customer is usually the source of the process technology, and the most common strategy emerging today is to lower the capital investment risk by forming joint venture relationships with smaller companies that also market DRAMs.

As a result, the typical relationship is exclusive and longer-term. Examples are LG Semicon Co. Ltd. as a supplier to Hitachi Ltd., Powerchip Semiconductor Corp. as a supplier to Mitsubishi, and Winbond Electronics Corporation as a future supplier to Toshiba Corporation. Another portion of the market includes customer-supplier relationships that are not exclusive. An example is Siemens' purchase of capacity from the dedicated foundry market during periods of tight capacity in 1995.

Analysis of supply and demand in this segment correlates strongly with the overall picture of supply and demand in the DRAM industry. This level of business is also highly volatile, as IDMs tend to pull production back internally during times of oversupply.

There are no known dedicated foundries exclusively in this class of capacity, although the leading-edge dedicated foundries, such as Taiwan Semiconductor Mfg. Co., United Microelectronics Corporation, and Chartered Semiconductor Manufacturing Pte. Ltd., have taken on small amounts of memory product production. This segment is serviced primarily by IDM suppliers and will likely continue to be over the long term. However, we do expect many new players and changing strategies over the coming three to five years as traditional DRAM suppliers adopt more diversified product strategies.

Leading-Edge and Mainstream Logic Capacity

Because the leading-edge and mainstream logic capacity class contains the broadest range of product classes and market opportunities, the customer base has been primarily the fabless company. IDMs are starting to increase their use of SCM suppliers in this segment for two primary reasons.

First, the critical size of an IDM required to maintain and build leading-edge capacity is increasing dramatically with the cost of a typical fab. Therefore, medium-size IDMs (for example, VLSI Technology Inc.) are increasing their use of outside production sources to supplement their internal production in a strategic fashion. Ultimately, it is Dataquest's belief that these medium-size IDMs will eventually migrate to a fabless model and that they will be a major reason for dramatic growth in the fabless component of the semiconductor market over the next 10 to 15 years.

Second, small to medium-size companies that have not generally competed in the leading-edge or mainstream logic markets are utilizing outside capacity to develop new products. An example of such a company is Analog Devices Inc. These IDMs may or may not add internal capacity as these products achieve success.

The large IDMs, such as Motorola, National Semiconductor Corporation, and others, do not typically use outside sources to supplement capacity in this segment, as they generally wish to produce their advanced products internally for competitive reasons. However, such companies may outsource leading-edge products in a strategy to evolve into a fabless model.

Analysis of supply and demand in this segment for SCM can be isolated since the supply base is primarily the dedicated foundry, and the primary demand base is the fabless company. The leading-edge foundries and the majority of dedicated foundries, such as TSMC, UMC, and Chartered, are in this class of capacity.

A limited number of IDMs, such as IBM, Seiko Epson Corporation's S-MOS Systems, Sharp Electronics Corporation, and LG Semicon, have successfully penetrated the SCM market in this capacity segment, and a limited number of IDMs are currently using outside production sources in this capacity segment. Because of the small number in each case, the supply/demand analysis can be performed with a bottom-up methodology. Pricing studies also are highly reliable in indicating changes in supply and demand in this segment, as the wafers can be specified by the process flow and linewidth requirements.

Lagging-Edge Technology Capacity and Product Segments

The lagging-edge technology capacity class is probably the most elusive of the segments to characterize properly. Although some fabless companies have requirements in this capacity class, the primary customer base is the IDM company.

The large IDMs, such as Motorola, National Semiconductor, IBM, STMicroelectronics, and others, typically use outside sources to supplement capacity in this segment, as they off-load older products to contract manufacturers, while upgrading internal capacity in order to produce their advanced products internally. Large IDMs follow this strategy partly for competitive reasons, but also as an efficient use of capital spending. Upgrading a current fab is much less expensive than building a greenfield fab, because a large portion of already installed equipment can be directly applied to the subsequent generation. Mixed-signal and analog producers such as Unitrode Corporation or Allegro MicroSystems Inc. also supplement their capacity needs through the lagging SCM market.

Analysis of supply and demand in this segment for SCM has been hard to isolate because the supply base is primarily the IDM foundry and the primary demand base is other IDMs. Our conclusion, that the primary supply base is the IDM in this segment, may surprise many, as only a few have high profiles (such as American Micronics Inc. and Rohm Company Ltd.) and the dedicated foundries Newport Wafer-Fab Ltd. and Tower Semiconductor Ltd. have been growing rapidly. UMC also participates in this segment with their older fab. However, two factors support the conclusion that IDM suppliers have a larger share.

First, the internal or regionally "captive" Japanese market has been primarily focused in this segment of capacity. However, this concentration has decreased in the last couple of years, in part because of the general overcapacity of older 4Mb DRAM fabs. This internal market provides an IDM supply base to this segment.

Second, when Dataquest initiated the study of the SCM market in 1995, our survey of IDM customers informed us that 40 to 50 fabs in the world supplied SCM services in this segment of the market, and only a few were dedicated.

Ideally, a supply/demand analysis could be performed with a bottom-up methodology for this segment, and to date Dataquest has not developed adequate information as a basis for such analysis. We have begun the process recently, and hope to have a better handle on this area in the near future. In the meantime, pricing studies appear to be highly reliable in indicating supply/demand changes in this segment, as the wafers can be specified by linewidth requirements. Factory utilization rates at the dedicated foundries can also indicate changes. In the 0.6-to-1.0-micron category, prices have been declining at a much reduced pace, indicating that demand is approaching supply levels. However, the recent semiconductor downturn has stopped this trend temporarily. There are still new entrants in this segment, as the recent announcement by Texas Instruments Inc./Acer demonstrates, and we would expect a couple more new entrants in the near future.

Senior Technology Capacity and Product Segments

The senior technology capacity class is also a segment that has been difficult to characterize properly, although from the SCM market perspective this class still remains fairly small. The customer base has been exclusively IDM companies, which look to this segment as a way to supplement capacity and capital risk. International Rectifier Corporation and Philips Semiconductors Inc. are two examples.

The SCM supply base in this segment is relatively small as well, with the only dedicated foundry being Advanced Semiconductor Manufacturing Corporation of Shanghai. There are a couple of IDMs that could supply or have supplied this part of the market as well, such as Samsung Semiconductor and Delco Electronics.

Analysis of supply and demand in this segment for SCM could be relatively straightforward to isolate using a bottom-up approach, as the supply-and-demand bases are fairly narrow. However, Dataquest has yet to focus on this aspect of the SCM market and is not currently surveying for prices above 1.0 micron.

Furthermore, the barriers to entry in this capacity segment are quite high because of the specialized process flows, so new entrants are likely to be technology partnerships. We have seen no evidence of new entrants in the last year or so; however, the current base of suppliers is growing rapidly and likely gaining penetration of the overall market for this segment.

Dataquest Perspective

The SCM market structure is developing along lines of capacity segments that already exist in the semiconductor manufacturing infrastructure. There are four identifiable capacity segments, each with its own supply-and-demand characteristics and supplier and customer strategies.

Market research to date has been focusing on the leading-edge and mainstream capacity areas and likely has understated the current demand and market size for the lagging and senior technology segments. Although these segments are likely smaller in revenue terms than the leading-edge market, the two nonleading categories represent a combined 42 percent of the silicon consumed in the world and are growing markets. As the primary customers for these two segments are IDMs, we see that the overall IDM demand for SCM services will continue to grow at a healthy rate.

Perspective

Semiconductor Contract Manufacturing Services Worldwide

Market Analysis

A Changing Landscape for the Japanese Foundry Business

Abstract: *This Perspective analyzes foundry business trends for Japanese semiconductor companies on the basis of Dataquest's latest foundry shipments survey results. The prolonged recession of the Japanese semiconductor market increases the capital investment burden, and alliances are needed to build the ability to produce system LSIs—the wave of the future. In the changing environment, foundry business plays a much different, increasingly active role in the industry. Foundry business is gaining new meaning for Japanese semiconductor manufacturers, which are becoming foundry users themselves rather than foundry providers as in the past.*

By Yoshihiro Shimada

Start of Dataquest's Official Foundry Survey

Dataquest has been tracking semiconductor companies' brand shipment revenue trends in the annual market share survey. In 1997, we added a new item, foundry shipments and purchase, covering gross revenue from foundry business, as well as users and technology trends. Since foundry demand is continuously on the rise, the new survey focus is designed to shed light on this demand from the foundry company's perspectives and analyze the overall impact of foundry business on the semiconductor industry.

Most Japanese semiconductor companies have their own fabs and are generally referred to as integrated device manufacturers (IDMs). Japanese IDMs characteristically ramped new fabs producing the most advanced DRAMs, and as new fabs with more advanced technology are built, the old fabs are converted to produce other devices, including MOS logic, MOS microcomponents, and later, even analog. This has been regarded as the most efficient method of fab utilization and has actually been the most typical method. This traditional conversion cycle, however, has been changing recently. Instead of converting DRAM fabs to production of other

Dataquest

Program: Semiconductor Contract Manufacturing Services Worldwide
Product Code: SCMS-WW-DP-9807
Publication Date: June 29, 1998
Filing: Perspective
(For Cross-Technology, file in the Semiconductor Regional Markets and Manufacturing binder)

devices, companies are required to build new fabs with logic capabilities. The change is partially driven by the notable success of dedicated foundry providers led by Taiwan Semiconductor Manufacturing Company (TSMC), together with the high profitability they have demonstrated.

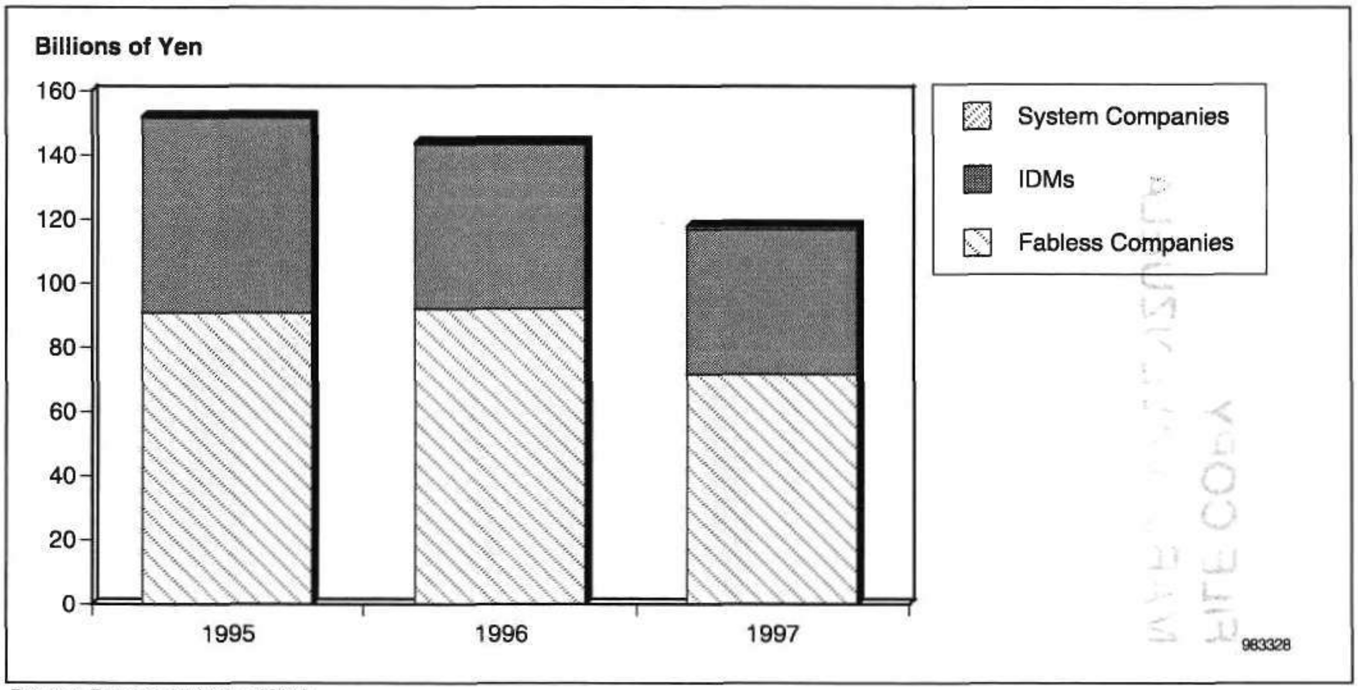
Foundry production as referred to throughout this Perspective includes the OEM production observed among Japanese and Korean companies.

Declining Foundry Shipments from Japan

In the 1997 semiconductor brand shipments ranking, Japanese companies again lost share in the worldwide market. At the same time, their total foundry shipments declined while the worldwide foundry market was expanding (see Figure 1). This makes a sharp contrast to the increasing commitment by Japanese semiconductor companies to foundry business. To put it simply, their decision came long after that of their competitors, especially dedicated foundry providers in Taiwan, who established technical leadership and developed close relationships with U.S. fabless companies.

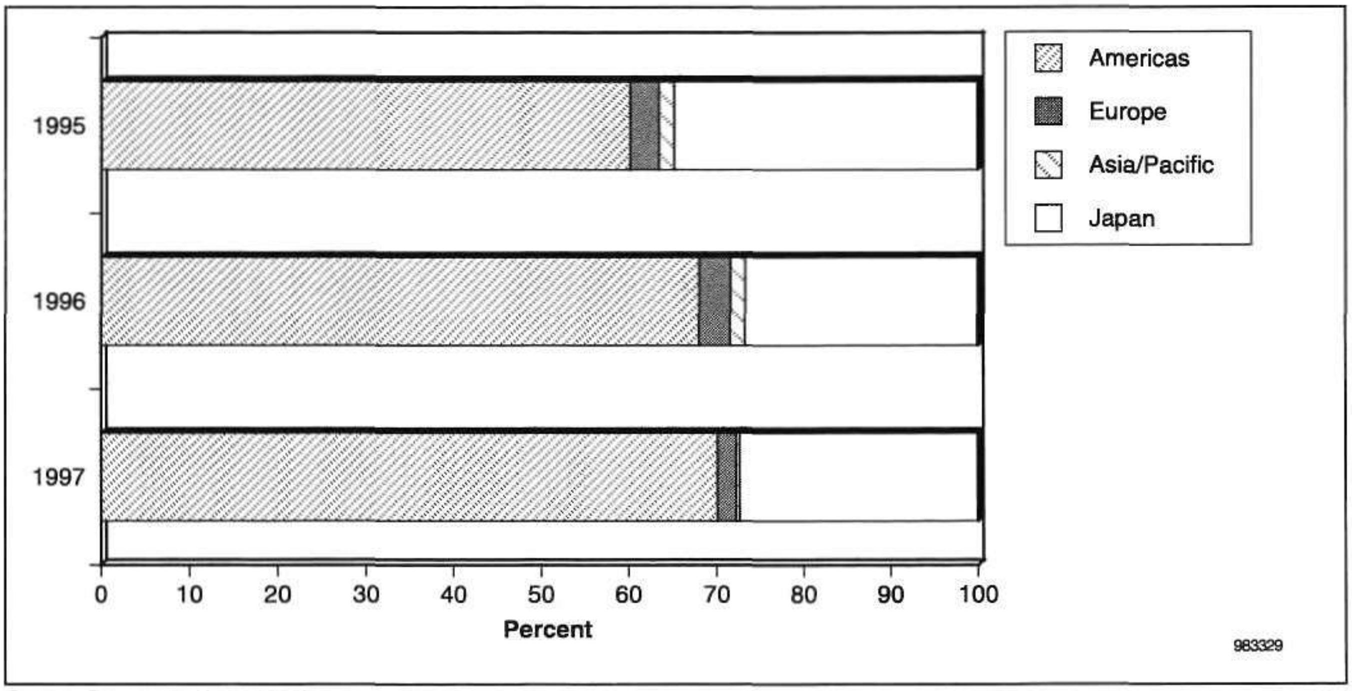
A major destination of foundry shipments by Japanese companies is the Americas market, which accounts for 70 percent of the total (see Figure 2). While the share of the Americas region has been on the rise since 1995, the absolute figure shows slight declines. This reduction in shipments comes mainly from reduced foundry business with U.S. fabless companies. At the same time, the value of shipments to the Japanese market has been declining, which reflects not only sluggish foundry contracts among Japanese companies, but also a decline in domestic delivery to foreign foundry users.

Figure 1
Japanese Companies' Foundry Shipments by User Type



Source: Dataquest (June 1998)

Figure 2
Japanese Companies' Foundry Shipments by Destination



Source: Dataquest (June 1998)

The downward trends are clearly evident in an analysis of revenue by product. The market share of logic and microcomponents, which accounts for a major portion of foundry shipments to Americas fabless companies, has dropped significantly compared to two years ago (see Figure 3). Instead, flash memory foundry has increased, with shipments from Japanese companies such as Sharp Electronics Corporation and SANYO Electric Company Ltd. to U.S. partners.

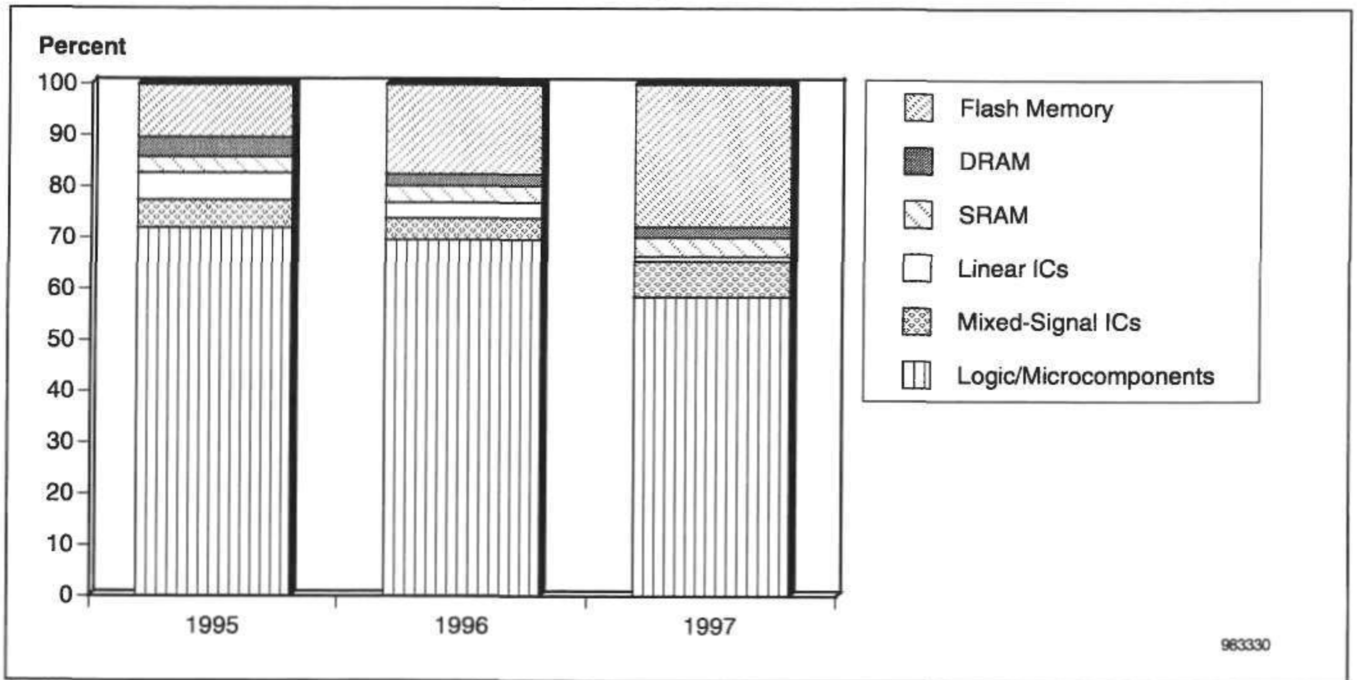
Technology trends are visible in the change in share by wafer size, down for 150mm and up for 200mm (see Figure 4). The major reasons for these changes include the following, given that 200mm fabs:

- Account for a large chunk of excess capacity because they were built during the previous boom
- Need to be operated to their capacity to vie effectively for the increasingly competitive foundry business
- Are more advanced than their 150mm counterparts in terms of design rule

The third point is substantiated by the fact that 0.5-to-0.8-micron processes using 150mm wafers lost share, while 0.5-micron or finer processes, which can be translated to 200mm fab technology, have gained sharply (see Figure 5). Finally, products with one to two metal layers lost share, while three-layer designs grew to 17 percent of the total in 1997. No contract has been won for four or more layers (see Figure 6).

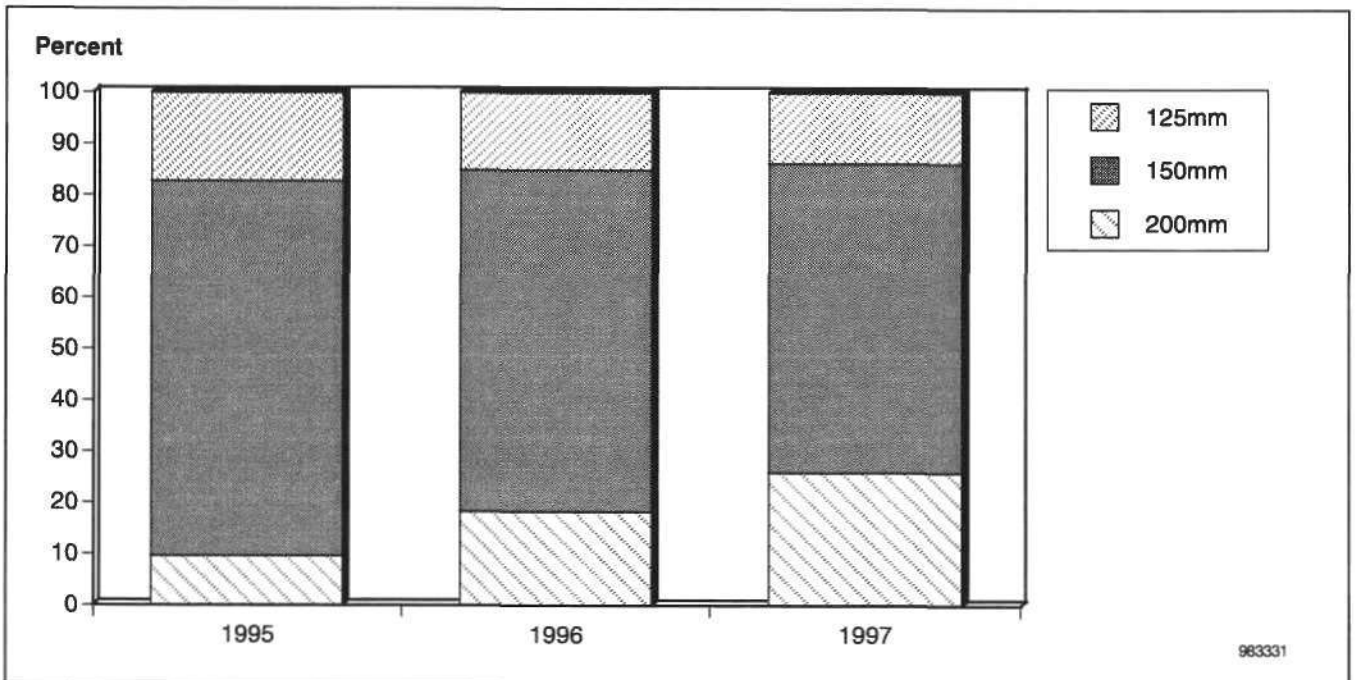
These technology trends suggest that Japanese foundries are focusing on higher capacity utilization for 200mm fabs, while they still have to establish capabilities to support U.S. fabless companies.

Figure 3
Japanese Companies' Foundry Shipments by Product



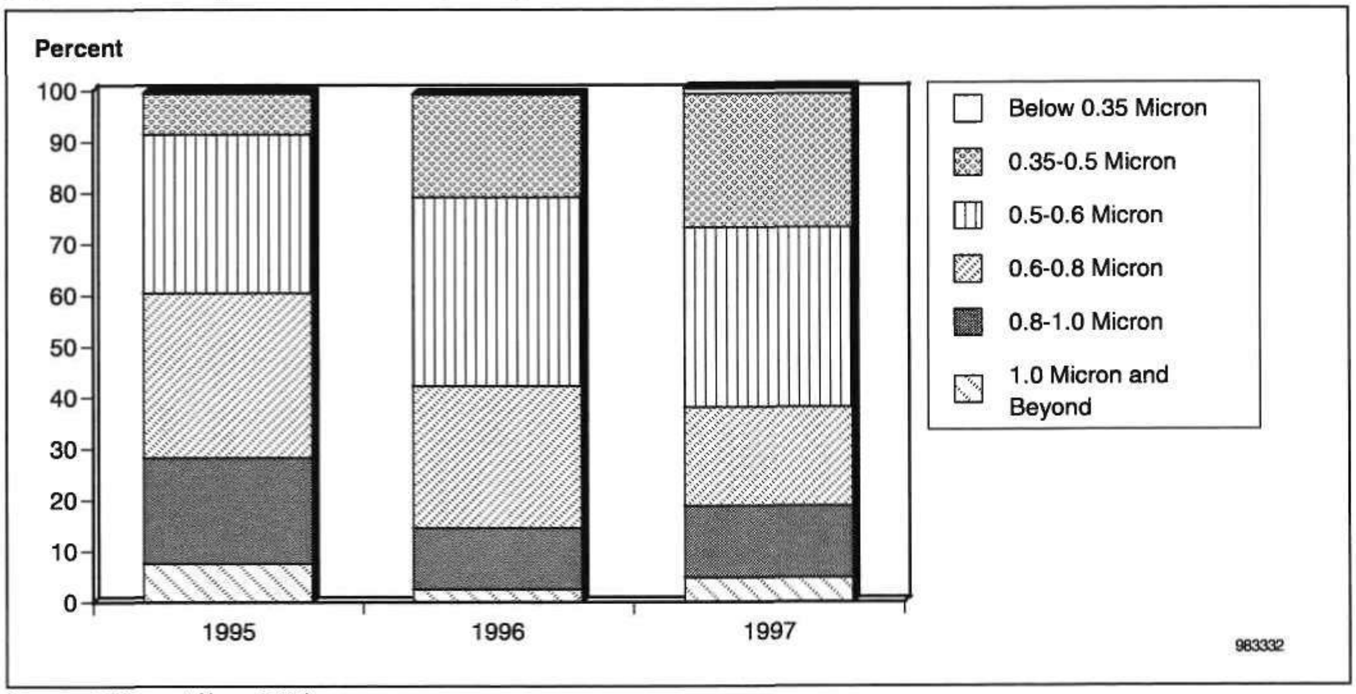
Source: Dataquest (June 1998)

Figure 4
Japanese Companies' Foundry Shipments by Wafer Size



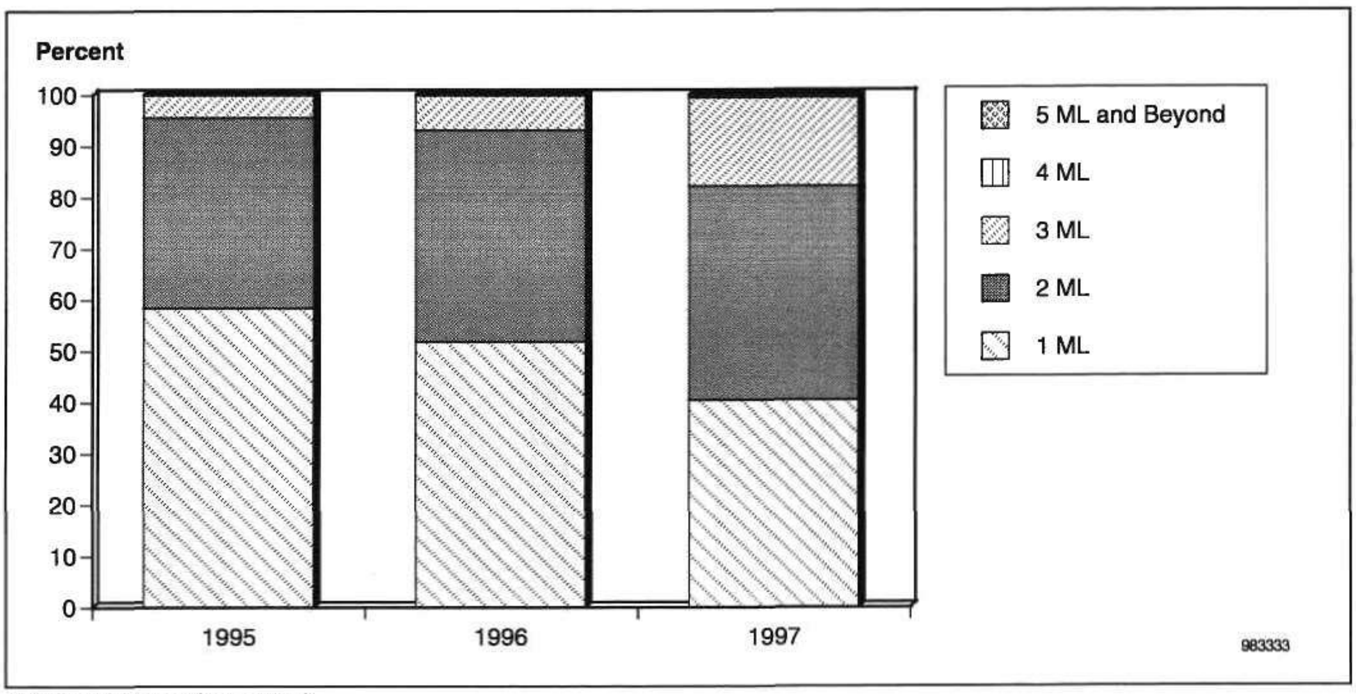
Source: Dataquest (June 1998)

Figure 5
Japanese Companies' Foundry Shipments by Geometry



Source: Dataquest (June 1998)

Figure 6
Japanese Companies' Foundry Shipments by Metal Layer



Source: Dataquest (June 1998)

Foundry Orders on the Rise

Showing a clear contrast to declining foundry shipments, foundry orders by Japanese companies have been increasing steadily, although their worldwide share is still fairly small. While Japanese IDMs have not yet utilized their DRAM capacity fully, their logic fabs are not meeting customer demand, either in volume capacity or in technological capability. Rather than converting memory fabs to logic, which requires additional capital spending, Japanese IDMs are trying to leverage the low production cost of dedicated foundry providers. Alliances and foundry deals involving Japanese companies can be classified into the following models.

Evolution from Joint Development to Foundry Production

Primary examples are Sharp, producing flash memory for Intel Corporation, and Hitachi Ltd. and Mitsubishi Corporation, which share development and production efforts for their own brands of flash products. The intent is to reduce the R&D burdens on circuit design, process technology development, and product planning, while optimizing a production system where partners are responsible for production resources that they can provide with a comparative advantage.

Generally, the manufacture of a product developed by a partner leaves a foundry (an OEM) with relatively little value added. Still, the foundry provider can benefit by gaining experience with a product that it would be difficult to develop or market on its own, not to mention the infusion of new technology, which may enable it to develop proprietary products. This type of partnership can be mutually beneficial as long as each partner has a key technology to license. By sharing the development process from the outset, the production process can be made more reliable. At the same time, it allows the partners to maximize flexibility and efficiency in marketing their own products.

Capacity Supplementation

Traditionally, Japanese companies have seen foundry contracts as a means of using their excess capacities and keeping fabs highly utilized. In particular, when companies are hit by recession just as fabs invested in during a booming market come on line, foundry use is considered to be the "last resort" to avoid idling capacities. Companies often accept orders that are far below the ordinary break-even point for brand shipments.

Foundry deals in the form of such capacity supplementation are typically limited to a specific period, especially in the case of an IDM, that is, until the IDM's own fab is ready for start-up. In the case of an OEM deal, foundry production may be a temporary relief for the customer until it has the ability to develop and manufacture its own products. On the other hand, the OEM may rely on the foundry deal as a strategic instrument that effectively prevents the manufacturer from making inroads into the market.

At present, Japanese companies that order foundry production to supplement their capacities are primarily doing so in the DRAM field, such as Hitachi/LG Semicon, Fujitsu/TSMC, and Toshiba/Winbond Electronics.

The Hitachi/LG Semicon deal is unique in that the two companies—major players in the DRAM market with their own established brands—have entered an alliance in the form of a joint production arrangement. Hitachi also maintains a long-term relationship with Texas Instruments Inc. and operates diverse DRAM processes. This framework allows Hitachi to disperse burdens and risks related to product development and manufacture, but at the same time, Hitachi has presumably been loaded with the management of those diversified masks and processes. For LG Semicon Co. Ltd., the alliance is intended to ensure a jump-start of its new business thrust by leveraging technology and production capacities.

The other two deals differ from that of Hitachi and LG Semicon. TSMC and Winbond Electronics Corporation do not intend the first step of entering the DRAM market for foundries. The decision by TSMC to start a DRAM foundry with Fujitsu seems to represent a point of confluence for TSMC's strategy to establish "0.35-micron and beyond DRAM cell" technology, which was included in its technology road map. On the other hand, Fujitsu intends to disperse risks related to capital spending. These two companies' strategies match, which has led to their foundry deal. The Toshiba/Winbond alliance, which follows a similar pattern to the TSMC case, is characterized as part of their broader partnership, including LCDs.

Strategic Alliance

The Toshiba/Motorola alliance has served as a model for a constructive relationship between Japanese and U.S. semiconductor industries facing much-publicized trade friction. This broad-based, long-term (seven-year) relationship embraced a number of models and paved the way for a myriad of subsequent alliances. Among these were joint product development initiatives uniting the strengths of the partners, committed assistance in increased access to the Japanese market, wafer fab production at a joint venture (for instance, Tohoku Semiconductor), and factory-based collaboration in production efforts.

Nevertheless, the relationship seems to have matured to a stage requiring redefinition as the Japanese semiconductor market is losing its attractiveness in the global context and semiconductor production in the country is waning in terms of comparative advantage. The Hitachi/TI alliance faces a similar situation. Under the long-term relationship, the two companies chose a U.S. joint venture rather than a foundry contract. However, the joint venture was discontinued this March. In this sense, foundry is becoming a less desirable option for IDMs, which have traditionally used it as part of a strategic alliance. Foundry business itself increasingly makes sense on the basis of its flexible, low-cost production.

Evolution from Joint Production

Mitsubishi Electric Corporation has established Powerchip Semiconductor Corporation with UMAX Group of Taiwan to reduce financial burdens from capital spending, use the Taiwan semiconductor industry and its increasingly credible resources, and explore a new DRAM user (since UMAX is a PC motherboard manufacturer). The deal includes a new attempt to reduce the workload for marketing efforts through the joint venture, as opposed to the traditional approach that foundries are solely responsible for production. Powerchip is authorized to ship its own products in excess of a certain production level under its own brand. If this happens, shipments to Mitsubishi Electric will be on a partial foundry basis that goes beyond the traditional, narrow definition.

The Powerchip case relied on UMAX's high expectations for profits from the booming DRAM business as well as Mitsubishi's expectation of securing users for its products. In this sense, this type of alliance cannot be positioned as a general model. Nevertheless, it certainly suggests one of the feasible directions for the industry, which is seeking a way to reduce capital investment requirements by leveraging the technological prowess of each company.

This categorization seems to depict, among other things, the versatile roles of Taiwan companies. Backed by rich financial resources, they have successfully developed semiconductor production into the broad relationships shown here. Japanese PC manufacturers have accelerated procurement from Taiwan companies on an OEM basis since the mid-1990s. The viability of these complementary roles is based on the fact that semiconductor companies in the two countries are both primarily vertically integrated electronics manufacturers. This long-term relationship seems to lay the foundation for diverse alliances in semiconductor production and can serve as the core of a strategy.

Dataquest Perspective

Japanese semiconductor companies largely assume foundry business to be less than profitable, which clearly reflects the "opportunistic" nature of the Japanese foundry business model. Foundry business is forced to assume this less-than-exalted position for several reasons. First, obsolete fabs, rather than leading-edge ones, are used for foundry. Second, the primary purpose of foundry production lies in maximizing utilization. Finally, foundry production is considered a part of complementary or diverse alliances between IDMs. However, with the emergence of TSMC, which has proven the high profitability of the dedicated foundry business, Japanese companies are looking for opportunities to improve the profitability of their own foundry contracts. Many are expecting foundry deals to fill a growing gap between demand and supply capacity stemming from the prolonged recession of the semiconductor market. However, this expectation is no longer feasible, as evidenced by declining foundry revenue. Clearly, the tide has turned. The foundry market continues to establish itself by offering lucrative opportunities for specialized manufacturers. It cannot be viewed as the last resort for IDMs to replenish idling capacities.

Dr. Morris Chang of TSMC, in his recent speech at Dataquest's Semiconductor Conference 98, stated, "It is not correct to think of foundry as a manufacturing issue. Rather, foundry is a service business, and without that notion, you cannot be successful in the business." Foundry service as a reliable and viable business becomes feasible only when there is no need for the manufacturer to adjust a process conflict with its own products, which strongly suggests the need for the specialized company.

For dedicated foundry providers, Japanese semiconductor companies can be primary customers because of their broad product lines and business structure, which require ever-growing capital spending. The benefits they offer, that is, elimination of the need for capital investment, including broad process development and optimization toward volume production, are highly attractive for Japanese companies. Not many Japanese companies, however, have a clear, corporatewide foundry strategy; only a handful of them are prepared to deploy foundry business by keeping the optimum balance with brand businesses. What Japanese companies need is to establish core competence in the semiconductor business, which entails a redefinition of "strategic domains" in many cases. Dataquest believes that it is increasingly becoming a critical management issue for Japanese companies to utilize foundry providers (especially Taiwanese companies) effectively as an integral part of the redefinition process.

Perspective

Semiconductor Contract Manufacturing Services Worldwide

Technology Analysis

Flash Fab Capacity Explosion Continues

Abstract: *The flash memory market has expanded rapidly and is expected to continue its ascent in the future. But pricing collapsed in 1997 because significant new fab capacity came on line. This Perspective gives insight into the existing and anticipated flash memory chip manufacturing capability of flash industry leaders.*
By Bruce Bonner and James Hines

The Flash Market Takes Off

The flash market is exploding. The growth of bits and units continues unabated, and factories somewhere, someplace, are producing this deluge of chips. The five-year compound annual growth rate (CAGR) of bits through 1997 was an incredible 150 percent, and bit growth is expected to expand at a five-year rate of nearly 65 percent through 2002. Part of this increase in the supply base is due to major players adding capacity, but much of it comes from new companies entering the market or from companies that had been just dabbling getting serious and putting substantial capability in place. The massive amount of flash available has, in turn, encouraged designers to use flash more and more, ensuring this cycle will continue for the foreseeable future.

The one downside to this expanding flash universe is that supply now exceeds demand, depressing prices and slowing market revenue growth. In fact, in spite of a 119 percent growth of bits in 1997, industry revenue was essentially the same as in 1996, indicating a price plunge of more than 50 percent for the year.

The manufacture of flash memory devices involves special processing requirements that differ from those of conventional MOS digital logic and other memory devices. The flash memory cell employs a floating polysilicon

Dataquest
Program: Semiconductor Contract Manufacturing Services Worldwide
Product Code: SCMS-WW-DP-9806
Publication Date: June 15, 1998
Filing: Perspective
(For Cross-Technology, file in the Semiconductor Regional Markets and Manufacturing binder)

gate structure similar to those found in EPROM and EEPROM devices. The cell functions by storing a bit in the form of an electrical charge on the floating gate, and it is erased by removing the charge from the floating gate. In the case of a flash memory device, this is accomplished by taking advantage of a phenomenon known as "tunneling," whereby electrons can be made to travel from a polysilicon electrode through silicon dioxide, which is normally an effective insulator. This method of cell erasure is highly dependent on the quality of the silicon dioxide and the surface morphology of the polysilicon floating gate. The manufacturer must possess the process expertise to form this structure with the material characteristics that allow the device to function as designed.

The flash memory process flow differs from that of most MOS logic processes in that it has fewer levels of metal interconnect but more levels of polysilicon. Typically, flash memory designs employ two to three polysilicon levels and one to two metal levels, while logic designs often have a single level of polysilicon and as many as four or five metal levels. By this criterion, the flash memory process is more like the DRAM process. The average logic fab would not have the right equipment mix to produce flash memories cost-effectively. A DRAM fab would be a better match in terms of the equipment set, but the fab would also need flash process expertise.

The effect of this is that there are relatively few fabs in the world that can make high-quality flash, in high volume, for a low cost. Also, higher density tends to separate the haves from the have-nots, because defect density affects yield exponentially relative to die size.

This document is a summary of the largest flash manufacturers both in market share, as shown in Table 1, and capacity. One of the challenges of determining worldwide flash capacity is that second-tier manufacturers do not have dedicated fabs for flash; they combine it with other nonvolatile memories, such as EPROM or EEPROM and, in some cases, embedded microcontrollers. Thus, adding up the overall capacity of fabs *capable* of running flash wafers produces a deceptively high total. Real capacity is much lower and can be shifted to other products as the need arises.

Intel

Intel Corporation is the largest vendor of flash memory, holding the No. 1 spot with estimated revenue of $850 million, a 31 percent market share. The amazing thing about this achievement is that it was accomplished largely with non-Intel fab capacity. First, NPNX Corporation produced 8Mb devices, then Intel entered into a technology and factory agreement with Sharp Electronics Corporation and let the NPNX link die. These outside resources were key because, at that time, Intel was processor-centric and did want to invest in flash. When the flash market expanded and Intel decided not to put all its eggs into one basket, Fab 7 at Rio Rancho, near Albuquerque, New Mexico, began to see significant investment and conversion from logic products. It is now used exclusively for flash memory production. Fab 7 is a 6-inch line, with an estimated capacity of 35,000 wafer starts per month.

Table 1
Top 10 Worldwide Companies' Vendor Revenue from Shipments of Flash Memory Worldwide (Millions of U.S. Dollars)

Rank	Company	1996 Revenue	1997 Revenue	Percentage Change	1997 Market Share (%)
1	Intel	950	850	-10.5	30.6
2	Advanced Micro Devices	542	613	13.1	22.1
3	Fujitsu	369	443	20.1	16.0
4	Atmel	330	245	-25.8	8.8
5	Sharp	149	144	-3.4	5.2
6	SGS-Thomson	96	79	-17.7	2.8
7	Silicon Storage Technology	91	75	-17.6	2.7
8	Texas Instruments	56	62	10.7	2.2
9	Macronix	39	47	20.5	1.7
10	Mitsubishi	18	38	111.1	1.4

Source: Dataquest (May 1998)

Intel is now converting Fab 9, which is next to Fab 7, to flash, committing $1 billion to the project. Part of Intel's strategy for this is to merge its processor technology and flash methodology into a single process development, based at its headquarters in Santa Clara, California. Then it will use what it calls a "copy exactly" procedure to transfer it from Santa Clara to the Rio Rancho plant. The company hopes this will speed its ramp-up of 0.25-micron production now, but, more important, it hopes to accelerate a shift to 0.18-micron production. Table 2 shows Intel's flash fab production.

Table 2
Intel Flash Fabs

Fab Name	City and State	Country	Products Produced	Initial Production Date	Maximum Wafer Starts per Month	Wafer Size (mm)	Minimum Feature Size (Micron)
Fab 7	Rio Rancho, NM	U.S.	Flash memory	1984	35,000	150	0.40
Fab 9	Rio Rancho, NM	U.S.	Flash memory	1999	30,000	200	0.25

Source: Intel, Dataquest (May 1998)

FASL—AMD and Fujitsu Joint Venture

Advanced Micro Devices Inc. is the second-largest flash memory vendor, and its market share has expanded steadily over the years, with estimated flash revenue of $613 million, or 22 percent of the total. Fujitsu Ltd. has also grown very quickly, racking up sales of $443 million in 1997 and a market share of 16 percent, or third place in the flash horse race. Combined, AMD and Fujitsu show a 38 percent share of the 1997 market, pulling ahead of Intel-Sharp's 36 percent.

AMD followed in Intel's footsteps in that it went outside when it needed more capacity. Unlike AMD, Fujitsu at that time was not a major supplier of flash, so this was a technology transfer, with AMD teaching Fujitsu how to make flash in high volume. But their agreement was very different from the Intel-Sharp link—they formed a separate joint venture based in Fukushima, Japan, that builds products for both of them and that allows each to share the success of the other. Exclusive sales territories help keep this relationship on an even keel. AMD does have one older fab that predates the FASL agreement, Fab 14, detailed in Table 3, used for older low-density (2Mb and below) flash and EPROM products.

There are two fabs at FASL, each with two phases (see Table 4). Initial shipments from Fab 1, Phase 1, commenced in 1994, and Phase 2 came up in 1996. Fab 2, Phase 1, just began volume production this year.

Table 3
AMD Flash Fab

Fab Name	City and State	Country	Products Produced	Initial Production Date	Maximum Wafer Starts per Month	Wafer Size (mm)	Minimum Feature Size (Micron)
Fab 14	Austin, TX	U.S.	EPROM, 1Mb, 2Mb flash, PLD	1984	15,600	150	0.70

Source: AMD, Dataquest (May 1998)

Table 4
FASL Flash Fabs

Fab Name	City and State	Country	Products Produced	Initial Production Date	Maximum Wafer Starts per Month	Wafer Size (mm)	Minimum Feature Size (Micron)
Fab 2 Phase 2	Aizu Wakamatsu Shi	Japan	4Mb, 8Mb, 16Mb, 32Mb flash	1999	12,500	200	0.25
Fab 2 Phase 1	Aizu Wakamatsu Shi	Japan	4Mb, 8Mb, 16Mb flash	1998	20,000	200	0.32
Fab 1 Phase 2	Aizu Wakamatsu Shi	Japan	4Mb, 8Mb, 16Mb flash	1997	12,500	200	0.32
Fab 1 Phase 1	Aizu Wakamatsu Shi	Japan	4Mb, 8Mb, 16Mb flash	1994	12,500	200	0.50

Source: AMD, Dataquest (May 1998)

Atmel

Atmel Corporation is the fourth-largest flash memory supplier, accounting for $245 million in 1997 sales, or 9 percent of the total. The company is trying to retreat from the "commodity" memory business by focusing on combined-technology parts for specific applications.

Atmel started out in flash as a major supplier of EEPROMs. This actually created a controversy—just what is a flash memory? Some would say it is a single-cell memory, such as Intel's or AMD's NOR-type devices. Others, such as the Semiconductor Industry Association, say it is a device that allows block erase, a function that erases many cells at a time, to occur. The latter allowed Atmel to use EEPROM technology to make chips with flash functionality that operate at low voltages, a key advantage for the largest flash market, digital cellular telephones. Since then Atmel has introduced single-cell flash.

The company produces flash in four multiuse fabs, but one of these, Fab 6 in Rousset Cedex, France, is being ramped down because of its older, 0.5-micron technology. As shown in Table 5, Atmel's other French facility, Fab 7, is its newest, producing ASICs, microcontrollers, and EPROMs in addition to flash. It uses 200mm wafers with a 0.35-micron lithography, capable of 25,000 wafer starts per month for the four products produced there. The product mix at Fab 5 is memory focused, with EEPROM and EPROM also run there. Fab 4 has less wafer capacity and older lithography and is therefore suitable for lower-density products.

Table 5
Atmel Flash Fabs

Fab Name	City and State	Country	Products Produced	Initial Production Date	Maximum Wafer Starts per Month	Wafer Size (mm)	Minimum Feature Size (Micron)
Fab 7	Rousset Cedex	France	Flash, ASIC, MCU, EPROM	1997	25,000	200	0.35
Fab 5	Colorado Springs, CO	U.S.	EPROM, EEPROM, flash	1994	50,000	150	0.35
Fab 3	Colorado Springs, CO	U.S.	EPROM, flash EEPROM, EPLD, analog	1990	30,000	150	0.40
Fab 6	Rousset Cedex	France	ASIC, MCU, EEPROM	1988	10,000	150	0.50

Source: Atmel, Dataquest (May 1998)

Sharp

Sharp Electronics Corporation is the No. 5 flash supplier, based on 1997 estimated results of $144 million, or a 5 percent market share. Sharp entered into an agreement with Intel in 1993 that basically got it into the flash business. Initially, the company acted as a foundry for Intel, but it has come into its own in recent times, expanding sales with both Intel-compatible and its own devices. As shown in Table 6, the first facility, Factory 3, is currently running a 0.4-micron process but started at 0.6 micron. The second fab, Factory 4, is using a Sharp-developed 0.25-micron process, with Sharp and Intel going separate ways because of Intel's use of a logic (read Pentium) derivative for 0.25-micron technology, which it will not allow to go outside an Intel-owned fab.

Table 6
Sharp Flash Fabs

Fab Name	City and State	Country	Products Produced	Initial Production Date	Maximum Wafer Starts per Month	Wafer Size (mm)	Minimum Feature Size (Micron)
Factory 4	Fukuyama	Japan	Flash, 64Mb DRAM	1998	14,000	200	0.25
Factory 3	Fukuyama	Japan	Flash, 32Mb MROM, SRAM	1993	16,000	200	0.40

Source: Sharp, Dataquest (May 1998)

SGS-Thomson

SGS-Thomson Microelectronics B.V. has been in the flash business for some time but recently added to its existing fab in Agrate, Italy, a new fab in Catania that will either make or break its effort. In 1997, Dataquest estimates that SGS-Thomson sold $79 million worth of flash memory, which equaled a 2.8 percent market share. Recently the company announced a development program with Mitsubishi Electric Corporation for high-density multilevel cell (MLC) flash and a 0.18-micron process. Instead of aiming this at mass storage, which is its most common use, SGS-Thomson wants to be a second source for Intel's Strataflash MLC products, which are intended for high-density code store applications. The SGS-Thomson flash fabs are detailed in Table 7.

Table 7
SGS-Thomson Flash Fabs

Fab Name	City and State	Country	Products Produced	Initial Production Date	Maximum Wafer Starts per Month	Wafer Size (mm)	Minimum Feature Size (Micron)
R1 Phase 1	Agrate	Italy	EPROM, flash	1991	20,000	150	0.55
R1 Phase 2	Agrate	Italy	EPROM, flash	1998	19,700	200	0.40
M5 Phase 3	Catania	Italy	EPROM, flash	1996	20,000	200	0.50
M5 Phase 4	Catania	Italy	EPROM, flash	1997	16,000	200	0.25

Source: SGS-Thomson, Dataquest (May 1998)

Silicon Storage Technology

Silicon Storage Technology Inc. is a fabless flash company that has developed basic flash technology, which it calls SuperFlash, and licenses it both to its foundry partners and to other companies. In 1997, it had sales of $75 million, or 2.7 percent of the total. SST's initial foundry partner was SANYO Semiconductor Corporation, and it later joined with Taiwan Semiconductor Mfg. Co. SANYO flash fabs are listed later in this document.

Texas Instruments

Texas Instruments Inc. is not typically associated with flash memory, but it did have 1997 revenue of $62 million, or 2 percent of the market. The company has developed basic flash technology as part of its DRAM programs. Its interest is in using flash as an embedded memory in digital signal processor and microcontroller products, but it does sell some discrete products, including the only x32 architecture on the market, which are made in the fabs listed in Table 8.

Table 8
Texas Instruments Flash Fabs

Fab Name	City and State	Country	Products Produced	Initial Production Date	Maximum Wafer Starts per Month	Wafer Size (mm)	Minimum Feature Size (Micron)
AMOS-1	Avezzano	Italy	4Mb, 16Mb DRAM, 4Mb flash	1990	22,000	150	0.40
LMOS	Lubbock, TX	U.S.	EPROM, flash DSP, speech	1978	28,000	150	0.60

Source: Texas Instruments, Dataquest (May 1998)

Macronix

Macronix International Company Ltd. is the leading nonvolatile manufacturer in Taiwan. It is well positioned to supply the Asia/Pacific PC BIOS market. The company increased sales from $39 million in 1996 to $47 million in 1997—an achievement given that flash prices were plummeting. Macronix's market share in 1997 was 1.7 percent. As shown in Table 9, the company has two fabs, with another planned to come on line in 2000.

Table 9
Macronix Flash Fabs

Fab Name	City and State	Country	Products Produced	Initial Production Date	Maximum Wafer Starts per Month	Wafer Size (mm)	Minimum Feature Size (Micron)
Fab 1	Science Park	Taiwan	ROM, EPROM, flash, logic	1992	35,000	150	0.45
Fab 2	Science Park	Taiwan	ROM, EPROM, flash, logic	1997	20,000	200	0.35
Fab 3	Science Park	Taiwan	ROM, EPROM, flash, logic	2000	30,000	200	0.25

Source: Macronix, Dataquest (May 1998)

Mitsubishi Electric

Mitsubishi Electric Corporation is expanding its flash business rapidly, with a focus on low-voltage, portable applications using the DiNOR technology it developed for this market. The company's flash revenue doubled from 1996 to 1997 to $38 million, or 1.4 percent of the market. Mitsubishi is developing 0.25-micron and smaller processes with SGS-Thomson in its Kumamoto facility. Table 10 shows Mitsubishi Electric's fabs.

Table 10
Mitsubishi Electric Flash Fabs

Fab Name	City and State	Country	Products Produced	Initial Production Date	Maximum Wafer Starts per Month	Wafer Size (mm)	Minimum Feature Size (Micron)
SA-2A	Saijo-Shi	Japan	Flash, MCU, 4Mb SRAM	1991	20,000	150	0.40
Kumamoto	Kumamoto	Japan	Flash, MCU	1998	25,000	200	0.25

Source: Mitsubishi, Dataquest (May 1998)

Samsung

Samsung Electronics Company Ltd. is the No. 11 flash supplier, with 1997 sales of $34 million, up from $31 million in 1996 and equaling a 1.2 percent market share. Samsung promotes NAND flash with Toshiba Corporation and also has developed a single-chip flash card, named SmartMedia, with Toshiba. Samsung is rumored to be working on NOR-style flash for embedded applications. As shown in Table 11, it makes its lower-density products in Fab 3 and its higher-density products in Fab 4.

Table 11
Samsung Flash Fabs

Fab Name	City and State	Country	Products Produced	Initial Production Date	Maximum Wafer Starts per Month	Wafer Size (mm)	Minimum Feature Size (Micron)
Fab 3	Kiheung	Korea	4-32Mb flash, ASIC, MROM, EEPROM, SRAM	1988	25,000	150	0.40
Fab 4	Kiheung	Korea	64-128Mb flash, ASIC, MROM, EEPROM, SRAM	1990	25,000	150	0.30

Source: Samsung

Toshiba

Toshiba Corporation invented flash memory, so in a way, it is unjust that it is the No. 12-ranked manufacturer of flash. In 1997, it shipped $34 million worth of flash, or 1.2 percent of the market, down from $79 million in 1996. Most of this was the NAND-style flash the company developed with Samsung. As shown in Table 12, Toshiba builds flash in a development fab in Kawasaki.

Table 12
Toshiba Flash Fabs

Fab Name	City and State	Country	Products Produced	Initial Production Date	Maximum Wafer Starts per Month	Wafer Size (mm)	Minimum Feature Size (Micron)
Bldg. 108 D-2	Kawasaki-Shi	Japan	16Mb 64Mb DRAM, flash	1990	1,300	200	0.35

Source: Toshiba, Dataquest (May 1998)

SANYO

As noted previously, SANYO Semiconductor Corporation is mainly a fab for SST, and the company shipped $31 million worth of flash in 1997, down from $50 million in 1996. This translates to a 1.1 percent market share. As shown in Table 13, SANYO makes flash in a variety of nondedicated plants.

Table 13
SANYO Flash Fabs

Fab Name	City and State	Country	Products Produced	Initial Production Date	Maximum Wafer Starts per Month	Wafer Size (mm)	Minimum Feature Size (Micron)
-	Ojiya Shi	Japan	Flash, MCU	1997	10,000	200	0.35
C 2	Ojiya Shi	Japan	DRAM, logic, SRAM, flash	1994	25,000	150	0.50
B 1	Ojiya Shi	Japan	EEPROM, flash, logic, ASSP, 8-bit MCU, 1Mb DRA	1989	28,000	150	0.50
VL3	Anpachi-Gun	Japan	SRAM, EEPROM, disk drive IC, custom, CCD, nROM	1986	30,000	125	0.35

Source: SANYO, Dataquest (May 1998)

Hitachi

Hitachi Ltd. is a company to watch in data storage flash. Although it had only a 0.4 percent market share in 1997, its sales increased to $11 million over sales of $2 million in 1996, a gain of more than 500 percent. More important, the company's AND technology, developed with Mitsubishi, has the write speed, power, and cost advantages of NAND. The company is shipping part of its production as CompactFlash cards, a good way to jump-start sales. Its two fabs are detailed in Table 14.

Table 14
Hitachi Flash Fabs

Fab Name	City and State	Country	Products Produced	Initial Production Date	Maximum Wafer Starts per Month	Wafer Size (mm)	Minimum Feature Size (Micron)
K2-2F	Nakakoma-Gun	Japan	Flash, SRAM	1995	5,000	200	0.40
N2-1F	Hitachinaka-Shi	Japan	64Mb DRAM, 64Mb flash, MPU	1994	30,000	200	0.35

Source: Hitachi, Dataquest (May 1998)

Dataquest Perspective

The future of the flash memory industry, like that of the overall semiconductor industry, lies in investment today for a possible return in the future. Consider that the current DRAM market share leaders, Samsung, NEC , Hyundai , Hitachi , and Micron, are not among the top 10 companies in flash market share! In terms of bit shipments, the DRAM market is well over 10 times larger than the flash market; the clear threat is that a significant diversion of DRAM capacity to flash could upset the current market order, not to mention changing the ranking of the leaders. And this investment is relatively inexpensive, because older, fully depreciated fabs could be used for market entry.

For purchasers of flash memory, now is a good time. For the foreseeable future, there will be abundant supply from many vendors owing to an increasingly competitive market. However, the other side of this is a dark cloud for vendors. Participating in the flash market long term is an obvious strategy for mainstream memory makers. It will be the nonvolatile chip of choice, and a company should enter this emerging segment as soon as possible to reserve a place in it. But the danger posed by other heavyweight manufacturers with the same brilliant idea gives pause, as well as a sinking feeling in the area of the pocketbook. This will be an expensive game to play, and unless a company has something special to offer, it may perhaps be a game to avoid for the time being.

For More Information...

Inquiry Hotline:	+1-408-468-8423
Via e-mail:	scndinquiry@dataquest.com
Via fax:	+1-408-954-1780
Dataquest Interactive:	http://www.dataquest.com

Perspective

Semiconductor Contract Manufacturing Services Worldwide

Market Analysis

1997 Fabless Semiconductor Review

Abstract: *Once again, fabless semiconductor companies proved their viability, growing by 13.4 percent to $7.7 billion in revenue in 1997, when the broader semiconductor market managed growth of only 3.5 percent. This Perspective examines in detail the top 50 fabless semiconductor companies, analyzes the products and applications of the fabless sector, and forecasts the growth of this important and exciting group.*

By James Hines

Fabless Semiconductor Revenue Grows 13.4 Percent in 1997

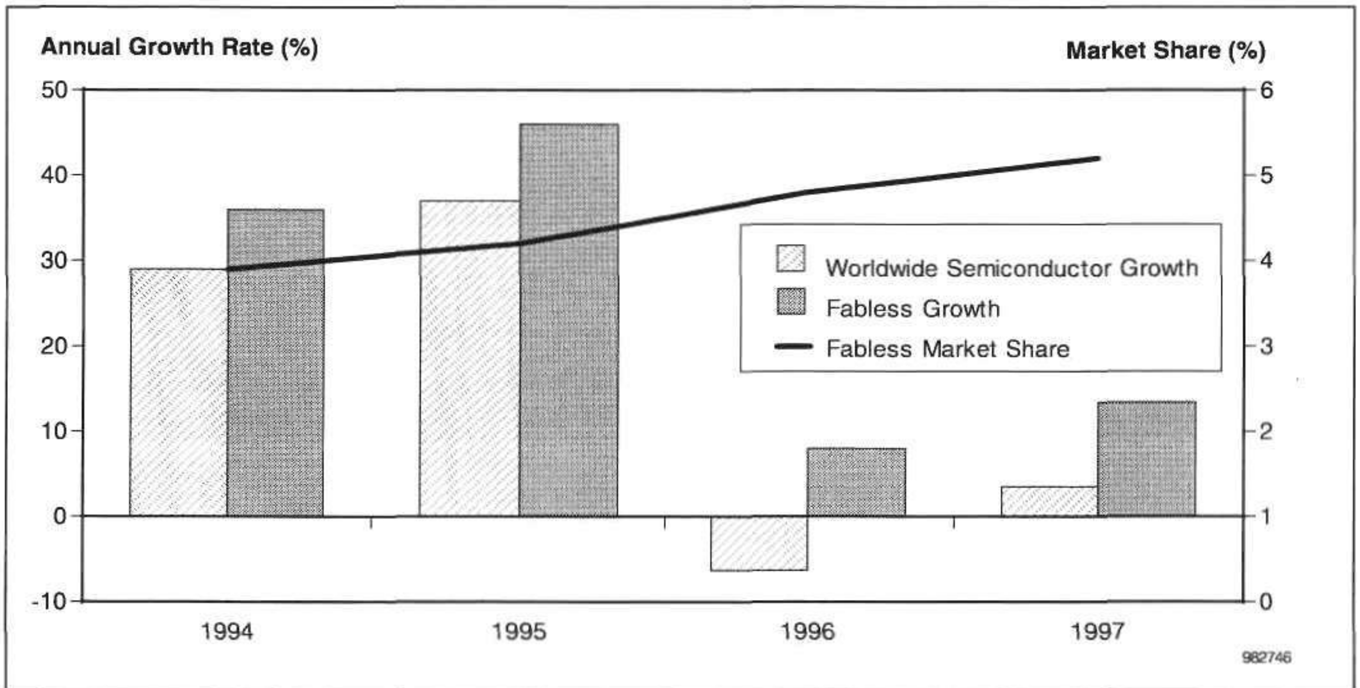
Continuing their trend of outperforming the overall semiconductor market, fabless semiconductor companies as a group saw their revenue grow by 13.4 percent in 1997 to $7.7 billion. By comparison, the worldwide semiconductor market grew only 3.5 percent, ending the year at $147.2 billion. As a result, the fabless companies' share of the worldwide semiconductor market increased to 5.2 percent in 1997. This Perspective identifies the leading fabless semiconductor companies, examines the driving forces behind their growth, and offers some thoughts on the direction of the fabless sector.

The fabless business model continues to prove its viability. The growth in revenue of fabless companies has consistently outpaced that of the broader semiconductor market, as shown in Figure 1. Even when the semiconductor market contracted in 1996, the fabless companies as a group maintained revenue growth. Participation in some of the hottest semiconductor application markets, a focus on product design, and, more recently, the availability of relatively inexpensive foundry capacity, have combined to propel the fabless sector to growth rates that are 7 to 14 percent higher than those of the worldwide semiconductor market.

Dataquest

Program: Semiconductor Contract Manufacturing Services Worldwide
Product Code: SCMS-WW-DP-9805
Publication Date: June 1, 1998
Filing: Perspective
(For Cross-Technology, file in the Semiconductor Regional Markets and Manufacturing binder)

Figure 1
Increasing Market Share of Fabless Semiconductor Companies



Source: Dataquest (May 1998)

Who Are the Top Players?

Table 1 lists the top 50 fabless companies, based on calendar year 1997 merchant semiconductor sales. The data for this table was obtained from Dataquest's annual survey of semiconductor companies, which includes both fabless companies and integrated device manufacturers (IDMs), companies that own and operate their own wafer fabrication facilities (fabs). Companies without their own fabs were pulled from the survey and sorted by 1997 revenue to provide this list of fabless companies. For the purposes of this analysis, companies participating in joint-venture fab projects are considered fabless companies. For example, Cirrus Logic Inc. obtains most of its wafers from two joint-venture fabs, MiCRUS (with IBM) and Cirent (with Lucent).

Cirrus Logic remains atop the list of fabless semiconductor companies, as it has for the past few years. However, the commanding lead it once enjoyed has been eroded by two consecutive years of declining semiconductor revenue. In 1997, revenue dipped slightly, to $880 million, well below the billion-dollar mark the company reached in 1995. Cirrus has been undergoing a transition in its product strategy over the past two years, placing a greater emphasis on storage, communications, and mixed-signal linear ICs, and it has seen its share of the highly competitive graphics market decline. At the same time, competitive pricing pressures have further dampened revenue growth. Still, Cirrus retains a strong competency in the design of complex ICs, having announced more than 25 new products last year, and this capability will serve it well as the semiconductor market moves into its next growth cycle.

Table 1
Top 50 Fabless Semiconductor Companies' Revenue, 1996 to 1997
(Millions of U.S. Dollars)

1996 Rank	1997 Rank	Company	1996 Revenue	1997 Revenue	Change (%)
1	1	Cirrus Logic	891	880	-1.2
3	2	Altera	497	631	27.0
2	3	Xilinx	566	612	8.1
11	4	Sun Microsystems	170	550	223.5
4	5	S3	464	437	-5.8
17	6	ATI Technologies	130	260	100.0
5	7	ESS Technology	227	245	7.9
7	8	Lattice	200	242	21.0
6	9	Adaptec	214	238	11.2
8	10	PMC Sierra Semiconductor	188	214	13.8
15	11	C-Cube Microsystems	150	171	14.0
10	12	Oak Technology	172	163	-5.2
16	13	Actel	149	156	4.7
22	14	VIA	110	151	37.3
9	15	Trident Microsystems	180	144	-20.0
14	16	Chips & Technologies	151	131	-13.2
20	17	Level One Communications	112	127	13.4
21	18	Integrated Silicon Solution Inc.	111	125	12.6
25	19	TCS	83	123	48.2
27	20	Alliance Semiconductor	76	120	57.9
NA	20	NeoMagic	-	120	NA
35	22	Acer	50	115	130.0
13	23	Eupec	160	111	-30.6
18	24	Silicon Integrated Systems	127	110	-13.4
23	25	Exar	96	102	6.3
26	26	Integrated Circuit Systems	79	95	20.3
30	27	DSP Group	67	76	13.4
24	28	Silicon Storage Technology	91	75	-17.6
29	29	Q Logic	68	73	7.4
32	30	Catalyst	54	70	29.6
19	31	OPTi	119	68	-42.9
31	32	Micro Linear	55	62	12.7
NA	33	8x8	-	60	NA
33	34	Quality Technologies	52	54	3.8
38	35	ACC Microelectronics	45	50	11.1
36	35	WaferScale Integration	48	50	4.2
39	37	Integrated Storage Devices	41	48	17.1
37	38	Quality Semiconductor	46	47	2.2

Table 1 (Continued)
Top 50 Fabless Semiconductor Companies' Revenue, 1996 to 1997
(Millions of U.S. Dollars)

1996 Rank	1997 Rank	Company	1996 Revenue	1997 Revenue	Change (%)
47	39	G-Link USA	15	34	126.7
41	39	Zoran	29	34	17.2
NA	41	Fagor	-	32	NA
44	42	Chip Express	24	31	29.2
40	42	Seeq Technology	32	31	-3.1
NA	44	Power Innovations	-	29	NA
43	44	QuickLogic	25	29	16.0
NA	46	Melexis	-	22	NA
46	47	Symphony Laboratories	17	19	11.8
46	48	Spectra Diode Labs	17	17	0
48	49	Logic Devices	14	14	0
51	50	Appian Technology	10	11	10.0
		Other Fabless Companies	584	311	NA
		Total Fabless Companies	**6,806**	**7,720**	**13.4**

NA = Not available
Source: Dataquest (May 1998)

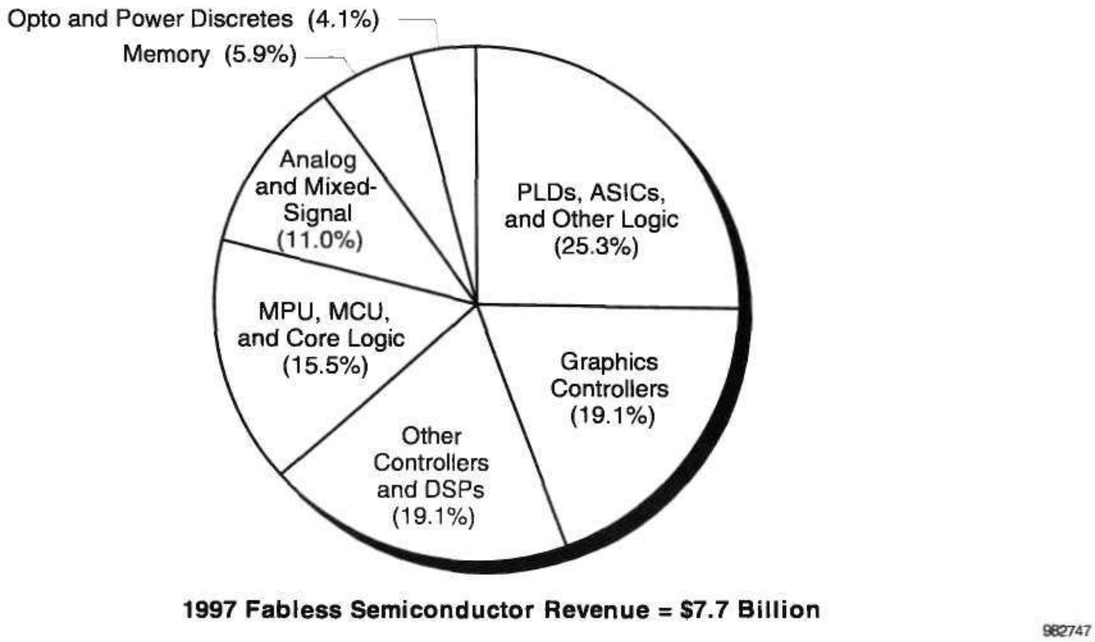
Sun Microsystems Inc., long known as a computer systems company, was also the fastest-growing fabless semiconductor company in 1997, with a spectacular spurt of 224 percent to $550 million in merchant semiconductor sales. Sun's Microelectronics group has apparently met with considerable success in marketing its line of SPARC microprocessors to other OEMs. With the explosion in Internet, intranet, LAN, and WAN applications, Sun has effectively leveraged its SPARC technology into a sizable chip business in support of OEM companies developing microprocessor-based network products. Considering the high rates of growth expected for networking hardware, Sun should continue to see strong demand for its semiconductor products in the coming years.

The programmable logic device (PLD) companies, Altera Corporation, Xilinx Incorporated, Lattice Semiconductor Corporation, and Actel Corporation, always seem to appear near the top of Dataquest's fabless list, and this year is no exception. Altera finally overtook Xilinx, its solid 27 percent growth rate enough to edge it into the No. 2 position in the overall fabless ranking. The two companies are now virtually tied in their race for PLD market leadership, and it will be interesting to see if Altera is able to maintain its growth momentum. Lattice also showed strength, with revenue increasing 21 percent to $242 million. As a group, PLD companies grew 13 percent—average performance in comparison to all fabless companies, but certainly superior to the semiconductor industry average.

Fabless Semiconductor Product Segmentation

The product mix of fabless semiconductor companies is heavily weighted toward computing and related applications. Figure 2 shows a segmentation of 1997 fabless revenue by product type. Taken as a whole, microprocessors, microcomputers, core logic, and microperipherals (graphics, audio, mass storage, and other controllers) account for more than half the business for fabless semiconductor companies. Most of these products are targeted directly at the personal computer and related peripherals markets. Dataquest estimates that PC-related products account for about half of PLD revenue and a fraction of the remaining segments, as well. Together, PC and computing-related applications are the source of 55 to 65 percent of fabless semiconductor revenue. This application segment is a key driver for the fabless sector, as it is for the broader semiconductor industry.

Figure 2
Fabless Semiconductor Product Segmentation, 1997



Source: Dataquest (May 1998)

PLDs, application-specific ICs (ASICs), and other logic devices make up the largest segment in this breakdown of 1997 fabless semiconductor revenue, at 25 percent. PLDs represent the bulk of revenue in this area, at slightly more than 22 percent of the total. This is about the same proportion as last year, and PLD revenue did grow at the same rate as the total for all fabless companies. The PLD segment continues to be the largest single product category among fabless companies, and it is dominated by just a few players. These products can address a broad spectrum of user-defined applications, and the homogeneity of their physical design makes them particularly well suited to foundry manufacturing. Furthermore, the support-intensive nature of the PLD business provides a barrier to entry that will tend to favor the concentration of market share among these established PLD vendors.

If Dataquest had not chosen to break out graphics controllers as a separate segment, the combined segment for all microcontrollers—including graphics, audio, mass storage, and other controllers—would have been the largest, at almost 40 percent. But because graphics controllers alone represent a significant portion of fabless revenue, we are tracking it as a standalone segment. Indeed, at 19 percent of the total, graphics controllers are a close second to PLDs for the largest single product category. This is the hottest segment in the fabless sector, having experienced the highest rates of growth, but it is also the most dynamic and the most ruthless.

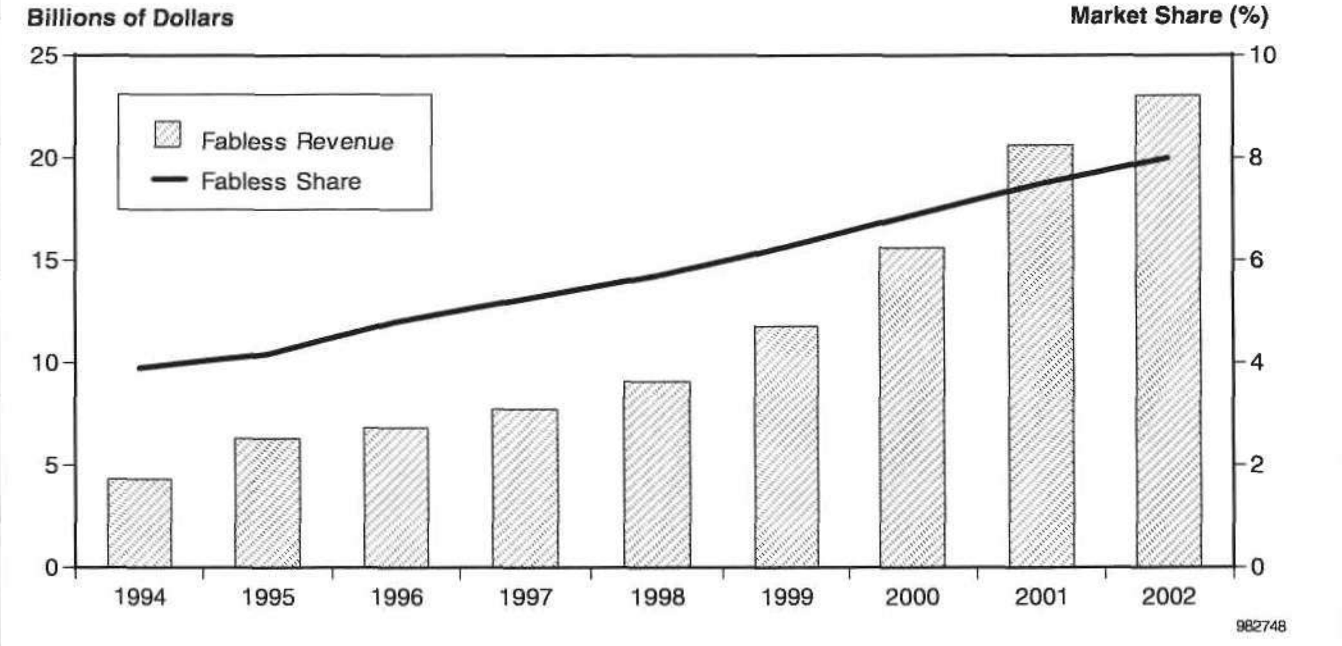
The rapid pace of technological innovation and constantly changing standards create a chaotic environment in the graphics market. The leader among fabless companies in this segment, S3 Inc., saw a dip in revenue in 1997 following a meteoric rise from its start to nearly $500 million in sales. ATI Technologies Inc. appears to be the up-and-coming fabless graphics company of the moment, having grown 100 percent to move into a still-distant second. Trident Microsystems Inc. and Chips & Technologies Inc. have seen their fortunes in the graphics market falter, as has Cirrus Logic, while NeoMagic Corporation made its debut at No. 6 and could be a company to watch.

The Future Is Bright for Fabless Companies

Because the fabless sector is very dynamic, with new start-ups taking off and former bright stars fading into oblivion all the time, it is necessary to take a top-down approach to forecasting the growth of fabless companies as a whole. The methodology employed for this document was to examine historical trends in the penetration of fabless companies into the various semiconductor application markets and to project these trends against Dataquest's overall forecast of worldwide semiconductor revenue. The result of this analysis is shown in Figure 3, with historical data points included for reference.

The revenue of fabless semiconductor companies is forecast to reach $23 billion by 2002, representing 8 percent of a $288 billion worldwide semiconductor market. Compared to 1997 fabless revenue of $7.7 billion, this forecast represents a compound annual growth rate (CAGR) of 24.4 percent; worldwide semiconductor revenue is forecast to grow at a 14.4 percent CAGR over the same period. Dataquest believes that expecting fabless revenue growth to be 10 percent higher than the semiconductor industry average is reasonable in view of the high-growth markets in which fabless companies are participating and the proven success of the fabless business model. Historical data, although admittedly limited to just a few years, does show that the revenue growth of fabless companies has consistently outpaced that of the semiconductor market by 7 to 14 percent. Barring any unforeseen dramatic shifts in the structure of the industry, there is no reason to expect a change in this trend.

Figure 3
Historical and Projected Revenue of Fabless Companies, 1994 to 2002



Source: Dataquest (May 1998)

Dataquest Perspective

In 1997, growth in the revenue of fabless semiconductor companies exceeded that of the industry by 10 percent. This superior performance by fabless companies on average should no longer come as a surprise to anyone who has been watching this sector. The fabless business model and its complement, the dedicated (or pure-play) semiconductor foundry, have proven to be a successful response to the increasing capital intensity of semiconductor manufacturing. Concentration of capital and concentration of capacity in the enormous fabs of the foundries bring the advantages of economies of scale and improved manufacturing efficiency to the fabless companies in the form of affordable wafer fabrication services. The foundries' focus on process technology development frees the fabless companies to concentrate on their own marketing and product development, shortening time to market. The result is an explosion in innovative and agile fabless companies offering a flood of new products to the most exciting and fastest-growing applications in the semiconductor market, all supported by foundry manufacturing. A fundamental shift in the semiconductor manufacturing infrastructure has already occurred, and the fabless phenomenon is a visible manifestation of this shift that will become an increasingly vital part of the industry in the years to come.

For More Information...

Inquiry Hotline: +1-408-468-8423
Via e-mail: scndinquiry@dataquest.com
Via fax: +1-408-954-1780
Dataquest Interactive: http://www.dataquest.com

Perspective

Semiconductor Contract Manufacturing Services Worldwide

Market Analysis

The Convergence of Foundries and ASIC Vendors in Manufacturing SLI

Abstract: *The emergence of "system on a chip," or system-level integration, will bring new challenges and opportunities in semiconductor manufacturing. The success of the foundry and fabless models can be expected to extend to the design and manufacture of SLI chips. What impact will the new manufacturing paradigm have on traditional ASIC vendors? And how can they respond to the competitive threat posed by the foundries?*

By James Hines and Jordan Selburn

What Is System-Level Integration?

System-level integration (SLI) can be defined as putting the functionality that previously required a printed circuit board onto a single silicon chip. Originally conceived in the early 1990s, advanced silicon manufacturing, design automation tools and component libraries are now allowing the "system on a chip" to move into the mainstream market. The initial system-level designs consisted almost exclusively of digital logic constructions, but today's designs can include embedded DRAM, flash memory, and analog functions, among others.

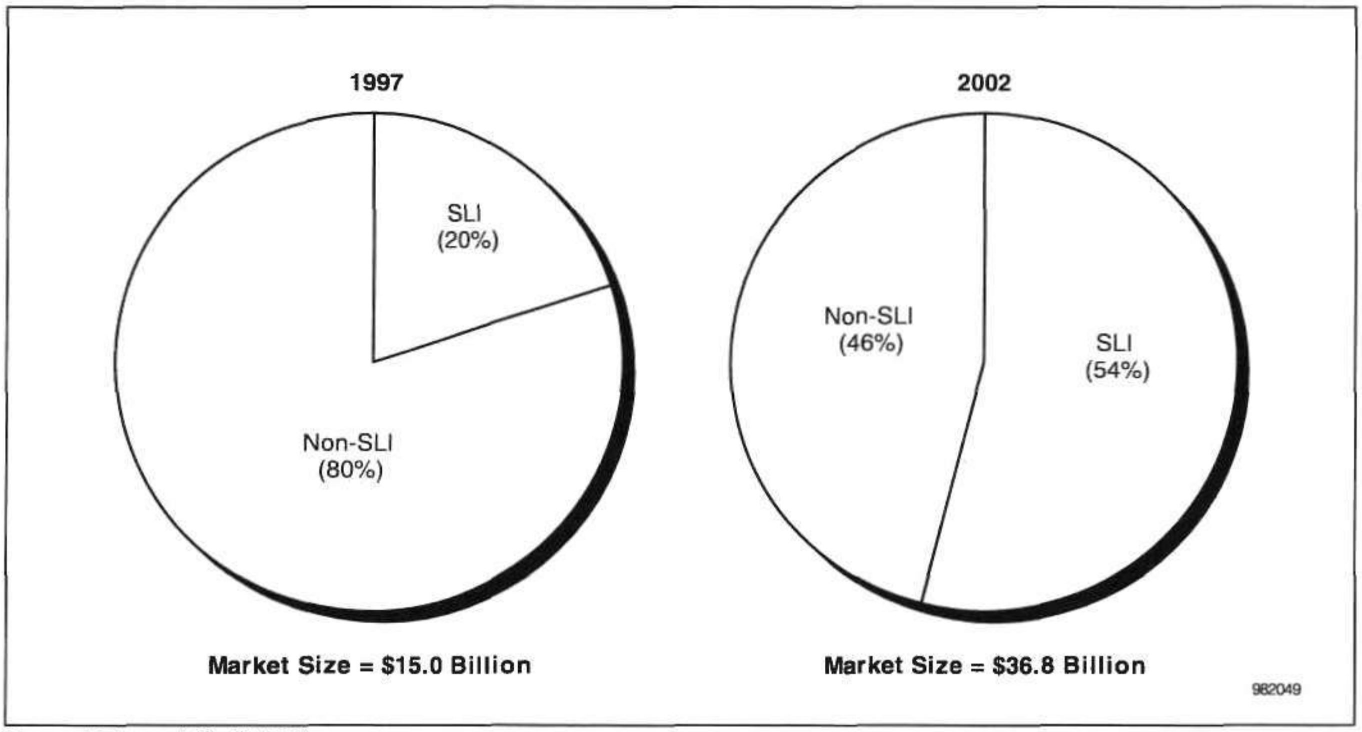
SLI Will Dominate ASIC Revenue

Fueling the projected growth in the ASIC industry, Dataquest expects system-level designs to contribute more than 50 percent of the market's total revenue by 2002 (see Figure 1). Clients should be aware, however, that the ASICs that will contribute most of the system-level integration revenue between 2000 and 2002 are the designs that are now on the drafting board.

Dataquest

Program: Semiconductor Contract Manufacturing Services Worldwide
Product Code: SCMS-WW-DP-9804
Publication Date: May 11, 1998
Filing: Perspective
(For Cross-Technology, file in the Semiconductor Regional Markets and Manufacturing binder)

Figure 1
ASIC Market Forecast



Source: Dataquest (April 1998)

SLI Driving Foundry Market Growth

Foundry market growth is outpacing the general semiconductor market and is being driven by the explosion of fabless semiconductor companies and a trend toward greater levels of outsourcing on the part of integrated device manufacturers (IDMs). Fabless semiconductor companies represent 35 percent of foundry demand in 1997, and we expect this to grow to 40 percent by 2002.

As will become clear, the foundries and their fabless customers are well positioned to benefit from the opportunities created by SLI technology. Figure 2 shows the forecast growth of the semiconductor contract manufacturing (SCM) market from 1997 through 2002 and the increasing share of the market represented by SLI designs. Foundries and traditional ASIC vendors will be in direct competition for many of these SLI designs.

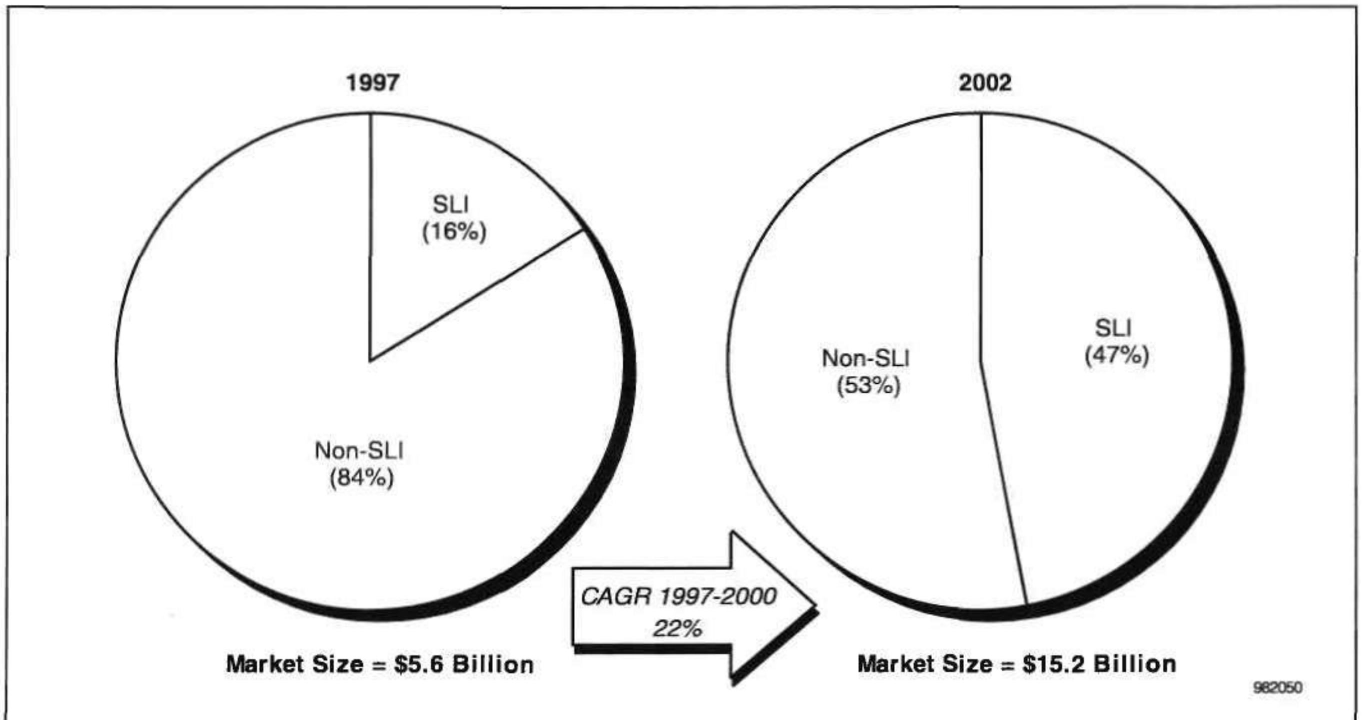
What Are the Major Drivers and Inhibitors of Foundry Manufacturing of SLI?

There are several factors that will influence the growth in foundry manufacturing of SLI designs, both positively and negatively. The major drivers and inhibitors are shown in Figure 3. The trend toward foundry manufacturing of SLI will be supported by the success of the Virtual Socket Interface Association (VSIA), International SEMATECH, an expanding application-specific standard product (ASSP) market, escalating fab costs, and the accelerated pace of technology development of foundries. Potential inhibitors include the continuing financial crisis in Asia, the low revenue per square inch of silicon inherent in SLI designs, lack of adequate electronic design automation (EDA) solutions to support the most advanced manufacturing technology, and manufacturing process integration issues.

How Will Foundries Compete for SLI Designs?

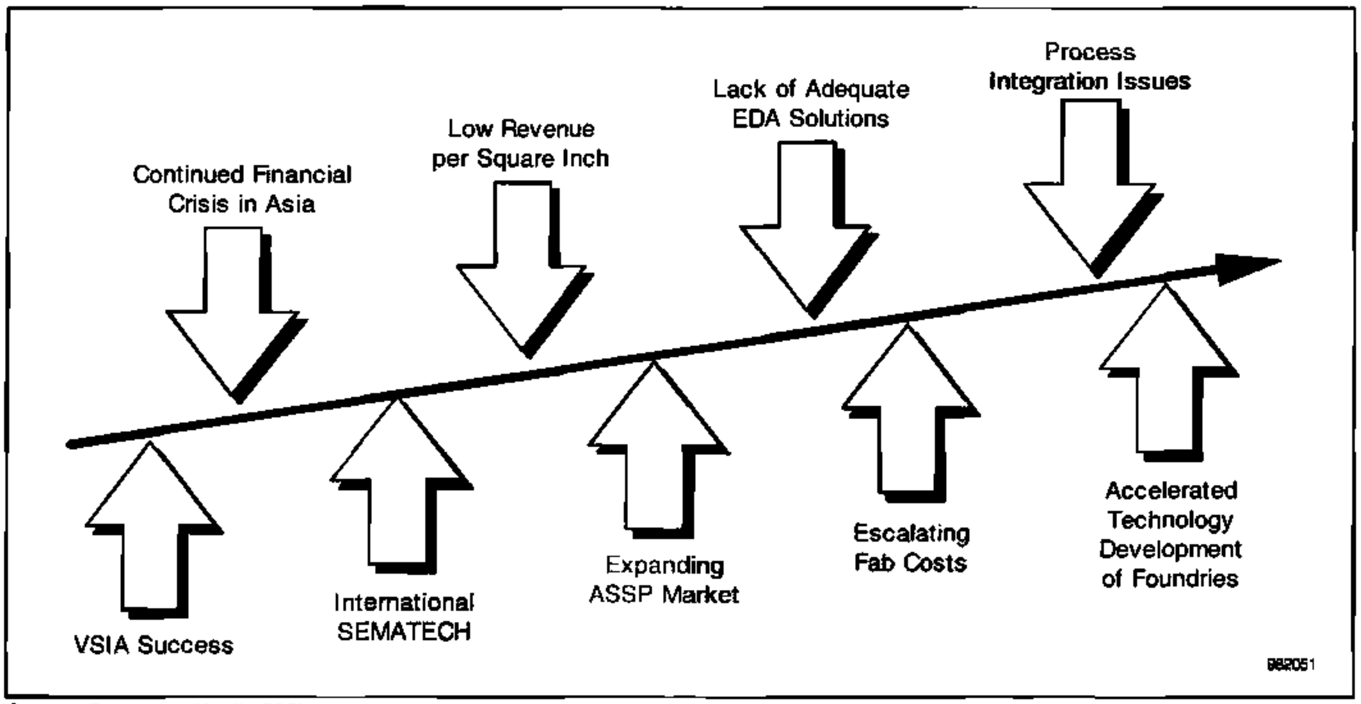
The challenge of manufacturing consumer-oriented SLI chips, as with many other semiconductor products, is fundamentally one of minimizing manufacturing cost. (In this category of SLI designs, it is assumed that lower overall system costs is one of the primary reasons for moving to SLI.) True, there are some technical problems to be overcome in mating logic and DRAM or other memory processes on the same wafer, but solutions are at hand, and even these will ultimately be evaluated on the basis of their impact on manufacturing cost. SLI chips, by virtue of their combination of memory and logic functions, will generate less revenue per square inch of silicon than most pure logic chips, including traditional ASIC designs. In order to sustain acceptable margins, costs must be reduced.

Figure 2
SCM Market Forecast



Source: Dataquest (April 1998)

Figure 3
Drivers and Inhibitors of Foundry Manufacture of SLI



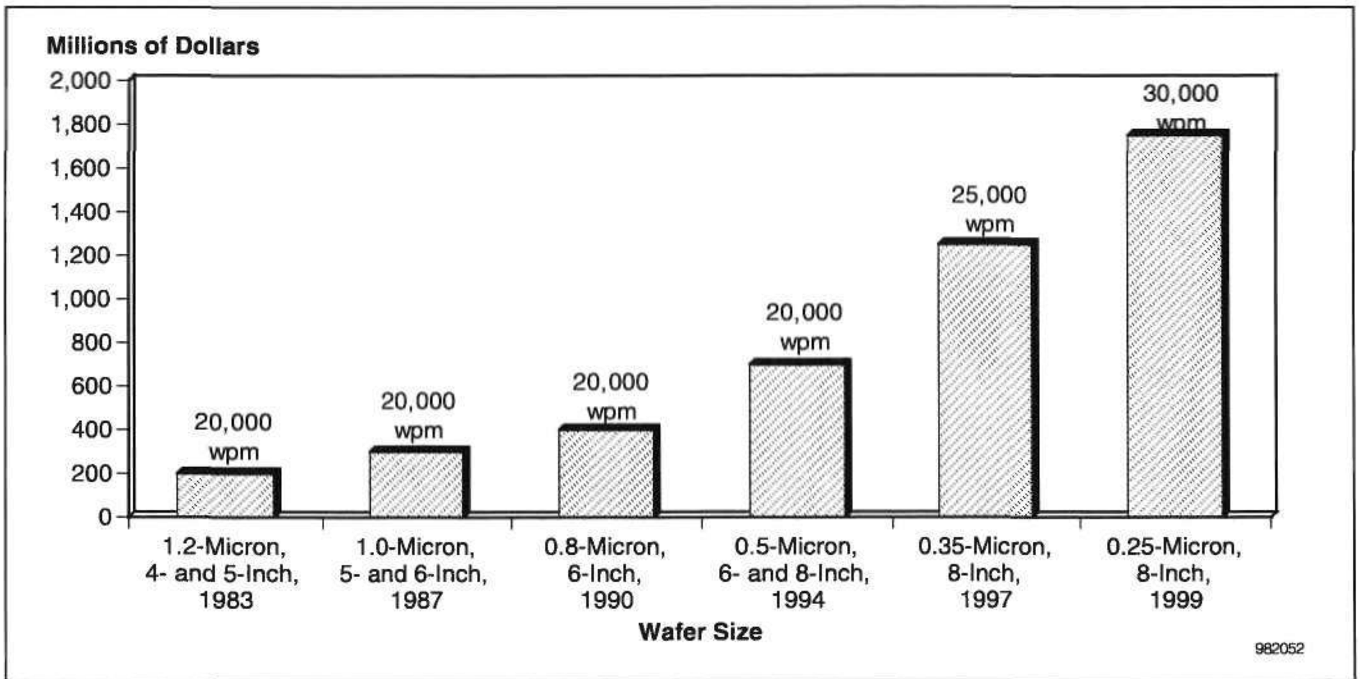
Source: Dataquest (April 1998)

Foundries are expert at minimizing manufacturing cost. This is achieved primarily through economies of scale, aggregating the demand of several customers in a high-volume factory operating at very high capacity utilization rates. In the capital-intensive semiconductor manufacturing business, capacity utilization is the key to achieving low manufacturing cost. Foundries have also standardized their process flows, enabling them to accommodate a variety of customer requirements with a minimum of configuration changes. Also, many foundries are taking advantage of developments in factory automation technology to further enhance manufacturing efficiency and reduce cycle time.

Concentration of Capital and Concentration of Capacity

Rising wafer fabrication facility costs greatly increase the capital requirements for semiconductor manufacturing companies. The escalating cost of new fabs is shown in Figure 4. Only large semiconductor manufacturers can justify investing $1.5 billion or more in a new advanced technology fab solely for production of their own products. Foundries keep their large fabs full by aggregating the demand of smaller customers, thus achieving high factory utilization rates. Higher fab costs will favor a concentration of capital in the large fabs of foundry suppliers, giving them greater economies of scale.

Figure 4
The Escalating Cost of Fab Construction



Source: Dataquest (April 1998)

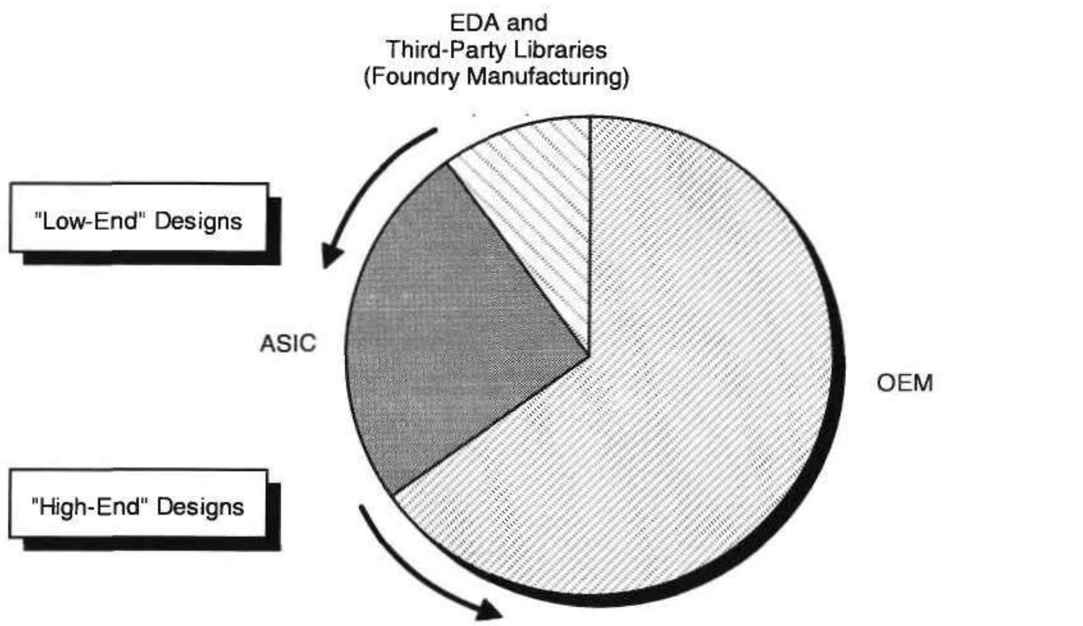
New fabs are not only more costly, but they are also larger in terms of total silicon production capacity. In 1983, semiconductors were being manufactured on 4-inch and 5-inch diameter wafers, and the largest fabs were being operated at 20,000 wafer starts per month. Since then, both the size of the wafers and the wafer capacity have increased, combining to give dramatic increases in capacity in terms of total silicon area. So a portion of the cost increase of a new fab can be directly attributed to an increase in the real silicon capacity of that fab. This trend is giving rise to a concentration of capacity in ever larger high-volume fabs, many of which are now being built by foundry companies. This increasing capacity per fab will make it more difficult for a dedicated ASIC vendor to fill a new captive fab.

Shifting Roles in Semiconductor Design

The widespread availability of standardized EDA tools and third-party libraries is enabling fabless companies and design service companies to compete for designs that have historically been the province of ASIC vendors. These designs are then manufactured by foundries. This shift in the distribution of semiconductor designs is shown in Figure 5.

Dataquest expects the emergence of these foundry-manufactured designs to squeeze the traditional ASIC companies and cause them to look toward systems OEMs for design opportunities. Fabless semiconductor companies and so-called "chipless" design companies are likely to participate in many SLI designs in a variety of low- to high-volume applications.

Figure 5
Semiconductor Design Market Segmentation



Source: Dataquest (April 1998)

The Impact of VSIA

The design of single-chip systems becomes almost impossible without the ability to reuse system-level macro (SLM) blocks. The Virtual Socket Interface Alliance is one of several ongoing efforts to enable design reuse; if successful, this would allow for rapid and widespread distribution of third-party SLMs. OEMs and design houses would then have access to the system-level macros necessary for foundry manufacture of system-level chips. In-demand SLMs will quickly become commodities, and their ability to add value will decrease rapidly.

The VSIA consortium has defined the problems that must be solved by OEMs and design houses to compete with ASIC vendors and is now working toward the solution. Dataquest believes that a usable implementation of a VSIA solution could occur in about two years. There are some major potential roadblocks in addition to the technical challenges, however. VSIA was initiated by the EDA community, and there is a lingering question as to whether the leading SLI ASIC companies will participate with their hearts as well as their minds. VSIA must also overcome the "designed by committee" problem—more than two people can't decide on where to have lunch, much less anything important.

How Will ASIC Manufacturers Respond to Competition from the Foundries?

ASIC Vendors Will Target Specific End Markets

To achieve economies of scale, the silicon foundries must try to appeal to as broad a customer base as possible. This requires a process technology that is designed to avoid shutting out potential customers rather than one designed to attract customers. The result of this approach is a process that is fairly fast with reasonably low power consumption; if the foundry tunes the process in one direction, it is likely to optimize it in the direction of highest logic density to minimize costs.

The ASIC vendor, on the other hand, can make trade-offs that result in a product optimized for some applications at the expense of others—for example, in a silicon process targeted for the wireless communications market, a transistor could be designed to sacrifice largely unneeded performance and reduce static and dynamic power consumption, extending battery life. An example of this is the trade-off between transistor speed and leakage current. In a cellular phone system-level ASIC, an optimal process would trade performance (to the minimum level required by the on-chip digital signal processor, or DSP) for a lower leakage current; a process targeted toward high-performance desktop applications such as workstations would make the opposite trade-off. This is one way that the dedicated ASIC vendors can continue to differentiate their products, although it can make that vendor highly vulnerable to variations in the targeted market. This approach can also make it more difficult to fill a modern high-capacity fab.

In comparison to markets for standard parts such as DRAM and microprocessors, ASIC vendors require significantly more customer interaction.

As a way to provide targeted support beyond the current capability of the foundries, ASIC vendors are (and, in some cases, have been for a while) setting up engineering teams dedicated to specific application markets. This approach also allows an ASIC vendor to design its own chips—ASSPs—and sell these parts to multiple customers. Examples of these include DVD controllers and Global System for Mobile Communications (GSM) chipsets. At present, foundries lag far behind leading ASIC vendors in application-focused customer support; making up this difference will be an expensive and time-consuming effort and may not be successful ultimately.

ASIC Vendors Will Take Foundry Business

One option for an ASIC vendor determined to own and operate a silicon fabrication plant is to compete with the foundries at their own game. Foundry business can allow an ASIC vendor to fill some unused capacity. Even if this business has a low gross profit margin (and the fab business is likely to have a low margin, compared to system-level ASIC designs), it can be beneficial for the ASIC vendor by spreading fab and other corporate fixed costs over a larger amount of production. Some of the issues in pricing against foundry competition are compensated for in the ASIC vendor's lead in process technology, which allows the production of smaller, lower-cost die. This lead, currently at about one process generation, is decreasing, however, and may not last more than a few more years.

ASIC vendors must be extremely careful not to overcommit to the foundry business, however attractive this business may seem during down cycles. When business for SLI designs improves, the ASIC vendor may not be able to book these higher-value opportunities if the fab is full of low-margin foundry business. Because the average design is in volume production for more than two years, the ASIC company must perform a careful evaluation of foundry production.

ASIC Vendors Will Partner with the Foundries

"If you can't beat 'em, join 'em." Some ASIC vendors are working with the foundries rather than competing against them. VLSI Technology Inc. and Wafer Technology Malaysia are an example of this type of working relationship. VLSI, while still making some investment in its captive San Antonio, Texas, fab, has the right to purchase a sizable amount of WTM's capacity; this capacity is scheduled to come on line in 2000. This partnership gives VLSI the option, for example, to tune the San Antonio process for the wireless market, which represents VLSI's largest segment, while using WTM for more generic production. In addition to the business partnership, VLSI and WTM are working together on process development.

Another major advantage to partnering with foundries is manufacturing flexibility. With a foundry partner, an ASIC vendor can reduce the business and financial risks associated with a new or expanded fab. In down cycles, the ASIC vendor does not carry the sizable fixed costs of unused fab capacity, yet retains the ability to quickly ramp production for a major SLI design. Also, the second-source capability of a foundry partner can be quite attractive to customers concerned about putting the manufacturing of a key system component in one fab.

Dataquest Perspective

The OEM Perspective

In most supplier wars, the customer comes out the winner, and the foundry-ASIC vendor battle is no exception. In this case, the OEM will have more competition vying for its mainstream SLI business. As the industry infrastructure of design houses and third-party system-level macro providers matures, OEMs will have a number of options:

- Outsource manufacturing to the foundries for the lowest-cost products, with the design done either in-house or by a third-party design services company. The former allows the OEM to maintain total control of intellectual property value-added, and the latter can provide easy access to a wide range of independent intellectual property and a broad selection of foundries. Some foundries are starting to offer turnkey solutions (for example, wafer fabrication, packaging, assembly, and testing services).

- Partner with ASIC vendors for application optimization. This is the current business model for most SLI designs, and it can provide the OEM with significant influence over the product development process within an ASIC vendor. This may continue to be the choice of OEMs striving to differentiate their products on a basis other than cost.

The Foundry Perspective

The name of the game in manufacturing SLI, as with most other semiconductor products, will be to minimize cost. Because of their superior economies of scale and manufacturing efficiencies, foundries are best suited to meet the challenge of low-cost SLI production. The concentration of capital in the high-capacity fabs of the foundries and the importance of manufacturing process technology will continue to drive the shift to the foundry model. The widespread availability of EDA tools and third-party intellectual property libraries, and the standardization efforts of the VSIA, will give designers the ability to implement SLI designs in silicon, which can then be transferred to the foundries for production.

The ASIC Vendor Perspective

ASIC vendors will come under increasing pressure from foundries. The time frame is far from certain, but in the not too distant future Dataquest believes that foundry manufacture will become a viable approach for many mainstream SLI designs. When this happens, the price pressure on dedicated ASIC vendors will become intense.

ASIC vendors must continue to focus on product differentiation. Either processes tuned to applications or dedicated customer support familiar with the market as well as the OEM will be critical factors. ASIC vendors that can target application markets will have the best chance to survive the foundry onslaught; those that try to be everything to every customer will almost certainly be doomed to failure.

For More Information...

Inquiry Hotline:	+1-408-468-8423
Via e-mail:	scndinquiry@dataquest.com
Via fax:	+1-408-954-1780
Dataquest Interactive:	http://www.dataquest.com

Dataquest
A Gartner Group Company

Perspective

Semiconductor Contract Manufacturing Services Worldwide

Market Analysis

Semiconductor Contract Manufacturing Wafer Pricing Trends, Spring 1998

Abstract: *In Dataquest's first survey of 1998, completed in February, foundry wafer prices continue to decline, although at a somewhat slower pace than seen in surveys of the past two years. Prices for 0.25-micron wafers, having started at lower-than-expected levels in September 1997, stay on a downward trend. Foundry capacity remains abundant, even for leading-edge technologies, so a competitive pricing environment is expected to persist through most of 1998.*

By James F. Hines

Dataquest's Foundry Wafer Pricing Survey

For 1998, Dataquest is increasing the frequency of its surveys of worldwide semiconductor contract manufacturing (SCM) foundry wafer pricing from semiannually to three times a year. As a result, the current survey was moved up to February, making the period between this survey and the previous one five months instead of six. The next survey is planned for June, which will establish the regular period of four months between surveys.

In February, a large number of SCM users and providers were surveyed and reported prices paid and charged for 150mm and 200mm foundry-processed CMOS wafers. The survey encompassed a variety of process technologies, categorized by minimum feature size and number of metal levels. Also, participants were asked to report prices for a number of special processing options, such as tungsten, chemical mechanical planarization (CMP), salicide, and epitaxial silicon. Finally, foundry users and suppliers were polled to obtain a consensus on the expected change in wafer prices over the next six months.

Dataquest
Program: Semiconductor Contract Manufacturing Services Worldwide
Product Code: SCMS-WW-DP-9803
Publication Date: April 27, 1998
Filing: Perspective
(For Cross-Technology, file in the Semiconductor Regional Markets and Manufacturing binder)

February 1998 SCM Wafer Pricing Update

Table 1 summarizes the results of the most recent foundry wafer pricing survey, conducted in February 1998. Participants were asked to report prices paid for foundry-processed wafers delivered during February 1998, assuming CMOS, unprobed wafers with 13 to 15 mask levels, a single level of polysilicon, and no epitaxial silicon. The minimum volume requirement was set at 1,000 wafers per month. The estimated average price is the average of all prices reported or, in cases of small sample size, Dataquest's estimate of the average price. The price range shows the minimum and maximum prices reported.

The Different Perspectives of Buyers and Sellers

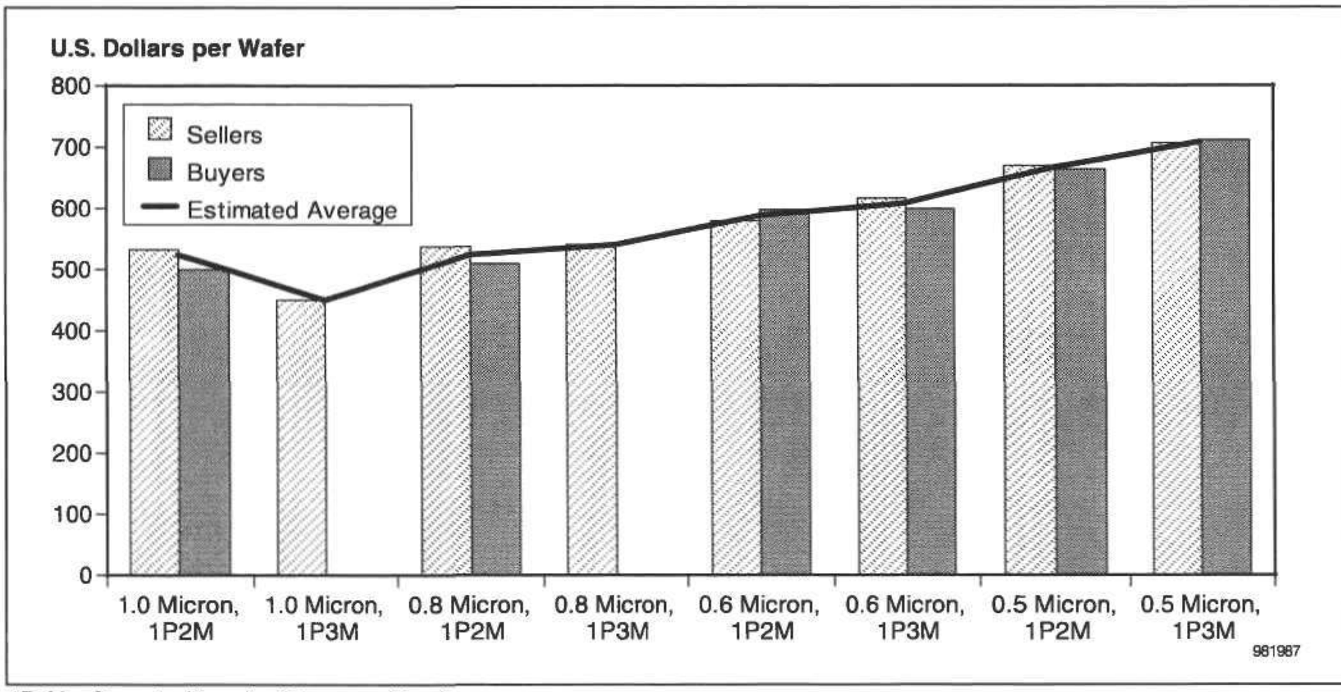
Responses of buyers and sellers may differ in a survey of this type, and this difference is shown in Figures 1 and 2. In general, buyers and sellers reported prices that were in fairly close agreement, and with few exceptions, sellers tended to report higher prices than buyers. This behavior is to be expected, with sellers generally resisting price reductions, while buyers continually drive for lower prices. For the past couple of years, buyers have been getting their way because excess capacity has kept downward pressure on foundry wafer prices across the board.

Table 1
February 1998 Foundry Wafer Prices (U.S. Dollars per Wafer)

	150mm Wafers		200mm Wafers	
Technology	Estimated Average Price	Price Range	Estimated Average Price	Price Range
1.0-micron, 1P2M	524	500-595	NA	NA
1.0-micron, 1P3M	450	400-500	NA	NA
0.8-micron, 1P2M	524	470-595	NA	NA
0.8-micron, 1P3M	540	460-635	NA	NA
0.6-micron, 1P2M	588	500-725	1,090	1,020-1,150
0.6-micron, 1P3M	608	550-700	1,165	1,150-1,180
0.5-micron, 1P2M	667	600-725	1,277	1,150-1,385
0.5-micron, 1P3M	708	624-765	1,325	1,100-1,500
0.35-micron, 1P3M	NA	NA	1,684	1,500-1,960
0.35-micron, 1P4M	NA	NA	1,833	1,700-1,945
0.25-micron, 1P3M	NA	NA	2,450	2,300-2,550
0.25-micron, 1P4M	NA	NA	2,590	2,400-2,700
0.25-micron, 1P5M	NA	NA	2,833	2,500-3,000

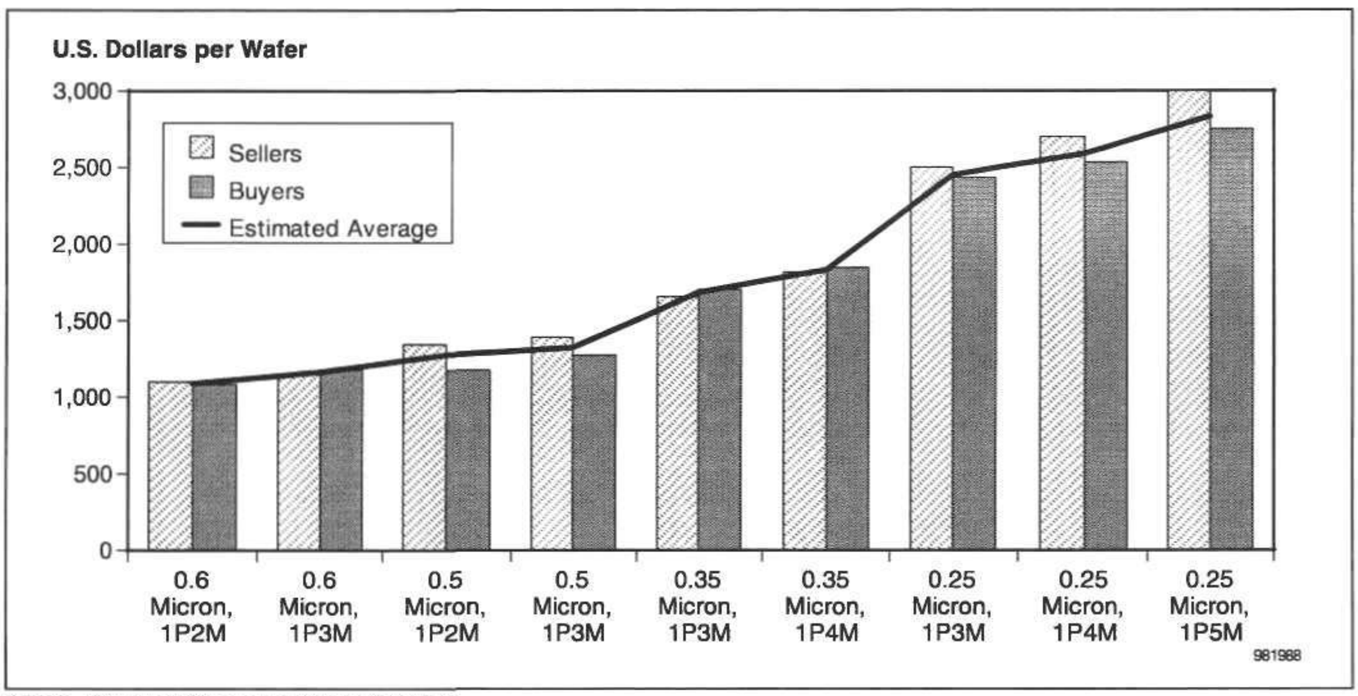
NA = Not available
1P2M = One polysilicon level, two metal levels
Source: Dataquest (March 1998)

Figure 1
February 1998 Foundry Wafer Prices: 150mm Wafers



1P2M = One polysilicon level, two metal levels
Source: Dataquest (March 1998)

Figure 2
February 1998 Foundry Wafer Prices: 200mm Wafers



1P2M = One polysilicon level, two metal levels
Source: Dataquest (March 1998)

Wafer Price Declines Continue but Show Signs of Slowing

Table 2 compares the average prices reported in February 1998 to those reported in the previous survey of September 1997. Foundry wafer prices have continued to slide during the past six months, reflecting the general overcapacity of the market since mid-1996. Pricing pressure generally is less severe than seen in the surveys over the past two years. Wafer prices appear to be approaching a limit that could be determined by manufacturing cost and the minimum gross margin that foundry suppliers are willing to accept.

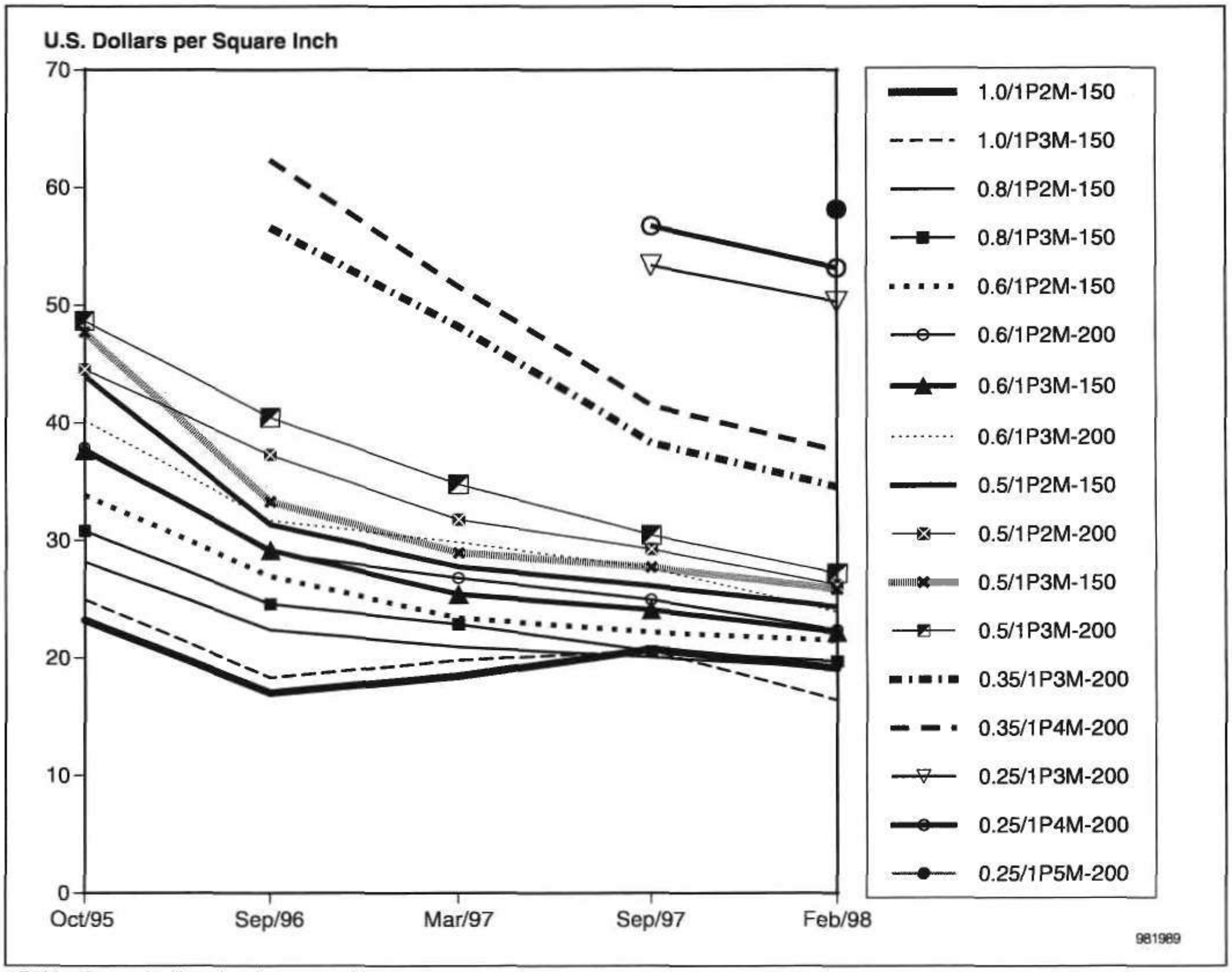
Figure 3 shows the history of foundry wafer prices over the two and one-half years that Dataquest has been conducting these surveys. Prices are plotted in dollars per square inch in order to normalize differences in wafer size. In almost all cases, but especially at 0.35 micron, the slope of the trend lines is clearly less steep than in previous periods. Also, for most of this history, prices for leading-edge technologies have shown a steeper decline than lagging-edge technologies. This has resulted in a convergence of wafer prices across technologies. In September 1996 the spread between 1.0-micron and 0.35-micron prices was about $45 per square inch; now it is only about $20 per square inch. Indeed, recent pricing history suggests that while advanced manufacturing technology is introduced at a substantial premium, higher volumes and progress on the technology "learning curve" result in cost reductions that are quickly passed on to customers. Without doubt, this trend has been accelerated in recent years by a competitive pricing environment.

Table 2
Change in Average Foundry Wafer Prices, September 1997 to February 1998 (U.S. Dollars per Wafer)

	150mm Wafers			200mm Wafers		
Process Option	September 1997	February 1998	Change (%)	September 1997	February 1998	Change (%)
1.0 Micron, 1P2M	568	524	-7.7	NA	NA	NA
1.0 Micron, 1P3M	565	450	-20.4	NA	NA	NA
0.8 Micron, 1P2M	550	524	-4.7	NA	NA	NA
0.8 Micron, 1P3M	563	540	-4.1	NA	NA	NA
0.6 Micron, 1P2M	608	588	-3.3	1,215	1,090	-10.3
0.6 Micron, 1P3M	660	608	-7.9	1,345	1,165	-13.4
0.5 Micron, 1P2M	716	667	-6.8	1,425	1,277	-10.4
0.5 Micron, 1P3M	759	708	-6.7	1,483	1,325	-10.7
0.35 Micron, 1P3M	750	NA	NM	1,865	1,684	-9.7
0.35 Micron, 1P4M	NA	NA	NA	2,020	1,833	-9.3
0.25 Micron, 1P3M	NA	NA	NA	2,600	2,450	-5.8
0.25 Micron, 1P4M	NA	NA	NA	2,763	2,590	-6.3
0.25 Micron, 1P5M	NA	NA	NA	NA	2,833	NM

NA = Not available
NM = Not meaningful
1P2M = One polysilicon level, two metal levels
Source: Dataquest (March 1998)

Figure 3
Historical SCM Average Price-per-Square-Inch Trends, October 1995 to February 1998 (U.S. Dollars)



1P2M = One polysilicon level, two metal levels
Source: Dataquest (March 1998)

After a year of steadily rising prices, 1.0-micron wafer prices dipped in this survey. The price increases of last year were attributed to stronger-than-anticipated demand for such lagging technology, and it is possible that the shift in demand to more advanced technologies has accelerated. It is interesting to note that prices for 1.0-micron wafers with one level of polysilicon and three levels of metal (1P3M) fell a surprising 20.4 percent, while 1P2M prices fell only 7.7 percent—much more consistent with general market trends. There are very few designs at 1.0 micron that employ three levels of metal interconnect, so the 1P2M prices are probably a more reliable indicator of 1.0-micron wafer prices.

In the last survey, Dataquest commented on the unexpectedly low prices reported for 0.25-micron wafers. The extent to which 0.25-micron prices are depressed can be clearly seen in Figure 3: 0.25-micron wafers are selling at almost the same price at which 0.35-micron wafers sold just one year ago. These prices continue to fall, although not as steeply as 0.35-micron wafer prices did last year. The depressed prices of 0.25-micron wafers are an indication that capacity is ramping up ahead of demand.

Special Process Option Pricing

Prices for special processing options are shown in Table 3. These are processes outside the standard process flow that normally involve an additional cost. As noted in previous reports on wafer prices, tungsten, salicide, and CMP processes are becoming standardized, at least on 200mm wafers. These processes are becoming part of the standard process flow for advanced technologies, which are predominant at the 200mm wafer size.

Table 4 compares average special process option prices in this survey to those reported in the previous survey of September 1997. Like wafer prices, some process option prices decreased, but the results are mixed. Prices for tungsten increased for both 150mm and 200mm wafers. Prices for salicide decreased in both cases. The remainder of the process options showed price decreases for 150mm wafers and price increases for 200mm.

Future Trends in SCM Wafer Pricing

Survey participants were asked to predict the movement of foundry wafer prices over the next six months for 0.5-, 0.35-, and 0.25-micron wafers. Table 5 summarizes the results of this polling. In the last survey, five months ago, survey participants predicted a small decline in 0.5-micron prices, a moderate increase in 0.35-micron prices, and flat pricing for 0.25-micron wafers. In all cases, these predictions erred on the side of higher prices. As can be seen, prices actually fell across all technology categories. Even 0.5-micron prices, where further declines were predicted, fell at a faster rate than expected.

Table 3
February 1998 Foundry Wafer Process Option Pricing (U.S. Dollars per Wafer)

	150mm Wafers		200mm Wafers	
Process Option	Estimated Average Price	Price Range	Estimated Average Price	Price Range
Tungsten (Per Level)	33	0-35	34	0-35
Salicide	62	0-70	66	0-75
Epitaxial Silicon	57	40-70	165	100-250
CMP	51	0-52	60	0-75
Additional Mask Levels (Above 15)	59	50-75	103	95-125
Polysilicon (Above One Level)	67	50-85	120	100-140

Source: Dataquest (March 1998)

Table 4
Change in Average Foundry Wafer Process Option Prices, September 1997 to February 1998 (U.S. Dollars per Wafer)

Process Option	September 1997	February 1998	Change (%)	September 1997	February 1998	Change (%)
Tungsten (Per Level)	32	33	3.1	30	34	13.3
Salicide	70	62	-11.4	74	66	-10.8
Epitaxial Silicon	65	57	-12.3	149	165	10.7
CMP	52	51	-1.9	52	60	15.4
Additional Mask Levels (Above 15)	60	59	-1.7	102	103	1.0
Polysilicon (Above One Level)	83	67	-19.3	120	120	0

Source: Dataquest (March 1998)

Table 5
Expected Change in Foundry Wafer Prices over Next Six Months (Percent)

Median Response	0.5 Micron	0.35 Micron	0.25 Micron
Buyers	-5.0	-7.5	-10.0
Sellers	-7.5	-10.0	-5.0
Combined Total	**-5.0**	**-10.0**	**-10.0**

Source: Dataquest (March 1998)

Dataquest's current poll indicates that people are expecting pricing pressures to continue in each of the three technologies surveyed. In view of the excess capacity still present in the foundry market, this outlook is probably justified. It is reasonable to expect further price declines of 5 to 10 percent over the next six months in a competitive market in which supply exceeds demand. However, because the foundry market has already experienced severe price declines and foundry service providers are feeling the squeeze on their margins, it is likely that the big price drops are behind us.

Price declines on the order of those shown in Table 5 are likely to occur over the next six months. After that, in the last quarter of 1998, SCM demand should accelerate as the semiconductor industry mounts a sustained recovery. Although demand is not likely to overtake capacity this year, the uptick in demand might be enough to bring some stability to wafer prices by the end of 1998. This, and the prospect of increasing capacity utilization rates, will be a welcome respite for the foundries.

Dataquest Perspective

Here we go again with an all too familiar refrain: Foundry wafer prices continue to decline. The good news, for foundries, is that the rapid pace of price erosion seen over the past two years appears to be waning. It is still too early to draw any firm conclusions; after all, one data point does not constitute a trend, and an abundance of foundry capacity remains on the market. However, historical price-per-square-inch trends suggest that wafer prices may be starting to feel some support from the underlying manufacturing cost structure.

Further price declines can be expected over the next six months, but they are likely to be less severe than in recent history. Excess capacity, particularly in the leading-edge technologies of 0.5 micron and below, will ensure that a competitive pricing environment persists through most of 1998. By the end of the year, SCM demand should start to gain on capacity as the semiconductor industry emerges from its protracted slump. A spurt in demand, especially for leading-edge foundry wafers, will help bring a return to a more stable pricing environment, despite the fact that capacity will exceed demand well into 1999.

The full effect of the Asian financial crisis remains unknown, and to the extent that troubles in the region moderate worldwide demand for electronic products and the semiconductors that go into them, the anticipated upswing in foundry demand could be dampened, delayed, or both. This eventuality would have the effect of extending the current period of excess capacity and slow revenue growth into 1999 and perhaps beyond. Thus, there is a significant downside possibility to the expectation of a more stable pricing environment by year's end.

For More Information...

Inquiry Hotline:	+1-408-468-8423
Via e-mail:	scndinquiry@dataquest.com
Via fax:	+1-408-954-1780
Dataquest Interactive:	http://www.dataquest.com

Perspective

Semiconductor Contract Manufacturing Services Worldwide

Event Summary

Conference Call on Capital Spending and Wafer Fab Equipment Year-End Forecast Update: The Second Half of the "W" Unfolds

Abstract: *Aggressive investment in 0.25-micron technology throughout 1997, leading to a stronger-than-expected year, has only exacerbated the persistent overcapacity in the industry. As expected second phase downturn now unfolds, there are questions for 1998. How deep will the cutbacks be? When can a sustainable recovery really begin? This document is taken from a telebriefing held by Dataquest on January 9, 1998, concurrent with the release of Dataquest's forecast update on capital spending and wafer fab equipment..*
By Clark J. Fuhs, Ron Dornseif, James Hines, Takashi Ogawa, and Klaus Rinnen

Opening Statement

The Semiconductor Equipment, Manufacturing, and Materials Worldwide (SEMM) program tracks most aspects of the actual manufacturing of semiconductors worldwide. This document discusses the outlook and forecast for wafer fab equipment and capital spending and presents Dataquest's forecast for silicon wafers, supported by recent demand analysis tied to consumption patterns for semiconductor devices.

Forecast Overview

Dataquest has just released its year-end semiconductor capital spending and equipment forecast, summarized in Tables 1 and 2. The forecast process has several cornerstones, including semiconductor production by region, a worldwide database of existing and planned fabs, and independent comprehensive surveys of the equipment and semiconductor companies. Dataquest has just completed an update of the fab database and has scrutinized the fab activity planned worldwide.

Dataquest
Program: Semiconductor Contract Manufacturing Services Worldwide
Product Code: SCMS-WW-DP-9802
Publication Date: February 23, 1998
Filing: Perspective
(For Cross-Technology, file in the Semiconductor Regional Markets and Manufacturing binder)

Table 1
Capital Spending Forecast, 1996 to 2002 (Millions of U.S. Dollars)

	1996	1997	1998	1999	2000	2001	2002	CAGR (%) 1996-2002
Total Capital Spending	**44,996**	**44,685**	**43,029**	**49,075**	**70,476**	**86,266**	**82,139**	**10.6**
Percentage Growth	16.3	-0.7	-3.7	14.1	43.6	22.4	-4.8	-
Percentage of Semiconductors	31.4	29.5	24.4	22.9	25.7	28.6	23.4	-
Percentage if 300mm Pilot Excluded	31.4	29.5	23.5	20.9	24.9	28.6	23.4	-
Americas	14,115	14,830	15,321	18,764	24,373	27,984	28,619	12.5
Percentage Growth	15.3	5.1	3.3	22.5	29.9	14.8	2.3	-
Japan	9,654	8,342	7,782	9,077	13,437	15,111	14,679	7.2
Percentage Growth	-2.6	-13.6	-6.7	16.6	48.0	12.5	-2.9	-
Europe, Africa, and Middle East	5,069	4,751	5,398	5,642	7,713	8,604	8,491	10.5
Percentage Growth	23.7	-6.3	13.6	4.5	36.7	11.6	-1.3	-
Asia/Pacific	16,158	16,762	14,528	15,592	24,953	34,568	30,349	11.1
Percentage Growth	29.9	3.7	-13.3	7.3	60.0	38.5	-12.2	-

Source: Dataquest (January 1998)

Table 2
Wafer Fab Equipment Forecast, 1996 to 2002 (Millions of U.S. Dollars)

	1996	1997	1998	1999	2000	2001	2002	CAGR (%) 1996-2002
Total Wafer Fab Equipment	**21,684**	**22,318**	**22,722**	**26,636**	**37,497**	**44,503**	**42,837**	**12.0**
Percentage Growth	13.4	2.9	1.8	17.2	40.8	18.7	-3.7	-
Americas	5,825	7,001	7,665	9,618	12,432	13,950	9,973	16.9
Percentage Growth	10.9	20.2	9.5	25.5	29.3	12.2	6.3	-
Japan	6,650	5,599	5,776	6,898	9,677	10,499	9,973	7.0
Percentage Growth	5.2	-15.8	3.2	19.4	40.3	8.5	-5.0	-
Europe, Africa, and Middle East	2,802	2,753	3,390	3,395	4,546	5,074	5,095	10.5
Percentage Growth	18.9	-1.8	23.2	0.1	33.9	11.6	0.4	-
Asia/Pacific	6,407	6,966	5,892	6,724	10,842	14,979	12,941	12.4
Percentage Growth	23.3	8.7	-15.4	14.1	61.2	38.2	-13.6	-

Source: Dataquest (January 1998)

The survey results are one input into Dataquest's several forecasting models, which includes analysis of trends in semiconductor production, raw silicon consumption, spending ratios, investment cycles, new fab and expansion activity, DRAM silicon consumption analysis, and semiconductor revenue per square inch.

Dataquest's forecast shows the following highlights:

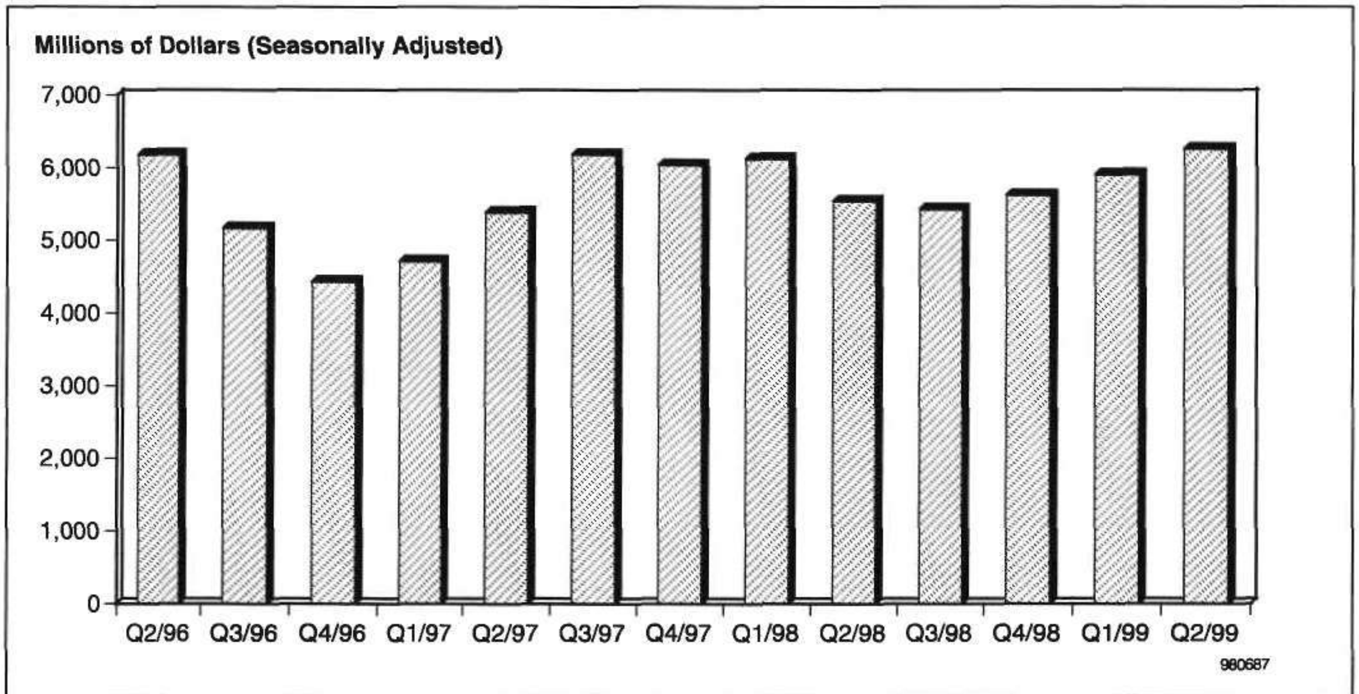
- The wafer fab equipment market in 1997 actually grew over 1996 as aggressive technology purchases continued late in the year and as a surprising resurgence in DRAM spending, primarily from Taiwanese companies, kicked in during the third quarter. Growth of about 3 percent over calendar year 1996 is now projected.

- However, the fundamentals have not changed much and indeed may have gotten worse as a result of the aggressive spending patterns in 1997.
- Overcapacity never went away, and acceleration of shrinks has actually exacerbated the situation.
- In DRAM, there has been a net capacity addition in the last 18 months beyond the requirements for silicon area. Dataquest is no longer convinced that the market will be balanced by the end of 1998 unless capacity is actively removed from the market.
- Dataquest's analysis of supply and demand in the foundry industry at 0.35-micron technology continues to show that, although demand is strong, supply base plans are about three months ahead of demand for the leading-edge 0.35-micron technology through 1999.
- The Asian financial situation, with the capital and credit constraints that currently exist, has created tremendous uncertainty with downside capital spending ramifications.
- Dataquest is therefore continuing to call 1998 a single-digit growth year, although essentially flat (see Table 2). The stronger-than-expected 1997 actually pushes the sustained recovery into mid-1999, and therefore the growth forecast for 1999 is now under 20 percent.
- The move to put 0.25-micron manufacturing capability in place, coupled with the retooling of fabs to migrate capacity away from DRAM to logic, has been the main focus of investment in equipment in 1997. Equipment areas such as chemical mechanical polishing, deep-UV lithography, factory automation, and epitaxial reactors have benefited.
- Although weak capacity spending for 1998 is forecast, the accelerated commitment to build 300mm pilot lines should provide some supporting strength to 1998.

Dataquest's top-line quarterly shipment forecast for wafer fab equipment is shown in Figure 1.

In the forecast "W" recovery profile, the technology buying surge in 1997 unexpectedly matched the second quarter 1996 peak of $6.2 billion. Dataquest believes the reasons for this strength are twofold. First, there are simply more companies and countries now investing in technology, from the United States to Europe, Japan, Korea, and now Taiwan and Singapore, extending the duration of this part of the cycle. Second, 0.25-micron-specific equipment—particularly chemical mechanical polishing (CMP), high-density chemical vapor deposition (CVD) and etch, as well as deep-UV lithography—have elevated the average selling prices (ASPs) for equipment, increasing the overall strength of revenue.

Figure 1
Wafer Fab Equipment Quarterly Revenue Forecast



Source: Dataquest (January 1998)

Although the current fiscal quarter of Applied Materials Inc. is likely to prop up the first quarter of 1998 at these levels, the middle two quarters of 1998 should experience significantly lower shipments as the spending cutbacks under way are realized. Dataquest is not calling for the decline to be as severe as in late 1996 and therefore is forecasting only a modest recovery acceleration after the third quarter of 1998, with conditions to remain sluggish until mid-1999.

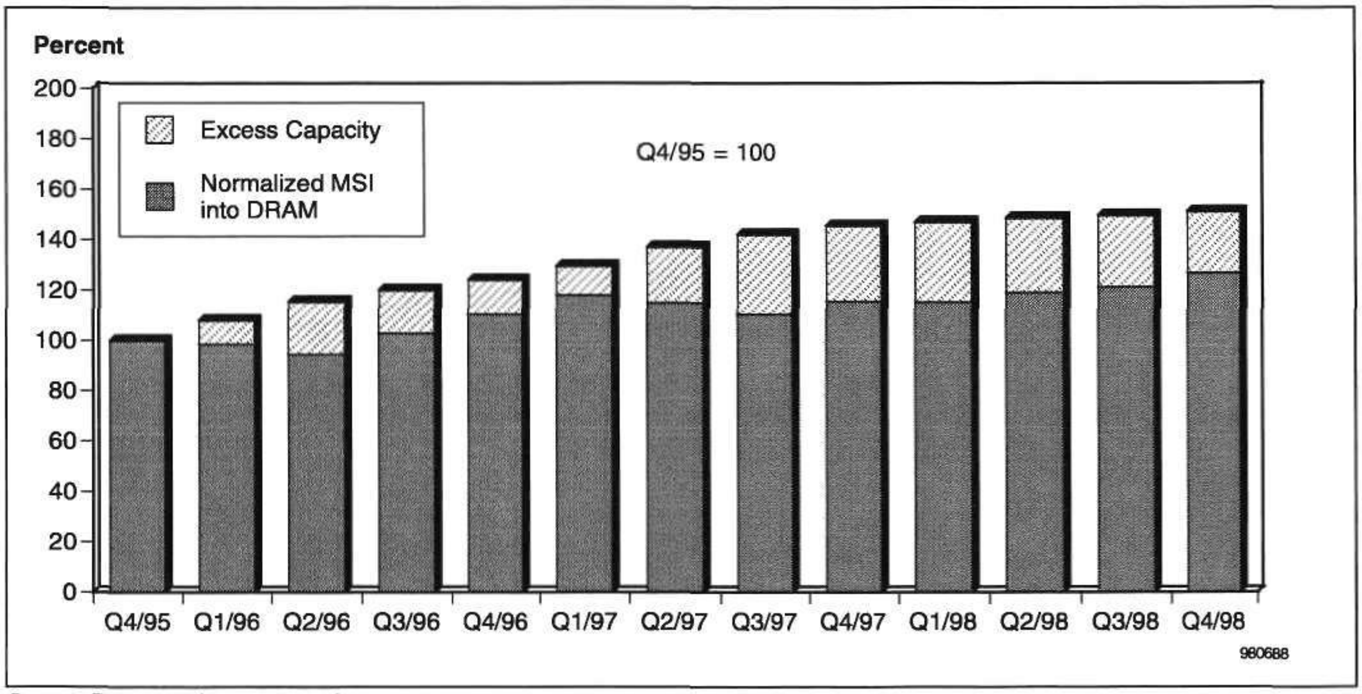
Dataquest would expect supply/demand dynamics to be fully corrected by later in 1999, driving a robust resumption of growth, with the wafer fab equipment market growing to more than $42 billion in 2001, from just over $23 billion in 1998.

Dataquest has forecast a flat-to-down year in 2002. The semiconductor capital markets are cyclical, in response to profitability cycles in the chip market. We forecast the chip market to have a DRAM price decline in 2001, which has been built into a spending decline the following year.

Overcapacity Persistent in the Industry

As mentioned earlier, overcapacity remains as the constant status. In DRAM, there has been a net capacity addition in the last 18 months beyond the requirements for silicon area. As shown in Figure 2, there is now a flat requirement for silicon area during 1997 and into 1998. Comparison of average die size over time explains this point. At the end of 1995, the average die size of the major product shipping (4Mb) was 50mm^2. By the end of 1998, with 0.25-micron technology being applied to the 16Mb DRAM, the average die size of the major product shipping will be about $30mm^2$. That calculates to a 6.7 times increase in the bits per square inch of silicon, or an 88 percent compound annual growth rate (CAGR) over three years, essentially keeping pace with the bit demand. In early 1996, overcapacity in DRAM was about 20 percent. With the shrink factor and the addition of net capacity of the last 18 months, the situation has not improved. Given these facts, Dataquest is no longer convinced that the market will be balanced by the end of 1998 without capacity being actively removed from the market.

Figure 2
DRAM Silicon Efficiency Gain, Accelerated Shrinks Keep Oversupply in Place



Source: Dataquest (January 1998)

Foundry Capacity Status and Outlook

Dataquest is currently in the process of revising the foundry market forecast and supply/demand analysis, which will be released later this month. In the meantime, the following section will briefly summarize the current situation in the foundry market and the near-term expectations for capital spending in the sector.

In the fast-growing 0.35-micron segment of the foundry market, capacity additions continue to stay ahead of demand, leading by about three months. This situation is reflected in the prices of 0.35-micron wafers, which have declined by about 35 percent, on average, over the past year. Ample supply and downward price pressures can be expected to continue through 1998 as several memory producers seek shelter in foundry from the ravages of the DRAM market. In particular, Korean companies, benefiting from a lower won-based cost structure, will be aggressive in their pursuit of foundry business in an effort to use some of their excess DRAM capacity at

0.35-micron. LG Semicon Co. Ltd. has previously demonstrated a willingness to lead prices downward, and it can be expected to assume this role again.

In 1998, 0.25-micron production capacity will be available from the leading foundries. There are already indications of pricing pressure in this segment, which leads us to believe that capacity is coming on line ahead of demand. Growth in demand for 0.25-micron foundry wafers might be slowed by the lack of the design tools needed to take full advantage of the improved performance offered by this technology. A delayed transition to 0.25-micron could result in extension of the pricing pressures experienced at 0.35-micron to this new technology.

Despite the competitive pricing environment that has existed for the past 18 months, dedicated foundry companies have managed to remain profitable. For the third quarter of 1997, Taiwan Semiconductor Mfg. Co.'s profit was up 28 percent over the previous year, and United Microelectronics Corporation's profit increased by 144 percent in the same period. The dedicated foundries view advanced technology capacity as essential to their sustained growth, so investment in this capacity is likely to continue in 1998, barring a major upheaval in Taiwan's capital markets. As previously mentioned, new entrants into the foundry market are expected to compete aggressively on price. To the extent that this competition causes profitability to deteriorate, capital spending plans for 1999 could be put at risk.

What about the Specifics of 1998?

For the past year, Dataquest has been calling for a "W" recovery pattern in wafer fab equipment, with the second-phase downturn being caused by the fundamentals of overcapacity and financial health eventually winning over the desire for technology. As this second phase now unfolds, there are questions for 1998. Dataquest believes it is important to look at the key spending assumptions for 1998.

Korean Companies

Korean companies accounted for just over 14 percent of all capital spending worldwide in 1997. Dataquest believes that all new Korean semiconductor investment projects have stopped in their tracks, and nobody has definitive answers as to when the situation will settle to the point that these projects can be restarted. In fact, the key issue to be looked at today is when and in what order the projects will be restarted for Korean companies. This forecast assumes that Korean companies will cut spending 40 percent in U.S. dollars (at an exchange rate of W 1,300/dollar). This totals about $3.3 billion for the big three companies.

Dataquest expects the situation to settle in Korea to the point at which a path for capital spending to follow can start by late spring. So which projects will be restarted? Because the U.S. fabs for Samsung Electronics Company Ltd. and Hyundai Electronics Company Ltd. are already essentially installed and operational, strategically, the European fabs would be placed ahead of any second phase in the United States. For this reason, Dataquest's forecast assumes that LG Semicon and Hyundai will restart the European projects first and perhaps take delivery of equipment very late in 1998. Samsung is likely to select a site in Europe in 1998 and possibly even break ground. The same could be said for LG Semicon in the United States. Further investment in the near term are likely to be domestic, including investment by Anam Semiconductor.

Taiwanese Companies

Taiwan's financial situation is the healthiest in Asia right now. The Taiwan foundries are still very profitable, and spending for 1998 seems fairly secure. Dataquest's forecast assumes that Taiwan foundry spending will increase over 40 percent to $4.3 billion.

Dataquest expects spending in DRAM capacity to remain at a high level. Some companies will cut spending, but companies such as Vanguard International Semiconductor Corp. (owned in part by TSMC) will actually increase spending heavily. Overall, in local currency, spending will be flat in the DRAM area but down about 15 percent in U.S. dollars.

Overall, Taiwanese spending is expected to increase about 13 percent in 1998 to $7 billion.

Japanese Companies

Japanese companies actually turned off spending very early in 1996 and have been spending only modestly during 1997. Dataquest expects this long-term and conservative approach to continue, with Japanese companies investing within their means and strategically. With the depreciation in the yen and the belief that near-term spending will be more "careful," this forecast assumes a 5 to 7 percent decline in 1998 in U.S. dollar terms.

300mm Equipment Investment

Investment in 300mm equipment has actually been increased in Dataquest's forecast for 1998, taking slightly different forms. Dataquest continues to believe that by the end of 2000, some eight to 12 pilot lines running 300mm wafers will be operational worldwide.

A "pilot line" is thought to mean a dedicated 300mm line with low-volume starts, representing between $500 million and 700 million of investment. Although this will be true for most companies, within Japan something different will take place. Japanese companies are expected to spend only $200 million to 300 million per company on equipment, placing it in an expanded "R&D center," without all the automation and in configurations that save capital. In this way, over the next two to three years, all the major Japanese companies will execute 300mm programs. Dedicated lines will come only after experience in the R&D center. This investment will begin strongly in 1998.

Dataquest's forecast is for $1.1 billion of wafer fab equipment (about 5 percent of the market) to be shipped in 1998, with more than half going into Japan.

Major U.S. and European Companies

The major U.S. and European semiconductor companies—Intel Corporation, Advanced Micro Devices Inc., IBM Microelectronics, Motorola Incorporated, Micron Technology Inc., Texas Instruments Inc., and the three major European companies—are expected to increase spending about 10 percent in 1998 as a group. This spending is seen to depend primarily on unit demand for semiconductors and is weighted toward logic processing.

Some of these assumptions may seem optimistic, and indeed Dataquest believes there is more downside risk than upside potential.

Downside Risk Scenario for 1998

As an aid to business planning for clients, Dataquest has developed a detailed second scenario for the 1998 wafer fab equipment market in order to give clients a "window" of outcomes possible if several of the key assumptions just outlined are changed. This section outlines only the forecast for 1998; for the most part, these changes simply reflect the timing differences of spending plans.

For the "downside risk" scenario, the following assumptions are made:

- Korean companies will cut back spending almost 60 percent in U.S. dollar terms, with at least one project in Europe falling out of 1998 (quite likely Hyundai's, because LG Semicon has significantly lower debt-to-equity ratios).
- Taiwanese companies' DRAM spending will be cut by 45 percent overall in U.S. dollar terms as funding from Japan is lost and profitability concerns govern loan approvals.
- Taiwanese foundry spending growth will remain at 40 percent, because the primary source of funds is the profitable players.
- Taiwanese company spending overall is therefore down only 2 percent, to $6 billion.
- Japanese companies will cut spending overall by 8 to 10 percent in yen terms, or 14 percent in U.S. dollar terms, compared to 1997.
- Spending on 300mm equipment will be reduced to $700 million, based on timing of shipments into Japan and the United States. Siemens' project appears safe in 1998 because the German government is funding a portion.
- The U.S. and European major companies that are increasing spending in 1998 will cut these levels back 5 to 10 percent. This places the group at a 4 percent growth and makes Intel's spending flat, compared to 1997. Philips Electronics NV, SGS-Thomson Microelectronics B.V., AMD, and now Motorola will continue to increase spending in this scenario for 1998.

Putting this all together, capital spending levels would be cut by about $3.7 billion compared to the 1998 forecast scenario, with these cuts reflected primarily in discretionary equipment spending and with all regions being affected. The wafer fab equipment market would be reduced by about $2.4 billion, with about 70 percent of the difference being related to lower DRAM spending.

Tables 3 through 5 detail how Dataquest would expect the forecast and downside risk scenarios to develop on both a segment and a regional basis.

Table 3
Capital Spending Forecast, 1998 Regional Scenarios (Millions of Dollars)

Regional Revenue and Growth	1997	1998 Forecast	1998 Downside Forecast
Americas	14,830	15,321	14,721
Growth (%)	5.1	3.3	-0.7
Japan	8,342	7,782	6,962
Growth (%)	-13.6	-6.7	-16.5
Japan (Billions of Yen)	1,001	1,012	905
Growth (%)	-4.7	1.1	-9.6
Europe	4,751	5,398	4,448
Growth (%)	-6.3	13.6	-6.4
Asia/Pacific	16,762	14,528	13,193
Growth (%)	3.7	-13.3	-21.3
Total Capital Spending	**44,685**	**43,029**	**39,324**
Total Growth (%)	**-0.7**	**-3.7**	**-12.0**

Source: Dataquest (January 1998)

Table 4
Wafer Fab Equipment Revenue Forecast, 1998 Regional Scenarios (Millions of Dollars)

Regional Revenue and Growth	1997	1998 Forecast	1998 Downside Forecast
Americas	c	7,665	7,290
Growth (%)	20.2	9.5	4.1
Japan	5,599	5,776	5,176
Growth (%)	-15.8	3.2	-7.6
Europe	2,753	3,390	2,791
Growth (%)	-1.8	23.2	1.4
Asia/Pacific	6.966	5,892	5,102
Growth (%)	8.7	-15.4	-26.8
Total Wafer Fab Equipment	**22,318**	**22,722**	**20,359**
Total Growth (%)	**2.9**	**1.8**	**-8.8**

Source: Dataquest (January 1998)

Table 5
Wafer Fab Equipment Revenue Forecast, 1998 Segment Scenarios (Millions of Dollars)

Equipment Segment	1997	1998 Forecast	Growth (%)	1998 Downside Forecast	Growth (%)
Worldwide Fab Equipment	**22,317**	**22,722**	**1.8**	**20,359**	**-8.8**
Steppers	3,623	3,861	6.6	3,524	-2.7
Photoresist Process (Track)	1,594	1,626	2.0	1,480	-7.2
Maskmaking Lithography	275	361	31.5	342	24.4
Other Lithography[1]	148	136	-8.7	116	-22.0
Total Lithography/Track	**5,641**	**5,984**	**6.1**	**5,461**	**-3.2**
Automated Wet Stations	1,207	1,131	-6.3	998	-17.3
Other Clean Process	486	479	-1.5	423	-13.0
Dry Strip	354	343	-2.9	313	-11.4
Dry Etch	3,107	3,004	-3.3	2,742	-11.7
Chemical Mechanical Polishing	516	718	39.2	672	30.2
Total Etch and Clean	**5,670**	**5,675**	**0.1**	**5,149**	**-9.2**
Tube CVD	753	817	8.6	684	-9.1
Nontube Reactor CVD	2,380	2,337	-1.8	2,084	-12.4
Sputtering	1,592	1,626	2.1	1,472	-7.6
Silicon Epitaxy	293	339	15.7	299	2.1
Other Deposition[2]	115	203	76.7	187	63.0
Total Deposition	**5,133**	**5,323**	**3.7**	**4,727**	**-7.9**
Diffusion	730	700	-4.1	586	-19.7
Rapid Thermal Processing	190	228	20.0	193	1.8
Total Thermal Nondeposition	**920**	**928**	**0.9**	**780**	**-15.2**
Medium-Current Implant	384	334	-13.0	303	-21.1
High-Current Implant	510	481	-5.6	407	-20.2
High-Voltage Implant	263	233	-11.6	197	-25.0
Total Ion Implantation	**1,157**	**1,048**	**-9.4**	**907**	**-21.6**
Optical Metrology	121	127	4.5	112	-7.3
CD-SEM	338	379	12.1	331	-2.2
Thin-Film Measurement	237	243	2.7	217	-8.6
Patterned Wafer Inspection	582	597	2.7	541	-7.0
Auto Review and Classification	261	278	6.4	246	-5.9
Auto Unpatterned Detection	157	153	-2.4	137	-13.0
Other Process Control[3]	606	637	5.1	554	-8.5
Total Process Control	**2,302**	**2,415**	**4.9**	**2,138**	**-7.1**
Factory Automation	1,090	971	-10.9	868	-20.4
Other Equipment	405	379	-6.3	329	-18.7
Total Factory Automation/Other Equipment	**1,495**	**1,351**	**-9.7**	**1,197**	**-20.0**
Total Wafer Fab Equipment	**22,317**	**22,722**	**1.8**	**20,359**	**-8.8**

Note: Some columns may not add to totals shown because of rounding.
[1]Includes contact/proximity, projection aligners, direct-write e-beam, and X-ray lithography
[2]Includes evaporation, MOCVD, MBE, and new categories of electrochemical deposition (ECD) and spin-on deposition (SOD) in 1998
[3]Includes manual detection/review and other process control equipment
Source: Dataquest (January 1998)

The U.S. market would be the least affected, with Asia/Pacific markets likely to see the largest negative impacts. The equipment technologies focused on enabling logic and 0.25-micron processing, such as CMP and deep-UV steppers, would not be affected much by these changed assumptions. However, the equipment segments dependent on capacity or DRAM-sensitive investment, such as diffusion tubes and implant, would be more heavily affected.

Although Dataquest believes that at least one of these downside assumptions will occur, the probability of a complete realization of the downside scenario is only 25 to 30 percent.

In summary, the sustainable recovery has been pushed out about six months, into late 1999. The industry is entering the second downturn of a "W" profile recovery at present, and uncertainty is the key word of the day. Companies will continue to concentrate on technology, with emphasis on 0.25-micron and 300mm technology. The industry clearly overspent again in 1997, and profitability of the semiconductor producers will now dictate near-term spending.

Should the downside scenario come to pass, there is a silver lining—the DRAM market will likely come into balance sooner, leading to stronger profitability in the chip sector and renewed higher growth in spending on equipment.

Silicon Wafer Forecast Review: Steady Recovery under Way

Silicon area growth for 1997 is estimated at 8 percent in terms of millions of square inches (MSI). Demand for 200mm wafers has come in about as forecast, but 150mm wafer demand was stronger than expected because of several factors, including a strong analog market, increased foundry demand from integrated device manufacturers (IDMs) at the lagging technology edge (the Tamagotchi effect), and increased semiconductor unit demand generally.

The wafer industry is in a recovery mode on a unit basis, with a sequential quarterly growth likely to be in the range of 1 to 4 percent for 1998, leading to a double-digit growth of over 12 percent for 1998. Dataquest expects growth to be maintained at that pace or slightly higher through the year 2000. The long-term CAGR is forecast to be 11.5 percent.

Supply is adequate across the board in the short and intermediate terms, including in the high-growth epitaxial wafer market. As a result, prices for 1998 are expected to be down from 1997 by another 7 to 10 percent.

Dataquest is in the process of updating the polysilicon supply/demand model, but the situation today has improved. The industry in nearing the safe zone for worldwide inventories.

The industry is ramping 200mm production adequately to meet demand fully in the near term, with production plans in place to meet demand for the next several years.

Dataquest's initial supply picture for 300mm wafers places the levels of production at about 200,000 per month or slightly above in 2000. Dataquest does not expect these plans to increase dramatically until commitments for production ramp-up by semiconductor producers are in place. Dataquest therefore does not expect prices to fall significantly below $1,000 for several years.

Questions and Answers

Question: I have several questions. First, the proportion of Korea's capital expenditure as a percentage of Asia/Pacific for the last two years has been close to 40 percent. What is your assumption for the forecast period, and do you see a crossover in capital expenditure coming from Taiwan, surpassing Korea, any time in the near future?

The second question relates to maskmaking equipment, which appears to have fairly strong growth ahead. Is that because write times are going up?

And the last question relates to the silicon forecast. What do you see as the mixture of test and epitaxial wafers and the influence on overall pricing? How do you see the pricing premium on epitaxial wafers in the foreseeable future?

Clark Fuhs (CF): Yes, actually we expect that the crossover will happen in 1998 for Taiwanese companies surpassing Korean companies in capital spending. We believe that the Taiwanese companies accounted for between 13 and 14 percent of the worldwide capital spending dollar in 1997, with Korean companies accounting for slightly more. Our forecast assumes that that will increase to 17 or 18 percent in 1998. So the crossover—where Taiwan is spending more than Korea—is happening in 1998.

I'll answer the silicon question first, and then turn to Klaus for the maskmaking issue. The silicon question, as I understand it, had to do with the various and different parts of demand—the test and monitor wafers part of the market versus the epitaxial part of the market. We see epitaxial demand growing stronger than overall demand by about 6 percentage points. Epitaxial wafers are still the high-growth market. Historically, the epitaxial premium has been between $1.60 and $2.00 per square inch, relative to prime wafers. We do not expect that to change fundamentally in the long term. However, we would expect that the near term may be closer to the lower end of that range than to the higher end and perhaps even go below the normal range in the very near term. This is simply because the suppliers have ramped up capacity throughout 1998 in anticipation of acceptance into the DRAM market and because they are ramping up a little bit above the most optimistic case or for the DRAM market penetration. There is aggressive pricing in the market right now. We see adequate supply in the epitaxial area.

In terms of test and monitor wafers, overall, about 21 percent of the market was test and monitor in 1996. That increased to about 24 percent in 1997, and it will be between 24 and 25 percent in 1998. That is purely a function of the fact that the 200mm market is ramping up, and that segment contains the highest percentage of test and monitor wafers.

Klaus Rinnen (KR): We do expect that the maskmaking industry will continue to grow at a fast pace. We expect it to outgrow, on a compound annual growth rate basis, the general market between 1997 and 2002—about almost double.

Both the optical and e-beam segments are expected to experience strong demand. This is driven by increasing unit demand for masks and the continuing drive to bring on line smaller line features and special capabilities. Unit demand for equipment is determined by the rapid increase in write times as the industry goes to smaller line widths and increased use of optical proximity correction and other techniques.

Q: Tables 1 and 2 show total wafer fab equipment growing at about 2 percent in 1998, whereas total capital expenditure is at about 4 percent. Can you give me the flavor of how the balance breaks out between back-end equipment and facilities and what growth assumptions you're assuming there?

CF: We do not cover the back end of the market specifically. But in a market like 1997's, where technology is favored and equipment purchases are favored over brick and mortar, the front-end equipment becomes a larger percentage of the overall capital spending dollar. That's basically why, in both 1997 and 1998, capital spending is going down slightly and wafer fab equipment going up slightly. And we expect the higher ASPs, quarter-micron technology investment, and lower relative spending on brick and mortar to carry over into 1998, as well.

The back end, of course, Dataquest does not cover. I would expect that, given some of the fundamental issues that are associated with the test industry, the tester market would outperform, in terms of capital spending, and the assembly market would, at least, be a market performer. So, back-end equipment overall would also tend to increase as a percentage of the overall capital spending dollar.

What's primarily being hit is the bricks and mortar. There were 47 fabs that came on line in 1996 and 44 that came on line in 1997, with most of the brick-and-mortar spending occurring in 1996 for those fabs. With only 32 fabs coming on line in 1998, brick-and-mortar spending is down on a relative basis.

Q: I realize that Dataquest primarily covers the front end, but in terms of the drivers for the back end, and specifically about testers, are you assuming that we will outperform the general market because of unit demand, because of growth in certain chip markets, or because of an upgrade cycle?

CF: We are stretching our ability to answer the question. But I understand the situation to be an upgrade cycle associated with the increase in speed of memory, primarily driven by the Intel PC 100 specifications. There is also new packaging technology that is associated with the Pentium II chip.

Q: This question ties into some of Dataquest's other programs' forecasts, but has the rapid and sustained decline of the DRAM market, which is obviously part of this whole scenario, accelerated plans? Are they being cut back? In other words, have your surveys in the last month gotten progressively worse or do you see this thing sort of bottoming out at this stage. I am curious, since the price of DRAMs has obviously collapsed, about what the latest scenario would be.

CF: Well, I think that the price collapse in the last quarter in the DRAM market is due, in part, to the continuing oversupply—the pricing actually started deteriorating in May—and also in part more recently to the currency issues in Asia. Dataquest published an estimate recently that, of the cost of making a DRAM chip in Korea, about 55 percent is won sensitive. That would basically tend to accelerate any downward pricing. It's our view that the current spot market price range of between $1.80 and $2.00 is probably where this thing is going to bottom. The question is, how long will it stay there? And when we will get some pricing relief, with a bounce back to a better market, in the $3.00 range—that's anybody's guess.

We're expecting this market to remain pretty depressed at the current levels for as long as the situation remains unclear in Asia. When the situation becomes a little bit clearer in Korea, in particular, and some of the fiscal issues get settled in Japan, perhaps by late spring to midsummer, we might see a rosier DRAM picture. But, until then, I think we're basically stuck with the current level.

Q: Is there any reason, just off the top of your head, to have the DRAM price bounce up a dollar at this particular juncture? Or is that just to be expected in very, very volatile markets?

CF: Well, I think anything bouncing up a dollar in the first half this year is going to be an aberration and not long lived. But, if you look at the historical pricing behavior going back into the 1970s, studying the monthly and quarterly price movements of the main product in DRAM (in today's market, that would be the 16Mb DRAM) during the initial stages of the transition, there normally is a price decrease, as we have seen. During the later stages of growth and maturity, approaching the peak, you usually run into a condition in the market that is more supply constrained, primarily driven by the fact that the silicon efficiency growth in bits per square inch has declined significantly. In these instances, the price has actually risen on average between 40 and 60 percent from the low and has been sustained for a number of quarters. So, if 16Mb DRAM remains the product of choice throughout 1999, then we would expect such pricing behavior to occur in the 16Mb DRAM.

Q: Given the DRAM overcapacity in Korea, how much capacity is being offered by the Korean manufacturers through the foundry market, and how long do you expect that that's going to be available?

CF: Whatever they can sell is what is available. And, from the perspective of the companies involved, LG Semicon has been in the foundry business for quite some time, for at least three years. So, in fact, we would expect it to increase its visibility and increase its allotted capacity on a permanent basis toward the foundry market. We believe it is LG's strategy to do that.

Samsung has publicly denied that it is in the foundry market, even though it really is in it. We would expect its capacity to come on board but be more opportunistic and remain in the market only as long as a less profitable DRAM market remains or as its other businesses are less profitable.

Hyundai has an established ASIC business with its unit in the United States. We would expect it to concentrate more on that business rather than the foundry business.

Q: Do you have an idea of how much capacity Samsung is offering?

CF: Unfortunately, we really do not have a firm figure. But, it could be significant. I would actually worry more about LG's capacity, because it has the ability to be permanently brought over.

Q: Earlier this year, in the Industry Strategy Symposium (ISS), there was a pretty large disparity between Dataquest's and VLSI Research Inc.'s view of capital spending and equipment spending. I'm wondering if you would care to comment, in particular, on what assumptions VLSI may have made that you would challenge.

CF: The proper answer to that question is, "No, I do not want to." But I will take a stab at it. I think in the question and answer session at ISS, it was quite clearly described that the difference between the 24 percent growth that VLSI Research has forecast for 1998 in wafer fab equipment and Dataquest's forecast of 2 percent growth is driven primarily by the difference in the assumptions about whether or not the Asian financial situation will have an impact on the near-term business. If you believe it will, as we do, then you're going to get a flat forecast.

If you believe that it will not and that capital in the semiconductor area will be impervious to the situation in Asia, then there will not be a secondary dip, there will be sequential growth in all quarters for 1998. When you run the numbers, you get a growth rate in the low 20 percent region. Data behind the 20 percent growth scenario also supports double-digit growth in Japan in U.S. dollar terms and minimal spending impacts from a depressed DRAM market. Those assumptions we do not agree with.

Q: Some of the leading logic manufacturers in the United States have indicated that they are going to put 0.18-micron technology into 200mm, delaying the transition to 300mm. They apparently do not see the economics paying back at 0.18 micron.

CF: Yes, there are two parts to the 300mm question. The first part has to do with when companies set up R&D or pilot lines associated with getting familiar with 300mm equipment and technologies. Although, in the near term, capital availability and equipment availability may affect that in a very limited way, we expect the bulk of the spending for R&D and pilot lines to go forward for 1998 and 1999.

The real question is when 300mm will become more economical than 200mm for a new fab. That is a subject of some debate right now. It increasingly looks as though 0.18 micron will be initially done on 200mm wafers. In the chip companies' minds, there are a lot of questions that have to be answered about the equipment costs. The key issue in the intermediate term is die size, the known driving force for economic payback in wafer-size transitions. At present, we believe that new 200mm fabs will be the most economical for some time yet. So our forecast is basically going forward with the fact that there will be many new 200mm fabs in 2001 and 2002. We think that production on 300mm wafers will probably start in some limited way in 2001, not before, but will not be in a sharp ramp-up mode until 2003.

Q: I didn't quite catch all the percentages you gave for your silicon segment and what they were about. Could you briefly restate those, please?

CF: Sure. The overall square-inch increase in silicon consumption in the world was 8 percent in 1997, relative to 1996. And the market in 1996 was 21 percent test and monitor, and in 1997, nearly 24 percent. The expected growth in 1998 is just over 12 percent growth in MSI, and 14 to 15 percent is basically the forecast per year for 1999 and 2000. The 1996-to-2002 compounding of growth rate is 11.5 percent.

Q: Could you comment on your forecast model with the different products mixes that the semiconductor producers will be turning out this year and the different assumptions about currency changes that will affect relative market shares of U.S. and Japanese equipment vendors?

CF: I'll answer the second one first. We normally do not like to comment on possible market share movements. But you can conclude from our forecast, with the U.S. and European markets stronger relative to the Japanese and Asian markets for 1998, that we would expect U.S. companies to gain, perhaps, a couple of points of share relative to Japanese companies in 1998. I think that's a conclusion that could be drawn fairly easily from the numbers we've published. The currency issues have already been taken into account in those forecasts.

The first question related to the assumptions. Our methodology is that, at the start, we make a set of assumptions on what technology is being purchased on an annual basis and on the split between memory investment versus logic investment. For 1996, 1997, and 1998, the memory investment was about 51, 41, and 30 percent, respectively, of the overall capital spending dollar. So the 1998 markets will be favoring, from a segment level, logic-based capacity additions rather than memory-based additions.

Q: In your forecast for equipment, you have ion implant declining a lot more than others, such as etch, deposition, and lithography. What's behind that?

CF: Ion implant is an overall capacity- and DRAM-sensitive segment, so it would tend to be hit a little bit more during the down cycles in the equipment market, which is related to the answer to the last question.

Lithography is also a capacity- and DRAM-sensitive segment. However, the migration from i-line to deep-UV is mitigating the normal downturn, because of an increased unit ASP. Etch and deposition is more logic sensitive and is related to an overall increase in the number of levels of metal, which in logic today is reaching five to six.

Q: Given that Korean companies tend to stay in the DRAM business, if they severely cut back on their capital spending plans, what do you think they'll be spending their money on other than lithography, maybe CMP, and etch? Would those be the main three areas?

CF: Well, I'm not sure that they are going to be any different from anybody else. They will be spending their money on what will give them more bang for the buck, enabling logic and quarter-micron technologies.

Q: Regarding DRAM pricing—do you see any reasons why there should be stable prices, if there is such a thing, above $3.00 in 1998?

CF: I can't add anything to the DRAM price forecast comments that we've already covered.

Q: On the silicon question: The pricing there has not been too terrific, either. I'm looking at your 8 percent and 12 percent growth forecasts, or the compounded annual growth. Has there been too much capacity added there, also? Or is it just the normal, big growth of the market driving that silicon usage?

CF: The silicon consumption that I just mentioned is a demand forecast, not a capacity forecast. Demand is going to be related more to semiconductor chip demand than to prices, and there is not much price elasticity in overall market demand there. The market does not consume or sell more wafers because they are cheaper. So, the demand forecast is really independent of the pricing environment.

Prices are under pressure in the silicon wafer market primarily because the suppliers are adding capacity at a rate faster than market growth.

Q: In Table 5, factory automation is shown at about 11 percent contraction for 1998. My question is kind of twofold. What would be a compound annual growth rate be for that looking a little bit further than one year? And then, second, a related issue: Environment isolation technology and factory automation at 300mm is, obviously, because of standard setting activity, going to be much more relevant to new fab construction costs. I'm wondering whether there will be a trend in the 200mm fabs yet to be built migrating toward that technology so there isn't one more lesson to learn going to 300mm.

CF: The compound annual growth rate of factory automation is 16 percent, about four points above the market. So, long term, we expect this segment of the business to indeed grow significantly faster than the market.

What's happening in 1998 is a combination of two things. First, there are just fewer fabs coming on line. Second, a lot of the activity in 300mm is not, in 1998, going to be sensitive to automation. As a result, 300mm automation business has slipped into 1999, and that is why the factory automation market is being hit a little bit more than the average in 1998.

In the longer term, the number of fabs will increase again in 2000. Fabs being built in 2000 and after, even for 200mm wafers, are expected to increasingly employ the 300mm standard automation systems, with isolated environments, simply because that standard will be the low-risk path that leaves open the possibility—however unlikely—of upgrades to 300mm wafers in the future.

Perspective

Semiconductor Contract Manufacturing Services Worldwide

Market Analysis

The Depreciating Won and Its Effect on the Foundry Market

Abstract: *The recent depreciation of the won will have a dramatic effect on the manufacturing costs of Korean semiconductor companies. Some of these companies have already entered, or will enter, the foundry market. What are the implications of this surge in low-cost capacity for the foundry market? This Perspective will examine the components of DRAM manufacturing cost in Korea and extend the analysis to foundry manufacturing.*

By James F. Hines, Clark J. Fuhs, and Jim Handy

Korea's DRAM Costs: What a Difference a Low Won Makes

With the significant depreciation of the Korean won against other world currencies, there has been concern about the effect of the won's slide on worldwide DRAM prices. Dataquest finds that there is a misconception about the magnitude of the effect of the depreciation of the won on the DRAM. Many think that prices will not be affected significantly by the won's recent 50 percent devaluation against the dollar. This is as far from the truth as it could be. The won's devaluation should be expected to have a phenomenal near-term effect on the asking price for a 16Mb DRAM in today's oversupplied market. Figure 1 shows a DRAM cost breakdown.

Current DRAM prices are cost-based. This means that most manufacturers are selling their DRAMs at the minimum prices they can justify. The bottom price of DRAM sales to the United States and Europe is limited by antidumping legislation—in order to protect local suppliers, DRAMs are not allowed to be sold into these markets at prices below their cost to manufacture.

The natural question to ask, then, is what effect the falling won will have on the cost to manufacture a 16Mb DRAM. The following is an estimate of the

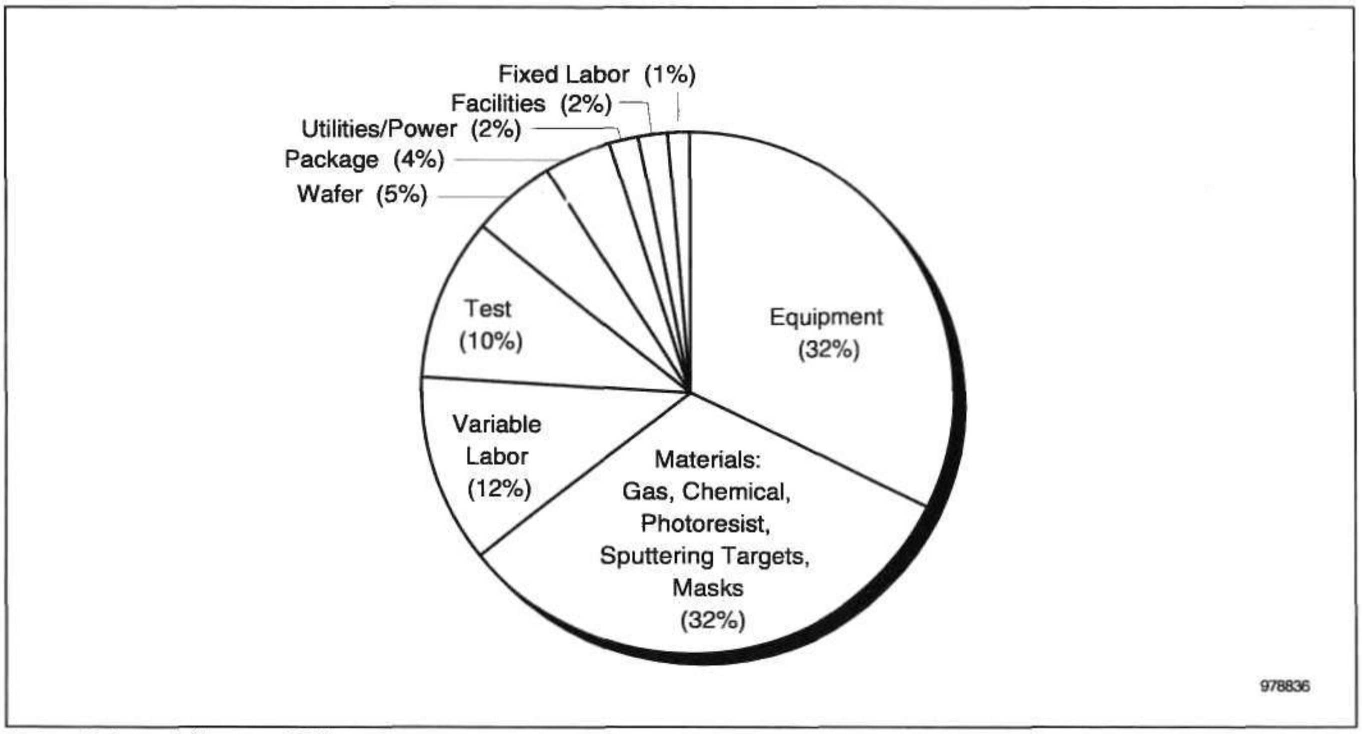
Dataquest

Program: Semiconductor Contract Manufacturing Services Worldwide
Product Code: SCMS-WW-DP-9801
Publication Date: February 2, 1998
Filing: Perspective
(For Cross-Technology, file in the Semiconductor Regional Markets and Manufacturing binder)

percentage breakdown of these costs, along with each component's sensitivity to the exchange rate. Transactions based in won are likely to become extremely inexpensive to the world market, while Korean transactions carried out in foreign currencies are likely to move very little.

- Equipment: Equipment costs account for about 32 percent of the cost of a DRAM chip. Although some in the United States believe that Korean DRAM manufacturers' cost of equipment is realized in foreign currency, this is true only in the rare cases in which an equipment manufacturer leases its product to the fab. In most cases, the capital equipment is purchased with a bank loan. Many of these loans are guaranteed by the Korean government and are drawn on Korean banks in won.
- Materials: Materials consume about another one-third of the cost of the DRAM. They can be broken down into several components, the majority of which are won-based, thus likely to impact the foreign cost of a DRAM when translated to a foreign currency:
  - Gas: Gases tend to be locally produced, either through an on-site plant or at the chemical manufacturer. Because very little in the way of bulk gases is likely to be imported, these transactions tend to be in local currency. Only a few, more exotic specialty gases are imported.
  - Chemicals: With the exception of certain exotic chemicals, Dataquest finds that the chemicals used in Korean wafer fabs are from the chemical-producing arms of Korean conglomerates. Once again, these would be purchased in won, and prices would not fluctuate much during this sort of devaluation.

Figure 1
Breakdown of Costs of a DRAM IC



Source: Dataquest (January 1988)

- Photoresist: Photoresist is one material likely to be purchased from a foreign supplier, such as Shipley, TOK, Hoechst, or others. These prices would increase in a devaluation of local currency.
- Sputtering targets: A high percentage of sputtering targets is produced by non-Korean suppliers such as Tosoh and MRC. These transactions are most likely to be conducted in foreign currencies at depreciated won exchange rates.
- Masks: There are mask shops in Korea that are probably used by all Korean manufacturers. Further, some of the large manufacturers have captive maskmaking operations. Payment to these shops would be in won; however, the raw glass used to make these masks will be procured from foreign suppliers using foreign currencies.

- Labor: The cost of labor (fixed plus variable) usually accounts for only 13 percent of the overall processing costs of the DRAM.
- Test: The 10 percent or so of a DRAM's cost involved in test follows much of what has been said here about equipment and labor. Workers are paid in won. Bank loans are made in won. These costs will follow the depreciation of the won against foreign currencies.
- Wafers: Raw wafers are produced in Korea for LG Semicon Co. Ltd. by LG Siltron and for Samsung Electronics Company Ltd. by Posco-Huls. Wafer cost accounts for about 5 percent of the cost of a DRAM. The only Korean manufacturer that would need to purchase a significant portion of its raw wafers from a foreign source would be Hyundai Electronics Company Ltd. With the exception of Hyundai, this cost is likely to fall with the falling won.
- Packaging/assembly: The 4 percent attributed in Figure 1 to packaging is a particular strength of Korean companies. As such, it is a business that is most likely to be conducted in won, and packaging costs should fall with the fall of the won.
- Utilities/power and facilities: Combined, these two categories account for about 4 percent of the cost to manufacture a DRAM. All of these are won-based in Korea and will fall with the falling won exchange rate.

There is some issue about the equipment costs. Some point out that any increases in capital expenditure will need to be transacted in dollars or yen. Although this is true, capital expenditure made in the current year is generally slated for use in production one or two years in the future. This means that any equipment being used to produce today's DRAMs was purchased before the won's slide.

Even so, there is some question of how the equipment is carried on the books. Korean tax laws allow the depreciation of fab capital equipment within 18 months to two years. Although the internal bookkeeping for these companies for the purposes of Korean tax laws may have already completely depreciated the equipment used in the fabs, there is the likelihood that the U.S. Department of Commerce or the European Commission will require a new set of books to be drawn up using a less aggressive depreciation schedule for use in any antidumping suit.

If a Korean DRAM manufacturer is paying for its equipment in won, then who bears the burden of a currency devaluation? The banks are shouldering this, and this is part of the reason why an International Monetary Fund bailout was needed early in December.

The upswing of this entire argument is that the costs to produce a DRAM in Korea are, at a minimum, 55 percent linked to the won and are quite likely more sensitive than that to the won's fluctuations. This implies that other countries are a very long way from seeing the bottom of 16Mb DRAM prices. Dataquest would not be surprised to see 16Mb DRAMs contracts drawn at prices below $2.50 by the middle of 1998.

Effect on the Foundry Market

With all the overcapacity in the DRAM market, some memory producers are looking to foundry as a way to fill their fabs with reasonably profitable product. Although there are some differences between DRAM and logic process flows, the foregoing analysis of DRAM manufacturing costs can be reasonably applied to foundry as well. Korean producers entering the foundry market will be competing against the leading dedicated foundry suppliers of the world, which happen to be concentrated in Taiwan. Although the New Taiwan dollar has undergone some depreciation in recent months, it has not come close to the dramatic declines experienced by the South Korean won. Therefore, just as won-based costs will be lower relative to costs denominated in U.S. currency, they will also be lower relative to costs denominated in Taiwanese currency, giving Korean producers a manufacturing cost advantage over their Taiwanese competitors and an opportunity to compete as aggressive price leaders.

Consider the perspective of the foundry customer for a moment. As with any other business, the foundry customer, whether it is a fabless semiconductor company, integrated device manufacturer (IDM), or system OEM, is always motivated to reduce costs as a means to greater profitability. Lower foundry wafer prices are good because they translate directly into lower cost of sales. But there are other costs and risks that must be considered in deciding where to buy foundry services. Three of the major considerations are:

- The cost of changing suppliers
- The ability of the supplier to meet future production requirements
- The risk of loss of intellectual property

When a company outsources some or all of their wafer production to a foundry, that foundry becomes a critical supplier of a complex technology that can greatly impact the prospects of the company. Great care must be taken to qualify the foundry's manufacturing process before committing production to it. Failure to do so could result in quality or reliability problems that will seriously disrupt production in the best case or possibly kill a product, especially in the fast-moving markets in which most fabless companies participate. That is why foundry customers follow a stringent qualification procedure that can take six to nine months to complete and tie up a significant portion of engineering resources. This is the cost of changing (or adding) foundry suppliers.

Today, with ample foundry capacity available and more being offered at ever lower prices, it is easy to forget that the situation was completely different a relatively short time ago. In early 1996, foundry capacity was not sufficient to meet demand, and many would-be foundry users had to go without—or at least make do with fewer wafers than they really needed. Foundry capacity, just like DRAM capacity, is cyclical in nature, and the day will come again when there is not enough to go around. How will those IDMs who made an opportunistic play in the foundry market allocate their finite capacity then, and what will it mean to their customers? These are the questions potential foundry customers must ask themselves, and they must then weigh the answers against the benefit of a lower price.

The essential difference between the dedicated foundry, as exemplified by Taiwan Semiconductor Mfg. Co., and the IDM foundry is that the dedicated foundry has no intention of ever competing with its customers. The IDM foundry may or may not compete with its customers, now or in the future—there are no guarantees either way. In order for a foundry to produce wafers for their customer, they need the design, usually in the form of mask sets or GDS *II* tapes. In some cases, these designs are laden with valuable intellectual property that the customer must place in trust with the foundry. The assurance of protection, offered by virtue of the dedicated foundry company's business charter, will have a very real value to some foundry customers.

In general, fabless companies and system OEMs are most sensitive to these issues. These customers are most likely to accept a reasonable price premium to remain with their existing dedicated foundry supplier. IDM customers might be more willing to accept some of these risks since they are relying on the foundry for a relatively small portion of their production, and as a result they will demand lower prices. Korean suppliers offering low-priced foundry services are likely to be most successful in attracting these IDM customers.

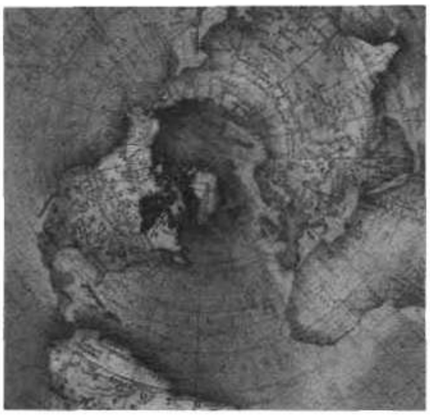
Dataquest Perspective

Foundry customers will evaluate suppliers and prices based on the overall impact on their costs. The factors described earlier, and perhaps others, will determine the premium a particular customer is willing to pay to obtain a higher level of service from one foundry provider over another. After all, semiconductor contract manufacturing is ultimately a service business, and that service has a measurable value. On the other hand, foundry suppliers have an interest in protecting their customer base, especially in times of excess capacity and increased competition. Foundry suppliers can be expected to respond to the competitive pricing environment to the extent needed to convince their customers that they are receiving fair value within the context of current market conditions.

Dataquest expects the main effect of the depreciation of the won on the foundry market to be a new wave of price cutting, primarily at the 0.35-micron and 0.5-micron technologies. The leading dedicated foundries will have to respond to some extent, but they will also work diligently to justify a price premium based on differentiated value in service. Therefore, Dataquest does not expect these companies to lose significant market share, but profit margins are likely to be adversely affected by intensified price pressure.

Korean memory producers will win some foundry business on the merit of being the lowest-priced suppliers. However, the cost of changing suppliers, concerns about future supply availability, and concerns over protection of intellectual property will dissuade many fabless companies, and perhaps some IDMs, from abandoning their dedicated foundry suppliers. These price leaders will attract mainly IDM customers that will view them as a short-term source of cheap wafers.

For More Information...
James F. Hines, Principal Analyst .... (408) 468-8605
Internet address .... james.hines@dataquest.com
Via fax .... (408) 954-1780
Dataquest Interactive .... http://www.dataquest.com



Dataquest

Year-End 1997 Forecast: Semiconductor Contract Manufacturing

Market Trends

Program: Semiconductor Contract Manufacturing Services Worldwide
Product Code: SCMS-WW-MT-9801
Publication Date: April 24, 1998
Filing: Market Trends

Year-End 1997 Forecast: Semiconductor Contract Manufacturing

Market Trends

Program: Semiconductor Contract Manufacturing Services Worldwide
Product Code: SCMS-WW-MT-9801
Publication Date: April 24, 1998
Filing: Market Trends

Table of Contents

List of Figures

List of Tables

Chapter 1
Executive Summary

The scope of this forecast is defined to include contract manufacturing of semiconductor wafers, including turnkey foundry services that combine back-end operations with front-end wafer fabrication.

Historical semiconductor contract manufacturing (SCM) market estimates have been revised downward, resulting in new estimates of $5,067 million in 1995 and $5,136 million in 1996. Regional splits have been redistributed, so that some SCM sales in Asia/Pacific are moved to other regions to account for an error in reporting the sales by region.

Dataquest defines four distinct capacity segments of the SCM market—leading-edge and mainstream memory, leading-edge and mainstream logic, lagging, and senior.

Worldwide SCM capacity, measured by total silicon area, is projected to grow at a compound annual growth rate (CAGR) of 21.5 percent from 1996 to 2001. Capacity growth will be led by the dedicated foundries, with a CAGR of 31.1 percent.

Analysis of the segmentation of SCM capacity reveals a shift toward the leading-edge/mainstream logic class of capacity at the expense of lagging technology. This trend is being driven by aggressive investment in leading-edge capacity on the part of dedicated foundries, which is creating a "technology bubble" of SCM capacity.

Worldwide SCM demand, in terms of millions of square inches (MSI), will grow at a CAGR of 22.4 percent from 1996 to 2001. Demand growth will be led by fabless semiconductor companies, with a CAGR of 27.5 percent; integrated device manufacturer (IDM) demand still outpaces general industry growth with a CAGR of 19.9 percent. SCM demand segmentation also favors the leading-edge/mainstream logic area, but not to the same extent as capacity.

Excess capacity in all four segments is projected for the years 1998 and 1999, decreasing in 2000 and 2001, with capacity shortages appearing in the lagging and senior segments. There is evidence of a "technology glut" developing in the foundry market, because demand for leading-edge technology has not kept pace with the rapid deployment of new capacity.

Senior capacity is projected to be in shortage by 2000, and capacity cannot be easily transferred from other segments. This could be an opportunity for foundries specializing in senior technologies.

The SCM market is forecast to reach $13.8 billion in 2001, representing a CAGR of 21.9 percent. A competitive pricing environment in the SCM market will persist throughout 1998, driven by continued excess capacity, and this will dampen revenue growth in the year despite strong growth in SCM demand on an MSI basis.

Competitive pricing pressures in the leading-edge segments can be expected to persist throughout most of 1999 as foundry capacity additions outpace demand growth. However, an increase in average price per square inch for the market as a whole will be driven by a shift to leading-edge technology.

The SCM market will experience exceptional growth in 1999 and 2000 when the foundry market will follow the overall semiconductor industry into a period of strong demand growth. The boom cycle is expected to continue through 2000 before industry capacity overshoots demand again in 2001. Demand for SCM services will be boosted in 2001 by IDMs that wish to avoid building the first 300mm or the last 200mm wafer fab.

Project Analyst: James F. Hines

Chapter 2
Introduction and Definitions

Highlights of This Chapter

The highlights of this chapter are as follows:

- The scope of this forecast is defined to include contract manufacturing of semiconductor wafers, including turnkey foundry services that combine back-end operations with front-end wafer fabrication.
- Historical SCM market estimates have been revised downward, resulting in new estimates of $5,067 million in 1995 and $5,136 million in 1996.
- A redistribution of the regional splits is explained—some SCM sales in Asia/Pacific are moved to other regions to account for an error in reporting the sales by region.
- Four distinct capacity segments are defined that will be used to characterize the SCM market. These are leading-edge and mainstream memory, leading-edge and mainstream logic, lagging capacity, and senior capacity.
- Demand-side and supply-side research methodologies are reviewed, showing the primary sources of information and key assumptions applied to the forecast.
- A list of definitions is included for terms used in this report and in other Dataquest publications on semiconductor contract manufacturing.

Introduction to Semiconductor Contract Manufacturing

The term "semiconductor contract manufacturing," as used in this report, refers to wafer fabrication services provided by a semiconductor wafer foundry. At present, Dataquest limits the definition of SCM to the wafer processing part of semiconductor manufacturing, also known as "front end" operations. Therefore, contract manufacturing of packaging, assembly, and test, or "back end," operations are excluded from this forecast. An exception to this rule is the case of the "turnkey" foundry, which provides the entire complement of manufacturing services, from wafer processing to packaging, assembly, and testing of finished integrated circuits and, in some cases, drop shipment to the end customer or distribution channel. Turnkey foundry services are included in our present forecast of the SCM market.

Revisions to Previous SCM Market Estimates

During the last SCM market share survey, conducted last fall, Dataquest determined that previous estimates for the size of the SCM market in 1995 and 1996 had been overstated. To bring these estimates in line with the most recent survey results, they were corrected in the report, *1996 Semiconductor Contract Manufacturing Market Share Estimates* (SCMS-WW-MS-9701, November 1997). This revision of historical market data has resulted in estimates for the worldwide SCM market that are 17.6 percent lower in 1995 and 21.1 percent lower in 1996. Table 2-1 compares the previous estimates with the revised numbers that are used as the basis for this forecast.

Table 2-1
Previous and Revised SCM Market Size Estimates, 1995 and 1996
(Millions of U.S. Dollars)

	Previous Estimate		Revised Estimate		Percentage Change	
	1995	1996	1995	1996	1995	1996
Americas	3,167	3,536	2,708	3,183	-14.5	-10.0
Japan	2,215	1,994	1,294	616	-41.6	-69.1
Europe, Africa, and Middle East	598	639	356	405	-40.5	-36.6
Asia/Pacific	172	338	708	932	312	176
Worldwide	6,152	6,506	5,067	5,136	-17.6	-21.1

Source: Dataquest (February 1998)

While Dataquest's estimates have been significantly lowered for all regions except the Asia/Pacific region, the greatest impact in absolute terms is in Japan. Our previous sizing of the Japanese foundry market overestimated the size of the "internal" Japanese market, which we believed to consist mainly of trading in older capacity to the mutual benefit of the large Japanese IDMs. Although we believe this practice continues as a means of concentrating production of mature products in fewer old fabs, it is a smaller portion of the Japanese SCM market than previously thought.

The large relative increase in the estimates of the Asia/Pacific SCM market are due in part to an error in reporting the regional split of SCM sales during the market share survey. Dataquest defines the region of sale by the location of the foundry customer, that is to say, the location from which the purchase order originates. In other words, the region of sale is determined by the invoice address, which is not necessarily the same as the ship-to address. The inflated Asia/Pacific numbers most likely represent finished foundry wafers that were shipped to back-end subcontractors, located in the Asia/Pacific region, for subsequent packaging, assembly, and test operations before ultimately being shipped to the original foundry customers. For purposes of this forecast, about $600 million of these sales have been redistributed to the other regions for the baseline year, 1996, to reflect this consideration.

The semiconductor contract manufacturing market structure development is and will continue to be directly related to the infrastructure for managing capacity generally in the semiconductor industry. Most of the attention in the last couple of years has been paid to the leading-edge and mainstream markets in which the fabless companies and dedicated foundry suppliers have been dominant. However, this represents only one of four different silicon-based capacity segments of the semiconductor industry.

Semiconductor Industry Capacity Infrastructure's Four Segments

To understand how the SCM market segmentation is likely to develop, it is critical to understand how and why the semiconductor industry has divided into four subsegments of capacity. Each of these four subsegments has independent capacity supply and demand characteristics, as well as barriers to entry or conversion that are typical. There is some interaction among the four subsegments; however, the nature of the barriers requires some time lag before interactive characteristics affect capacity.

Leading-Edge and Mainstream Memory Capacity

When the subject of memory is raised, DRAM comes first to mind. Indeed, more than 80 percent of the industry's memory capacity is used to produce DRAM, and for at least the last 20 years, DRAM has been a key driver for process technology. In 1997, the mainstream line width for DRAM production was 0.4 to 0.45 micron, with leading-edge technology at 0.35 to 0.32 micron and new products announced at 0.25 micron. Deep-UV lithography is starting to be implemented for critical layers.

The process flow characteristics of DRAM include three to four levels of polysilicon but only two levels of metal. Unique to this class of capacity is the process flow and knowledge to make a storage capacitor. Process flows that are not typically included are the widespread use of chemical mechanical polishing (CMP) and the process flow for creating a self-aligned silicide structure. Epitaxial silicon layers are also not typically used with DRAM.

The process flows included in this class of capacity for DRAM most directly match flash memory, and other nonvolatile memory devices. SRAMs can also be easily built using the process flow ingredients noted for this capacity class. However, without the self-aligned silicide flow to increase speed by means of a local interconnect, the SRAMs built in this type of fab would generally be limited to the commodity or slower SRAM markets.

Memory capacity's share of the capital spending dollar fluctuates between 30 and 50 percent but averages about 40 percent overall. At the end of 1996, the memory class of capacity represented about 25 percent of overall worldwide silicon consumption and about 63 percent of capacity at below 0.5 micron.

To be able to produce and compete effectively in the memory markets, fabs in other capacity classes would have to add capital to align with leading-edge linewidths and to include capability for the unique storage capacitor and additional polysilicon levels. This production market is one of the easier leading-edge areas to enter because the technology is well understood and easily purchased. Therefore barriers to entry exist, but are really limited to the availability of adequate capital.

Leading-Edge and Mainstream Logic Capacity

The leading-edge and mainstream logic capacity class has perhaps the broadest range of product classes that could be manufactured. For this reason, supply/demand analysis of individual types of products is not a practical exercise. In 1997, the mainstream line width for logic production was 0.45 to 0.55 micron, with the leading edge at 0.35 to 0.32 micron and new products announced at 0.25 micron. This line width range is nearly identical to that of the memory class, with the exception that the mainstream lags slightly. Deep-UV lithography is starting to be implemented for critical layers and, at 0.25-micron, could be used in about 40 to 50 percent of the mask layers.

The process flow characteristics of mainstream and leading-edge logic include two levels of polysilicon and three to six levels of metal. Process flows typical in this class of capacity are the widespread use of CMP, the process flow for creating a self-aligned silicide, and experience with the use of epitaxial silicon layers. Trench isolation techniques and process flows are starting to be required at the 0.25-micron level. The process flow and knowledge to make a storage capacitor has not typically existed in this class of fab capacity.

Virtually any kind of advanced logic or application-specific IC (ASIC) product could be manufactured in this kind of capacity. It is the capacity generally found within the dedicated foundry market today, primarily because the customer base of fabless companies competes in this product class. SRAMs can also be built using the process flow ingredients noted for this capacity class. Because the self-aligned silicide flow to increase speed by means of a local interconnect exists, the SRAMs built in this type of fab would generally be intended for the fast SRAM markets.

Advanced microprocessors also could be produced in this class of capacity. Although this is a simplistic representation, from a manufacturing perspective, the MPU is really a collection of memory cells and wiring. In the mid-1980s, both Intel Corporation and Motorola Incorporated migrated the memory cells in the SRAM design, rather than the DRAM cell, to increase processing speed. The increased area for an SRAM cell is not a large concern in MPU design. What emerged from these efforts is the fast SRAM market, in which Motorola has been one of the leaders.

Leading-edge logic capacity also fluctuates between 40 and 60 percent of the capital spending dollar (depending on the DRAM investment cycle), but in raw dollar terms is fairly stable and countercyclical, averaging about 50 percent overall. At the end of 1996, the advanced and mainstream logic class of capacity represented about 33 percent of overall worldwide silicon consumption and about 32 percent of capacity at below 0.5 micron.

Fabs in other capacity classes would have to add capital to align with leading-edge linewidths and to include capability for the unique self-aligned silicide process and the additional metal levels and CMP needed to produce and compete effectively in the advanced logic markets. This production market is one of the more difficult to enter because the technology is specialized and not easily purchased. Therefore, barriers to entry are high but can be hurdled with adequate capital and a technology partner or internal development. There is normally a significant time lag for this kind of conversion.

Lagging-Edge Technology Capacity and Product Segments

The lagging-edge capacity class also has a broad range of product classes that could be manufactured. In 1997, the mainstream line width for lagging product production was 0.7 to 0.9 micron (but could be as high as 1.2 micron), with leading edge at 0.55 to 0.6 micron and new products announced at 0.45 micron. The lithography being employed is generally a mix of g-line and i-line.

The process flow characteristics of lagging-edge logic include one or two levels of polysilicon and two levels of metal. The process flow and knowledge needed to make a storage capacitor has not typically existed in this class of fab capacity. Process flows that are not typically included are any use of CMP and the process flow for creating a self-aligned silicide. Epitaxial silicon layers are also not typically used with DRAM. The storage capacitor process flow could be, but is not typically, used in this class of capacity.

The type of products that make up the bulk of this capacity class are analog, mixed-signal analog, microcontrollers, optoelectronics, older memory generations, and some low-end logic products.

Lagging-edge capacity represents only between 5 to 7 percent of the capital spending dollar. At the end of 1996, the lagging-edge class of capacity represents about 18 percent of overall worldwide silicon consumption but only about 5 percent of capacity at below 0.5 micron and only for the most advanced mixed-signal capability.

Capacity additions are required for this class of capacity over time because the market for this set of products is growing, but the way capacity is added is quite different. Since the revenue generated per square inch of silicon is between 35 and 50 percent of that generated by leading-edge or mainstream products, suppliers cannot afford to spend much on manufacturing facilities and still maintain profitability. Therefore, they rely heavily on the used equipment market for adding new capacity. The other way capacity is added to this segment is by allowing older memory capacity to "trickle down," typically from the DRAM area. For example, most of the 0.5- to 0.6-micron capacity available now in Japan and Korea in this segment was producing 4Mb DRAMs in 1995.

Fabs in the leading-edge capacity classes would not have to add capital to migrate capacity to this segment, and thus manufacturing barriers to entry are not high. However, some barriers may exist in product design, particularly in analog and mixed signal, which may mean some delay in employing excess capacity.

Senior Technology Capacity and Product Segments

The senior technology capacity class can manufacture a relatively narrow range of product classes, almost all in the power and discrete areas. In 1997, the mainstream line width for senior technology production was 1.2 to 10.0 microns, with the leading edge at 0.9 to 1.0 micron and new products announced at 0.8 micron. The lithography being employed is generally a mix of g-line steppers and projection aligners.

The process flow characteristics of senior technology are unique and include perhaps one level of polysilicon, one level of aluminum metal on the front side, and back-side metallization schemes that may include alloys of nickel or chromium. The process flow and knowledge to make a power or discrete device are very specialized and include knowledge of how to handle very heavily doped boron, arsenic, or antimony substrates, with epitaxial silicon thickness ranging from 10 to 250 microns. Leading-edge logic epitaxial silicon is typically 5 to 8 microns thick. Specialized deep diffusion processes are also part of the process flow.

The types of products that make up the bulk of this capacity class are bipolar power transistors, power MOS field-effect transistors (MOSFETs), insulated gate bipolar transistors (IGBTs), power diodes, thyristors, small-signal diodes, and smart power devices.

Senior technology capacity represents only between 2 and 4 percent of the capital spending dollar. At the end of 1996, the senior technology class of capacity represented about 24 percent of overall worldwide silicon consumption (higher than the lagging technology segment) and none of the capacity below 0.5 micron.

Capacity additions are required for this class of capacity over time because this class' set of products represents a growing market, but the way capacity is added is different from other classes. Because the revenue generated per square inch of silicon is below even the lagging-edge capacity class, suppliers cannot afford to spend much on manufacturing facilities and maintain profitability. Therefore, they rely almost exclusively on the used equipment market for adding new capacity. Capacity additions by way of "trickle down" are also not typical because the process flow requirements are so vastly different. Most new capacity is added by companies already participating in the product markets.

Fabs in other capacity classes would have to inject significant capital to align with capability for the unique process flow requirements and the additional equipment and specialties to produce and compete effectively in the power and discrete markets. There is also a product design barrier, which may mean some delay in employing excess capacity. This means that the barriers to entry are actually quite high in this capacity class.

Forecast Methodology

Dataquest uses several sources of information in formulating a forecast for the SCM market. Because of Dataquest's breadth of coverage of the semiconductor and related industries, market research conducted in diverse areas can be leveraged for a highly informed perspective on the trends affecting the foundry market. In general, these sources are used to provide a baseline reference and to identify the most important trends that will influence the forecast. These include:

- Annual survey of SCM service providers for total SCM revenue, technology split, product types, regional distribution, and sales by customer type (IDM, fabless, or systems OEM)
- Annual survey of all worldwide semiconductor suppliers for market share, in which respondents are also asked to report total sales and purchases of SCM services for the year
- Foundry wafer pricing survey conducted three times per year
- Worldwide database of current and planned semiconductor wafer fabrication facilities (the fab database), which is maintained with an annual survey of semiconductor manufacturers and quarterly updates based on public announcements of new projects, accelerated or delayed plans, and closures

- The Dataquest semiconductor market forecasts, by product type and applications segment
- Individual company interviews and additional information obtained in the course of interaction with the SCM supplier and user communities

Demand-Side Research

Demand for SCM services comes from three types of companies. Fabless semiconductor companies design and market semiconductor products, but because they do not have their own fabs, they rely entirely on foundries for the manufacture of their products. IDMs design, manufacture, and market semiconductor products, using their own production facilities. However, these companies will often outsource a portion of their wafer production needs to foundries for a variety of reasons. Systems OEM companies are engaged in an electronic systems business, but they often design a specific semiconductor device for use in their end product. Lacking semiconductor fabrication facilities, systems OEMs, like fabless companies, rely completely on foundries to manufacture these semiconductor devices. Each of these demand segments has unique characteristics, and as a result, Dataquest adopts different approaches to forecasting the demand for each of them.

Fabless Semiconductor Companies

The fabless phenomenon arose from the dramatically lower capitalization requirements made possible by the emergence of the dedicated foundry. This facilitated the birth and rapid growth of many fabless start-up companies that no longer had to raise enough capital to build an entire wafer fab. The fabless sector, by its very definition, is highly dynamic, with many start-ups and many failures, with a few companies fortunate enough to hit on a successful product and ride the wave as long as they can. It is impossible to predict with absolute certainty which among the fabless will be the winners and losers. We do know, however, that the fabless model is a success and that the growth of fabless companies as a whole is likely to outpace the semiconductor market.

To forecast the demand for foundry services from fabless companies, Dataquest has adopted a top-level approach, rather than a company-specific bottom-up analysis. This has been done for the simple reason that there is so much "churning" in the fabless sector that the top players five years from now are likely to be quite different from the top players today. Based on historical penetration levels of fabless companies in the semiconductor application markets of data processing, communications, industrial, consumer, military/civil aerospace, and transportation, future penetration levels are projected. For the overall semiconductor market, the collective market share of fabless companies is projected to increase from 4.8 percent in 1996 to 7.5 percent by 2001.

Assumptions about the penetration levels of fabless companies in the semiconductor application markets combined with the forecast for these markets gives a revenue forecast for fabless companies. Making a further assumption about the average revenue per square inch of silicon that these companies generate produces a forecast of demand for processed silicon in MSI per year. This particular ratio, which can be thought of as a silicon productivity metric, is a function of product type, technology, and pricing environment. Table 2-2 shows trends for end-chip revenue per square inch for various product and technology segments.

Table 2-2
End-Chip Revenue per Silicon Area by Product and Technology (Dollars per Square Inch)

	Leading Edge	Mainstream	Lagging
MPU	300-600	150-250	90-150
MCU, ASIC, Logic	100-140	80-90	50-60
DRAM	80-90 (Micron 130)	60-75	45-50
Power Discrete and Analog	30-35	About 25	Under 15

Source: Dataquest (February 1998)

These values have proven to be relatively stable. They are, of course, influenced by pricing swings in the end-chip markets. In a competitive pricing environment, actual revenue per square inch will tend to be at the lower end of the ranges, while a stable pricing environment will support values at the upper end of the range. Because fabless companies are primarily in the MCU/ASIC/logic segment, with a mix of leading-edge and mainstream technologies, values in the range of $100 to $115 per square inch would be expected. Dataquest's assumptions incorporate some variation within this range, which is reflective of changing pricing dynamics in the end-chip markets in which these companies participate.

Integrated Device Manufacturers

By contrast, the situation is much more stable with the IDMs. These companies are generally larger than their fabless counterparts, and they have a more established history in the semiconductor industry. In forecasting the SCM demand from IDMs, the largest users can be identified and their future demand modeled individually. The projected demands of the individual companies are summed to give total IDM demand.

Dataquest has identified the top 24 IDM users of SCM services worldwide, as shown in Table 2-3. These companies are the largest consumers of foundry-processed wafers among IDM companies, and they can be expected to continue to make up the greatest portion of IDM demand throughout the forecast period. At this time, IDM companies in the Asia/Pacific region are not active users of foundry services. Most of these companies were surveyed in December 1997 as part of Dataquest's preliminary semiconductor market share survey, and they were asked to estimate their total foundry purchases for 1997. Using this as a starting point, spending patterns as a percentage of projected revenue have been modeled for each of these IDM companies.

Systems OEM Companies

Systems OEM companies represent a small part of the overall demand for SCM services today, but their demand is expected to grow as more of these companies start to design their own IC solutions and rely on foundries to manufacture them. Dataquest has sized this segment of SCM demand based on present usage levels and projected growth.

Table 2-3
IDM SCM Users

North America	Japan	Europe
Advanced Micro Devices	Fujitsu	Philips
Analog Devices	Hitachi	Robert Bosch
IBM Microelectronics	Matsushita	SGS-Thomson
Intel	Mitsubishi	Siemens
LSI Logic	NEC	
Lucent	SANYO	
Motorola	Sharp	
National Semiconductor	Sony	
Rockwell	Toshiba	
Texas Instruments		
VLSI Technology		

Source: Dataquest (February 1998)

Supply-Side Research

Suppliers of SCM services can be classified into two types: dedicated foundries and IDM foundries. Dedicated foundries rely almost exclusively on SCM services as their primary source of revenue and income. IDM foundries, on the other hand, are primarily engaged in a chip business, and they sell a portion of their wafer fabrication capacity as a foundry. In reality, wafer foundries span a continuum of strategic orientations, with true dedicated foundries such as Taiwan Semiconductor Mfg. Co. and Chartered Semiconductor Manufacturing Pte. Ltd. at one end and the more opportunistic DRAM manufacturers-turned-foundry at the other. In the end, it is not so much the classification of these suppliers that is important but the accurate projection of available foundry capacity.

Dataquest's basic approach to determining the amount of capacity available on the SCM market is simply to add up the capacities of all the current and planned foundry fabs. We rely heavily on the Dataquest worldwide fab database, which lists all currently operating and planned future fabs throughout the world. The information in the database is maintained through an annual survey of semiconductor manufacturers and quarterly updates based on company announcements and other publicly available information. (The fab database is available in separate reports for each of the four regions.) Also, the annual semiconductor market share survey provides a valuable reference point for the IDM foundries, which are asked to report the prior year's sales of foundry services. This information can be used to estimate the percentage of that company's total wafer capacity allocated to foundry services.

Dedicated Foundries

To more accurately represent certain companies in the midst of a strategy transition, Dataquest has adopted a somewhat less rigid criterion for determining whether or not a company is classified as a dedicated foundry. Rather than requiring that 100 percent of revenue be from the sale of SCM services, Dataquest will consider a company a dedicated foundry if it derives 75 percent or more of its revenue from SCM services and has a strategy that relies primarily on foundry services for future growth. This slightly broader definition allows the inclusion of such companies as United Microelectronics Corporation and Holtek Microelectronics Corporation, whose omission would not be a fair representation of the dedicated foundry segment.

Table 2-4 lists the 11 companies that have been identified as dedicated foundries for the purposes of this report. There are no Japanese companies on the list. Also, the vast majority of the dedicated foundries are based in the Asia/Pacific region, with four of them in Taiwan. Actually, this number is even higher, because the UMC Group includes three separate joint-venture companies in addition to UMC, all based in Taiwan. Dataquest has chosen to treat WaferTech, a joint venture of TSMC and several fabless companies, as a separate entity because it is located in North America. This will facilitate a regional breakdown of foundry capacity.

IDM Foundries

The IDM companies identified as significant suppliers of SCM services are listed in Table 2-5. These companies represent IDMs that have been historically active in the foundry market or are expected to become active SCM suppliers in the future. Some companies, such as Nan Ya Technology Corporation, Powerchip Semiconductor Corporation, and Mosel Vitelic Inc., have only recently announced their intention of participating in the foundry market, and their long-term commitment to the market remains to be seen. Nevertheless, they are included here in the interest of obtaining a comprehensive picture of SCM capacity.

Table 2-4
Dedicated Foundry Service Providers

North America	Europe	Asia/Pacific
Orbit Semiconductor	Newport WAFERFAB Ltd.	Amkor Wafer Fabrication Services (Anam)
WaferTech	Tower Semiconductor	Advanced Semiconductor Manufacturing Co. (ASMC)
		Chartered Semiconductor Manufacturing
		Holtek
		Taiwan Semiconductor Manufacturing Co. (TSMC)
		United Microelectronics Corp. (UMC) Group: UMC
		United Semiconductor Corporation (USC)
		United Integrated Circuits Corporation (UICC)
		United Silicon Inc. (USI)
		Worldwide Semiconductor Manufacturing Co. (WSMC)

Source: Dataquest (February 1998)

Table 2-5
IDM Foundry Service Providers

North America	Japan	Europe	Asia/Pacific
American Microsystems Inc.	Asahi Kasei Microsystems	Austria Mikro Systeme	Hyundai
IBM Microelectronics	Fujitsu	Philips	LG Semicon
IMP	Hitachi	SGS-Thomson	Mosel Vitelic
Lucent	Kawasaki Semiconductor		Nan Ya
Micrel	Matsushita		Powerchip
Mitel	Mitsubishi		Samsung
Texas Instruments	Nippon Steel Semiconductor		Vanguard
VLSI Technology	Oki		Winbond
	Ricoh		
	Rohm		
	SANYO		
	Seiko Epson (S-MOS)		
	Sharp		
	Toshiba		
	Yamaha		

Source: Dataquest (February 1998)

The main difference in comparing estimates of SCM capacity of IDM foundries and dedicated foundries lies in the very definition of these two types. A dedicated foundry allocates all (or almost all) of its available capacity to foundry services. Determining the SCM capacity of a dedicated foundry is a straightforward matter of adding up the capacities of its current and planned fabs. By contrast, the IDM foundry allocates only a portion of its total capacity to foundry services. Furthermore, this allocation percentage is variable, depending on market conditions for the company's IC products as well as the SCM market. At any point, an IDM must decide how to load its fabs to maximize profit or, in other words, to maximize revenue per wafer (assuming that cost per wafer is relatively constant within a given fab). Therefore, when prices for the company's IC products fall, the company will increase the allocation of capacity to foundry services, and when prices are rising, capacity will be shifted away from foundry services.

All of this movement of capacity between production of standard products and foundry services is not quite as complicated as it seems. The price swings in IC markets that influence the behavior of IDMs relative to foundry capacity allocation are themselves a function of capacity and demand. The balance of capacity and demand in the industry is cyclical and tends to be dominated by the DRAM market. Excess DRAM capacity eventually finds its way into other IC markets, especially the SCM market. Thus price declines, initially in DRAMs, spread to SRAM and other commodity memories, then to logic ICs and, of course, to the foundry market, reflecting the general overcapacity in the industry, which is not limited to the DRAM market. These capacity cycles have been incorporated into the foundry capacity allocation assumptions Dataquest has applied to each of the IDM foundry suppliers.

Definitions

- **Semiconductor contract manufacturing:** A service in which a supplier performs some or all of the semiconductor manufacturing operations under contract to a customer. In its broadest sense, SCM can encompass wafer fabrication, packaging and assembly, and testing of semiconductor products. For the purposes of this study, the definition of SCM is limited to front-end wafer processing operations and does not include packaging, assembly, and testing services except for those provided by a SCM supplier as part of a turnkey manufacturing service.
- **Foundry purchase**: Foundry purchases can include unprobed wafers, probed wafers, tested wafers (known good die), or packaged chips but must include the front-end wafer fabrication portion of the manufacturing process.
- **Turnkey foundry services**: Semiconductor contract manufacturing services that include, in addition to basic wafer processing, the subsequent manufacturing operations of packaging and assembly, testing, and drop shipment of finished IC products to the end customer or distribution channel. Turnkey services may include some or all of these additional steps.
- **Dedicated foundry:** Dedicated foundries are companies whose charter is to fabricate semiconductor products for other companies. Dataquest defines a dedicated foundry as one that derives 75 percent or more of its revenue from the sale of SCM services and has a strategy that relies primarily on the foundry business for future growth.
- **Integrated device manufacturer:** An IDM is a semiconductor supplier, merchant or captive, that manufactures its own products. The defining attribute of an IDM is the exclusive ownership and operation of one or more wafer fabrication facilities.
- **Fabless semiconductor company:** A fabless semiconductor company is a merchant semiconductor supplier that designs and markets but does not manufacture its own semiconductor products. A fabless company is defined as one that obtains more than 75 percent of its wafers from outside sources.
- **Systems OEM:** A systems OEM is an electronics equipment supplier that is neither a merchant nor a captive semiconductor supplier but that designs semiconductor devices for its own internal use and outsources the manufacturing of such devices to an SCM supplier.
- **Company base:** Company base is the geographical region in which a company is based, determined by the location of the company's headquarters.
- **Region:** Except as defined for "company base," region refers to customer location—that is, where the purchase order originates. Dataquest has defined four geographical regions: Americas; Japan; Europe, Africa, and Middle East; and Asia/Pacific. This definition differs from the region of shipment in cases of a foundry's being instructed by the customer to ship wafers to another subcontractor for subsequent processing.

Chapter 3
SCM Capacity and Demand Analysis

Highlights of This Chapter

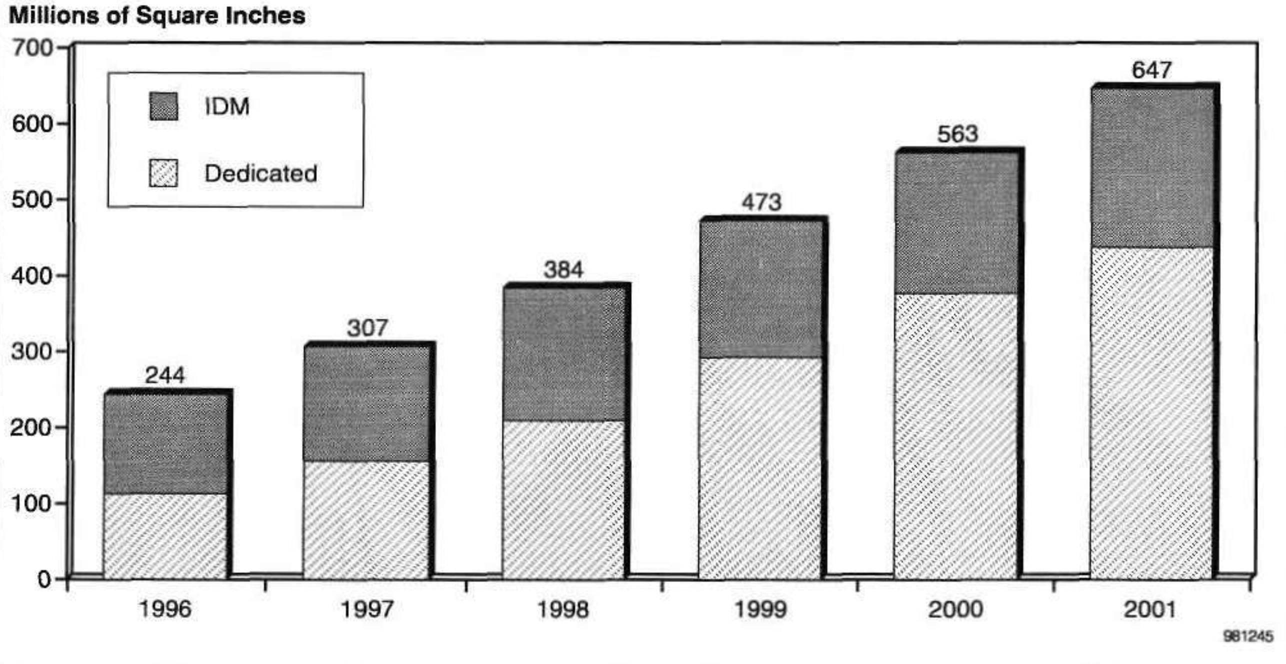
The highlights of this chapter are as follows:

- Worldwide SCM capacity, measured by total silicon area, is projected to grow at a CAGR of 21.5 percent from 1996 to 2001. Capacity growth is led by the dedicated foundries, with a CAGR of 31.1 percent.
- An analysis of the segmentation of SCM capacity reveals a shift toward the leading-edge/mainstream logic class of capacity at the expense of lagging technology. This trend is being driven by aggressive investment in leading-edge capacity on the part of dedicated foundries, which is creating a "technology bubble" of SCM capacity.
- Worldwide SCM demand, in MSI terms, will grow at a CAGR of 22.4 percent from 1996 to 2001. Demand growth is led by fabless semiconductor companies, with a CAGR of 27.5 percent, while IDM demand still outpaces general industry growth with a CAGR of 19.9 percent.
- SCM demand segmentation also favors the leading-edge/mainstream logic area, but not to the same extent as capacity.
- Excess capacity in all four segments is projected for 1998 and 1999, then decreasing in 2000 and 2001, with capacity shortages appearing in the lagging and senior segments.
- There is evidence of a "technology glut" developing in the foundry market, because demand for leading-edge technology has not kept pace with the rapid deployment of new capacity.
- Senior capacity is projected to be in shortage by 2000, and capacity cannot be easily transferred from other segments. This could be an opportunity for foundries specializing in senior technologies.

SCM Capacity

The research methodology that has been used to determine worldwide SCM capacity was discussed in Chapter 2. This chapter presents the results of that research and compares it to the demand for foundry services. Figure 3-1 shows the projected SCM capacity for both dedicated and IDM foundries, expressed in terms of silicon area, or millions of square inches. (MSI values can be converted to wafer equivalents by dividing by the wafer area—27.4 square inches for a 150mm wafer or 48.7 square inches for a 200mm wafer.) The total capacity is expected to grow at a compound annual rate of 21.5 percent from 1996 through 2001. Aggressive capital investment by the dedicated foundries is driving this growth in capacity, with a CAGR of 31.1 percent over the same period.

Figure 3-1
Worldwide SCM Capacity Forecast, by Foundry Type, 1996 to 2001



Source: Dataquest (February 1998)

The leading dedicated foundry companies have embarked on an aggressive capacity expansion program, and this is clearly evident in the SCM capacity projections shown in this document. Anticipating rapid growth in demand for foundry wafers, dedicated foundries are investing massive amounts of capital in new fab projects, mainly in Asia/Pacific and North America. These dedicated foundries want to be certain that they have ample capacity, and the required technology, to capitalize on the opportunity created by the accelerating trend toward foundry manufacturing.

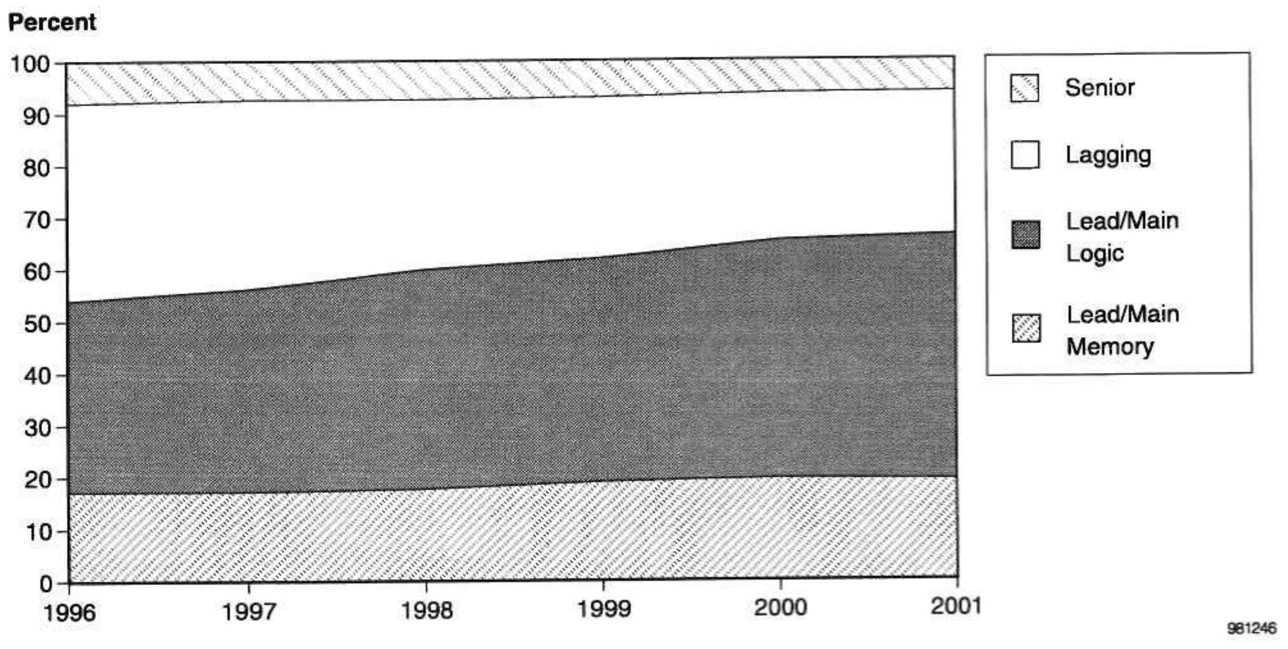
However, the five-year growth rate of IDM foundry capacity is expected to be much lower, 9.8 percent. With a few exceptions, SCM capacity from IDM suppliers tends to be more opportunistic, a means of partially offsetting excess capacity in the markets for the company's standard products. As a result, the long-term growth in IDM foundry capacity is fairly low, although there can be short-term increases caused by cyclical overcapacity in the industry at large. Dataquest assumes that the current period of general excess capacity will continue throughout most of 1998 but that demand will begin to catch up by the end of the year. The years 1999 and 2000 are expected to be a period of balanced to short supply in most semiconductor markets, bringing stable prices and strong revenue growth. It is during this next "boom" cycle that IDM foundries can be expected to reduce their foundry capacity allocation in favor of standard products. This is a simple economic decision—in a firm pricing environment, the standard products will generally yield higher revenue per wafer than foundry work.

SCM Capacity Segments

The previous chapter defined four segments of semiconductor production capacity that can be applied to the SCM market. These are leading-edge/mainstream memory, leading-edge/mainstream logic, lagging capacity, and senior capacity. Figure 3-2 illustrates how worldwide SCM capacity is distributed among these segments. Because of the way these segments are defined, dramatic shifts in capacity distribution should not be expected. For example, much of the 0.5-micron capacity would have been classified as leading-edge in 1997, but it will be considered part of the lagging-edge category by 2001. These segment definitions account for the industry's continual march toward ever-finer linewidths and are relatively independent of time.

As of 1997, worldwide SCM capacity was made up of 17 percent leading-edge/mainstream memory, 38 percent leading-edge/mainstream logic, 37 percent lagging capacity, and 8 percent senior capacity. By 2001, this distribution is expected to become 19 percent, 47 percent, 28 percent, and 6 percent. Although the leading-edge/mainstream memory and senior segments exhibit no major shifts, there is a definite bias toward leading-edge/mainstream logic at the expense of lagging-edge capacity. This is due to aggressive investment in leading-edge logic capacity on the part of the dedicated foundries. New foundry fab projects planned for 1998 and 1999 are predominantly 0.25 micron. Starting in 1999 or 2000, we will begin to see the first 0.18-micron foundry fabs. With investment patterns favoring the most advanced technology, a large portion of the growth in SCM capacity will be concentrated in the leading-edge/mainstream logic segment.

Figure 3-2
Distribution of SCM Capacity by Segment, 1996 to 2001



Source: Dataquest (February 1998)

Meanwhile, as today's leading-edge fabs age, they will make the transition to the lagging capacity class. A 0.5-micron fab is classified as leading-edge in 1997, but by 2001 the capacity of this fab will be considered part of the lagging segment. What is evident in the forecast distribution of capacity is a "technology bubble" resulting from the rapid expansion of dedicated foundry capacity centered in the most advanced technologies.

SCM Demand

On the demand side of the SCM market, Dataquest forecasts the following:

- Following two years of strong growth, the next cyclical downturn in the semiconductor industry will occur in 2001. The SCM market will see a pause in demand growth and a resumption of downward price pressures.
- Uncertainty over the optimum timing of the transition to 300mm wafer manufacturing will cause many IDMs—wishing to avoid building the last 200mm fab or the first 300mm fab—to increase their level of outsourcing to foundries. This will result in a surge in demand for SCM services from IDMs around 2001, and it will partially offset the cyclical downturn expected in that time.

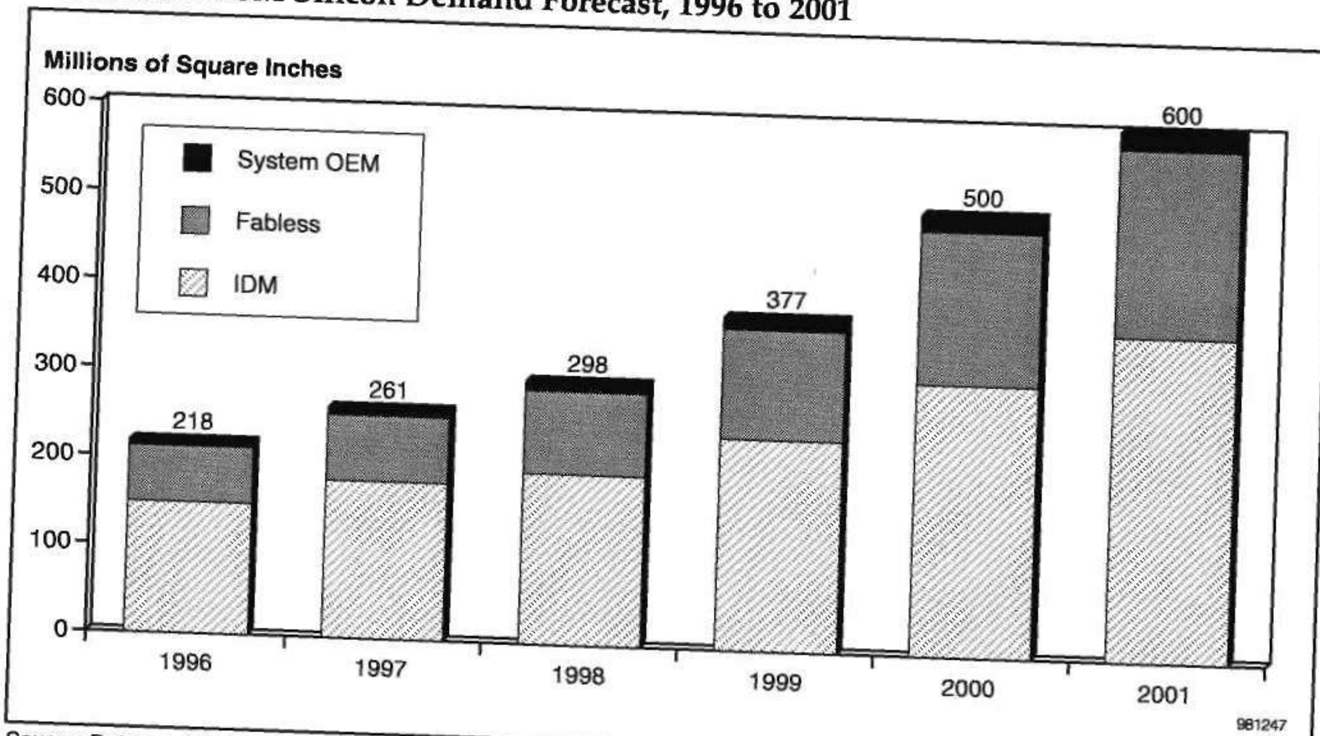
Figure 3-3 shows forecast demand for SCM services expressed in terms of silicon MSI. At present, IDM companies represent about two-thirds of the total demand for SCM services. This is mainly because of the fact that IDMs still make up the bulk of the semiconductor market. Despite the fantastic growth that fabless semiconductor companies have experienced in recent years, they accounted for only 4.8 percent of worldwide semiconductor revenue in 1996. This forecast assumes that the fabless share of the semiconductor market will increase to 7.5 percent in 2001.

Fabless companies, with their high growth rates, are very important to the growth of the SCM market, but IDM companies provide the foundation on which this growth will be built. Whereas the MSI demand from fabless companies will surge at a CAGR of 27.5 percent from 1996 to 2001, IDM demand will grow at a less dramatic pace, with a CAGR of 19.9 percent. In both cases, demand growth is outpacing the overall semiconductor market CAGR of 16.2 percent. However, because IDM demand is larger than fabless demand, the IDM segment will add more in absolute terms to overall SCM demand. From 1996 to 2001, fabless demand will increase by about 150 MSI, while the IDM sector will add almost 220 MSI. With the trend toward greater levels of outsourcing of semiconductor production, IDM companies represent a very large market opportunity for foundries.

SCM Demand Segments

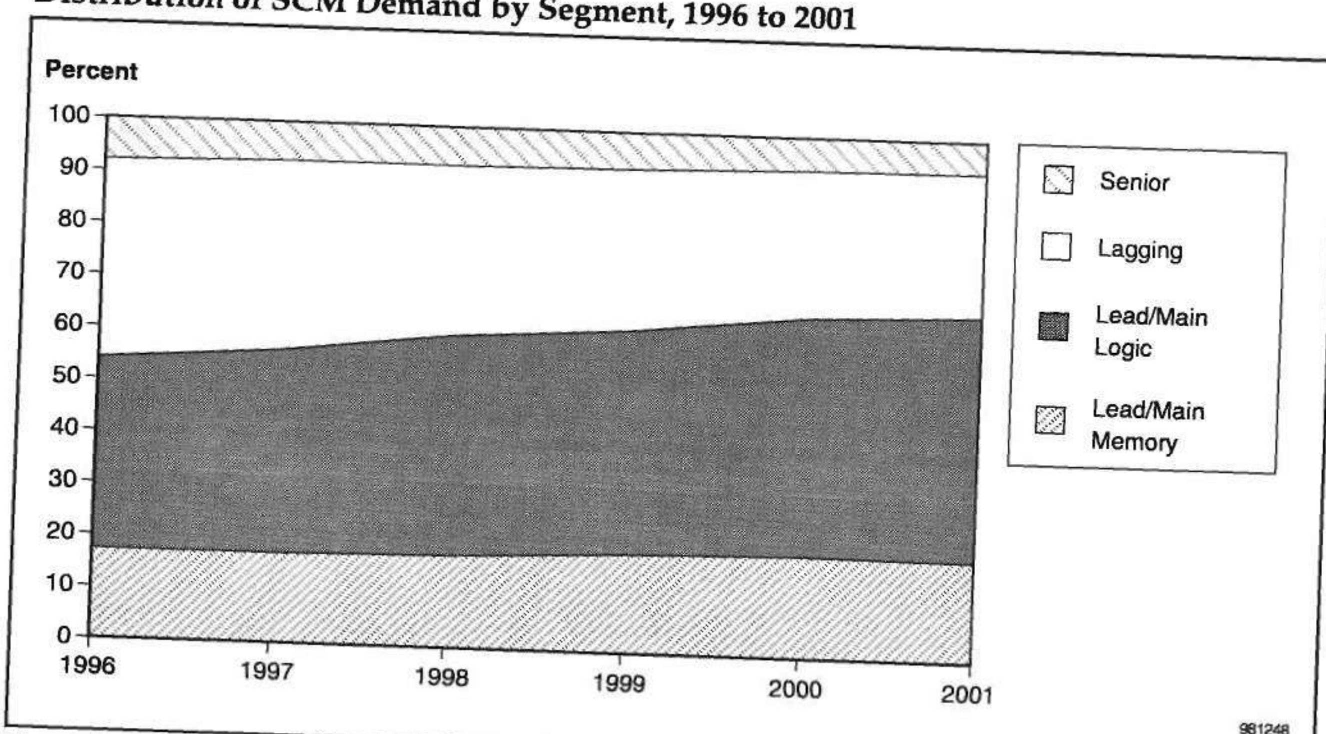
The same segmentation of capacity by technology classes has been applied to the demand side of the SCM market. Figure 3-4 shows the distribution of forecast SCM demand by capacity segment. Again, the timeless nature of the segment definitions should provide a relatively constant mix over the five-year forecast period. As in the capacity analysis, there is little change in the split for the leading-edge/mainstream memory and senior segments. Also, there is an expansion of leading-edge/mainstream logic demand at the expense of the lagging technology class. So, the trends in SCM demand segmentation appear similar to those of SCM capacity.

Figure 3-3
Worldwide SCM Silicon Demand Forecast, 1996 to 2001



Source: Dataquest (February 1998)

Figure 3-4
Distribution of SCM Demand by Segment, 1996 to 2001



Source: Dataquest (February 1998)

Some differences become apparent when we examine the actual percentages. In 1996, SCM demand was made up of 17 percent leading-edge/mainstream memory, 35 percent leading-edge/mainstream logic, 39 percent lagging capacity, and 9 percent senior capacity. By 2001, this distribution becomes 19 percent, 41 percent, 32 percent, and 8 percent. While the same shift in distribution from lagging to leading-edge/mainstream logic is evident, it is not as pronounced as that observed in the supply-side analysis. What is most important, however, is the actual balance of capacity and demand within these four segments.

SCM Capacity and Demand Analysis

Determining the balance of capacity and demand is a fairly straightforward process of calculating the relative difference, expressed as a percentage, of the silicon capacity and demand values from the preceding analysis. There is one additional consideration, however. The SCM market is not perfectly efficient. Some time is necessary to match customer demand with supplier capacity, during which some or all of the following activities may take place:

- Ramping up of new production capacity
- Customer qualification of the manufacturing process
- Resolution of process development issues

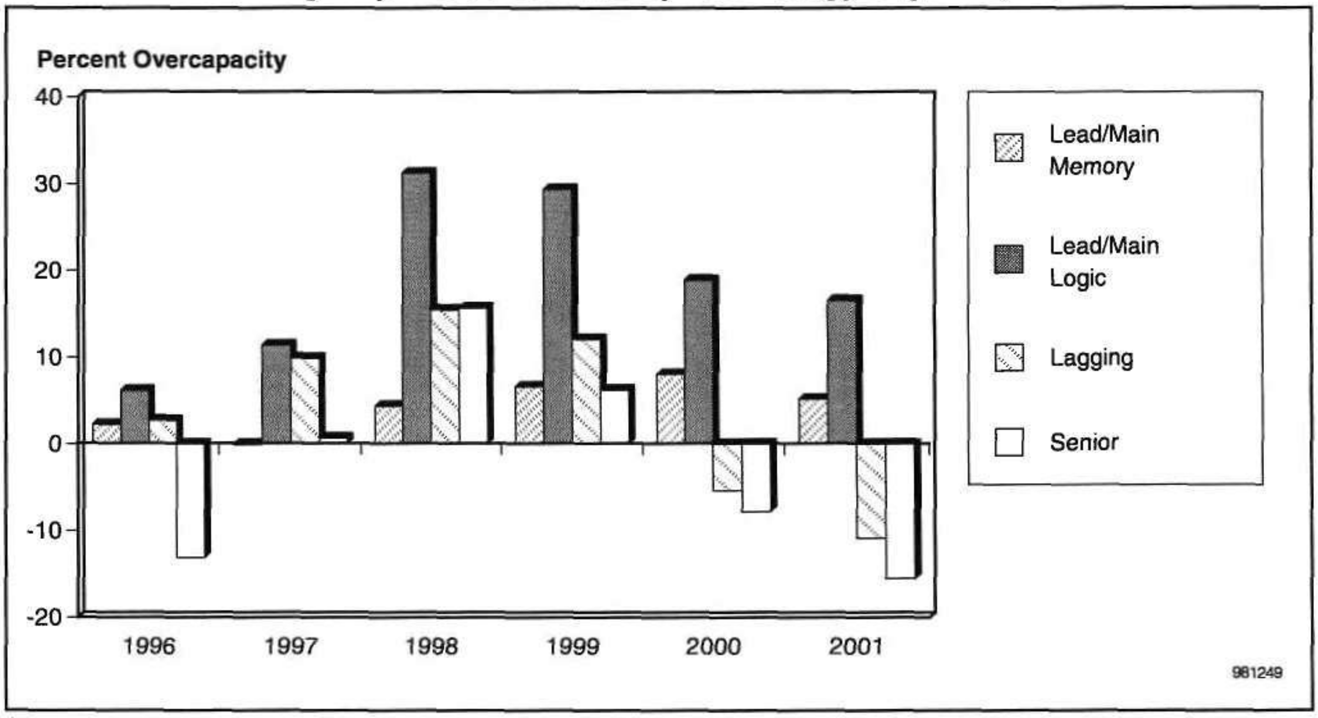
Dataquest estimates that, on average, the time required for these activities runs from three to six months. It may be longer in some cases, but this is a reasonable assumption for the average case. In calculating the balance of capacity and demand, a "supply efficiency offset" of four months is applied to the projected capacity curve. This adjustment can be thought of as a four-month lead time on capacity, and it has the effect of reducing the calculated overcapacity or increasing the calculated undercapacity, depending on the market situation.

Figure 3-5 presents the projected balance of SCM capacity and demand for each of the four segments through 2000. Any imbalance of greater than 5 percent can be considered significant and will have a measurable impact on pricing. The year 1996 was a time of transition, with all segments except senior capacity moving into overcapacity. Excess capacity continued to develop in 1997, concentrated in the leading-edge/mainstream logic and lagging areas. The trend will continue in 1998 and 1999, when Dataquest expects to see significant excess capacity across all technology segments. Finally, the surge in demand that begins in 1999 becomes more apparent in 2000 and 2001 as excess capacity is reduced in the leading-edge/mainstream memory and logic areas and a shortage actually develops in the lagging and senior segments.

Is There a Coming Technology Glut in the Foundry Market?

Recently, Dataquest has begun to observe the development of what we have termed a "technology glut" in the semiconductor industry at large. Continued high levels of capital investment in leading-edge capacity during a period of slow demand growth have resulted in an abundance of capacity at 0.35 micron and below. Is the same trend at work in the foundry market? The present analysis of foundry capacity and demand would certainly suggest that it is.

Figure 3-5
Worldwide SCM Capacity versus Demand by Technology Segment, 1996 to 2001



Source: Dataquest (February 1998)

A closer look at the leading-edge/mainstream logic segment suggests that, as the name implies, this segment represents the mainstream of the foundry market—advanced CMOS process technology being applied to the manufacture of digital logic circuits in a wide variety of applications. The earlier review of SCM capacity showed that dedicated foundries have been aggressively investing in new capacity in this segment. Demand for this foundry capacity is not on the same fast track, however. This is clearly evident in the rapidly increasing overcapacity of the leading-edge/mainstream logic segment seen in Figure 3-5. Demand is increasing, but it is behind the very steep ramp-up of production capacity.

The lagging and senior segments, on the other hand, are experiencing steadily increasing demand but only moderate capacity growth. Almost all foundry capital investment is being directed toward leading-edge CMOS capacity. Dedicated foundries, accustomed to their accelerated technology learning curve, are engaged in a technology capacity race, and their customers are not keeping up. The result is persistent overcapacity in the leading-edge/mainstream logic segment and a shortage of lagging and senior capacity developing in 2000.

The earlier discussion of capacity segment definitions in this report pointed out that the barriers to capacity movement from the leading-edge/mainstream classes to the lagging class are low. Therefore, the market can be expected to respond to the shortage of lagging capacity by shifting some of the excess capacity in the leading-edge/mainstream area to serve the demand for lagging technology. This adjustment can be accomplished with relative ease in the leading-edge fabs. However, the lagging segment of the SCM market carries with it lower average prices per square inch, so loading their leading-edge fabs with lagging technology products will cause the foundries to realize a lower return on assets. In essence, they will be forced to use expensive leading-edge factories to manufacture products based on an older generation of technology. In so doing, a foundry must accept a lower revenue and profit potential than if it were using the fab at its highest capability.

The situation in the senior capacity segment is entirely different because capacity cannot be easily shifted from the other capacity classes. The process requirements of the power and discrete products manufactured in this class of capacity are unique, as described in Chapter 2. The shortage of senior capacity in 2000 and 2001 will have to be made up, if at all, by fabs dedicated to this type of capacity. There has been much attention—and investment—focused on leading-edge digital CMOS capacity in the foundry industry, but there is opportunity for SCM suppliers in the less exotic, big line width realm of bipolar power transistors, power MOSFETs, IGBTs, power diodes, thyristors, small-signal diodes, and smart power devices.

Chapter 4
SCM Market Forecast

Highlights of This Chapter

The highlights of this chapter are as follows:

- The SCM market is forecast to reach $13.8 billion in 2001, representing a CAGR of 21.9 percent.
- A competitive pricing environment in the SCM market will persist throughout 1998, driven by continued excess capacity, and this will dampen revenue growth in the year despite strong growth in SCM demand on an MSI basis.
- Competitive pricing pressures in the leading-edge segments can be expected to persist throughout most of 1999 as foundry capacity additions outpace demand growth. However, an increase in average price per square inch for the market as a whole will be driven by a shift to leading-edge technology.
- The SCM market will experience exceptional growth in 1999 and 2000, when the foundry market will follow the overall semiconductor industry into a period of strong demand growth. The boom cycle is expected to continue through 2000 before industry capacity overshoots demand again in 2001.
- Demand for SCM services will be boosted in 2001 by IDMs wishing to avoid building the first 300mm or the last 200mm wafer fab.

SCM Wafer Pricing Assumptions

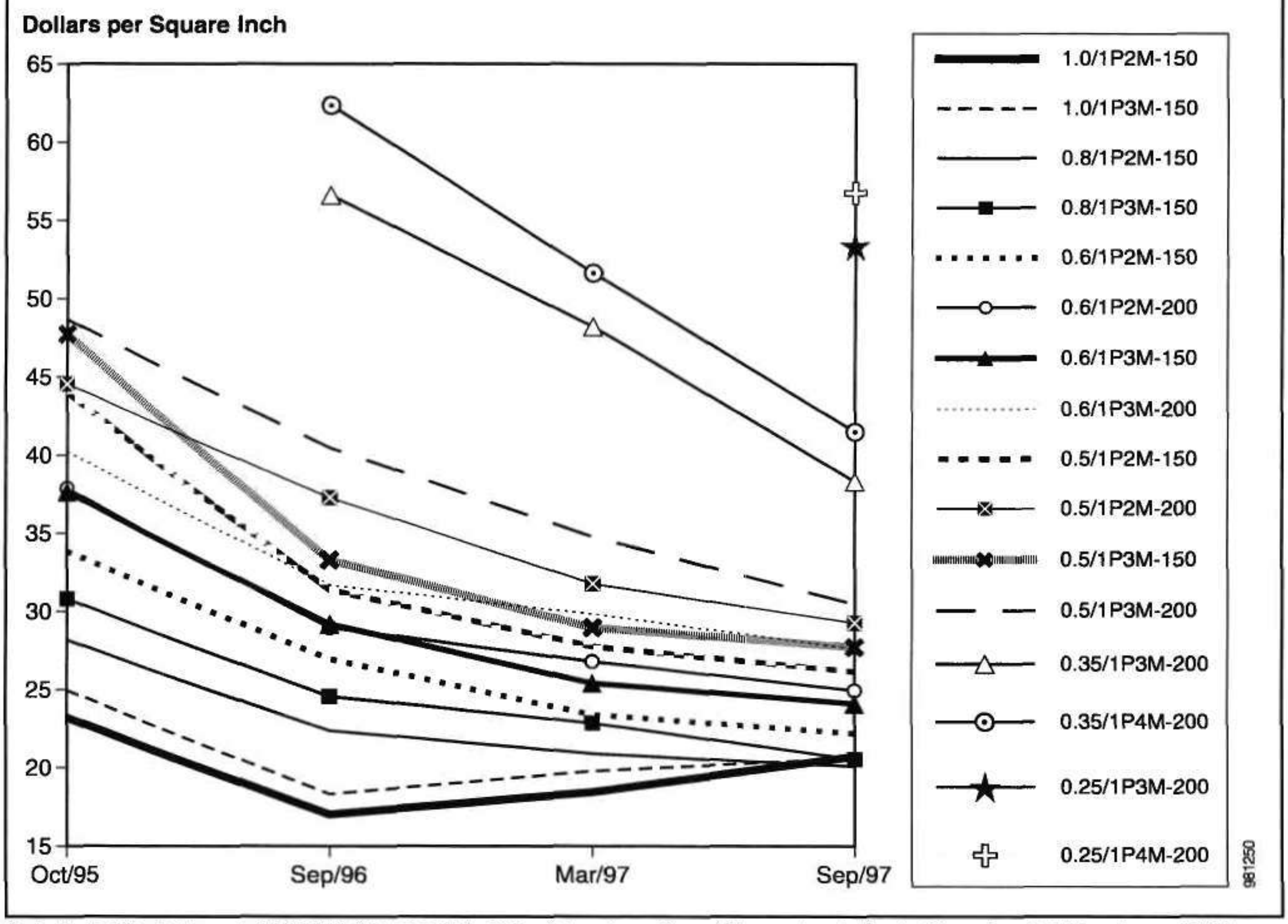
The previous chapter developed a forecast of demand for SCM services based on total silicon area, or MSI. It also examined the projected relationship between capacity and demand for the four capacity classes. To arrive at an SCM market forecast in dollar terms, some assumptions about the average price per square inch for foundry wafers must be made, and these assumptions will be influenced by the expected capacity/demand situation in each of the segments.

Historical Wafer Pricing Trends

To determine a baseline from which to forecast pricing movements within the foundry market, it is useful to examine the pricing trends of the past two years. In doing this, it must be borne in mind that this particular period has been a transition for the foundry market, and this has resulted in a very dynamic pricing environment. The foundry market shares many of the characteristics of a commodity market, and although not as extreme, foundry wafer prices have followed a trend similar to DRAM prices over this period, lagging by about six to nine months.

Figure 4-1 shows a history of foundry wafer pricing from four surveys conducted over a period of two years. Wafer prices have been plotted as dollars per square inch to facilitate the comparison of prices across wafer sizes. A premium of 5 to 10 percent is typical for 200mm wafers because of the greater silicon usage efficiency afforded by their larger circumference. Otherwise, price-per-square-inch trends track pretty well within technology categories.

Figure 4-1
Historical SCM Average Price-per-Square-Inch Trends, October 1995 to September 1997



Note: In the figure legend, 1.0/1P2M-150 stands for 1.0-micron drawn line width, one level of polysilicon, two metal levels, and 150mm wafer, and so on.
Source: Dataquest (February 1998)

The downward trend in wafer prices began in mid-1996 as the foundry market started to feel the effects of a growing surplus of capacity. Wafer prices for all technology categories had come down substantially by September 1996. Pricing pressure has continued through 1997, strongest at 0.35-micron and becoming progressively less severe toward the lagging edge of the technology spectrum. Prices for 1.0-micron have been steadily rising since September 1996, confirming the relative shortage of capacity observed in the senior technology segment.

This pattern of strong price declines at the leading edge and more moderate declines, and even some increases, at the lagging edge is resulting in a convergence of the price-per-square-inch trends across technology categories. However, there remains a substantial premium for 0.35-micron wafers despite the fact that this category has seen the greatest price declines. And the introductory prices of 0.25-micron foundry wafers (visible in the figure as two single data points in September 1997), although lower than expected, are still considerably higher than the rest of the market at $53 to $57 per square inch. A shift in demand toward the leading-edge technologies, as suggested in the demand projections of the previous chapter, could therefore provide some upward influence on the overall average price-per-square-inch trends in the SCM market, even in a competitive pricing environment.

Pricing Projections

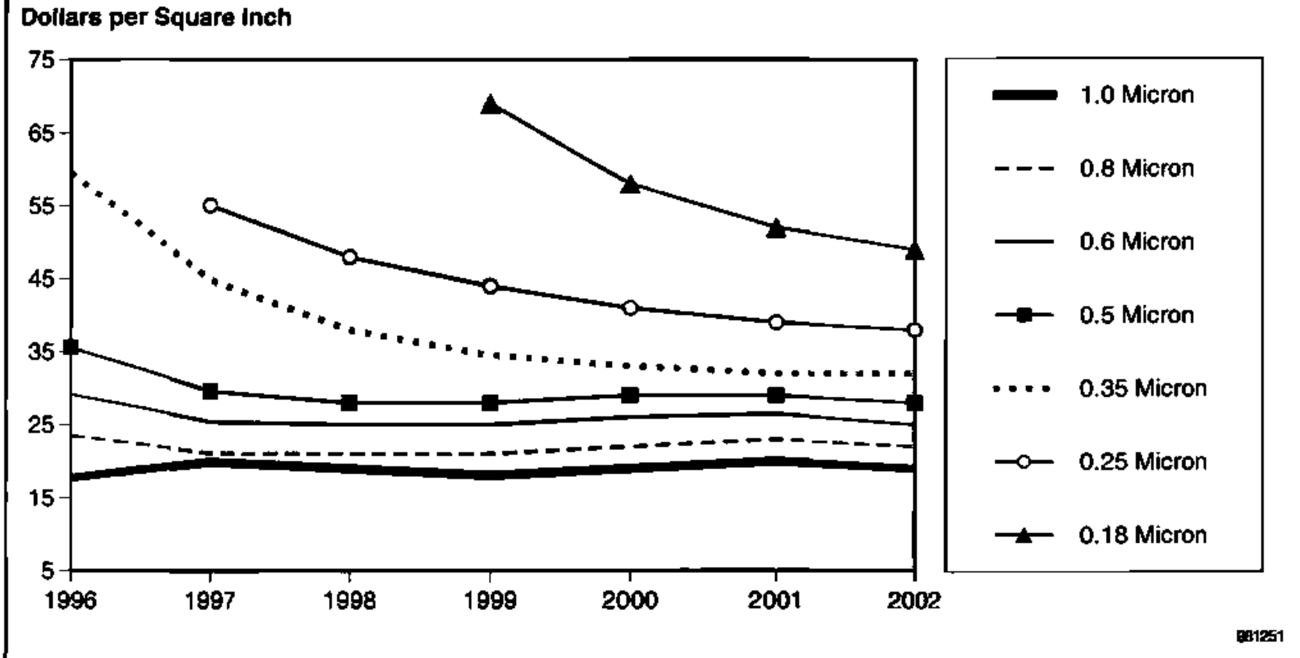
Foundry wafer prices are primarily influenced by the relationship between capacity and demand. Although there is some opportunity for differentiation among foundries on the basis of service, semiconductor manufacturing capacity is essentially a commodity. This conclusion is supported by the recent history of foundry wafer prices just reviewed. Therefore, in projecting pricing trends, Dataquest relies heavily on the capacity/demand analysis of the previous chapter. The pricing assumptions used in this forecast are plotted in Figure 4-2.

These pricing assumptions have been derived from a historical reference, which can be seen in the 1996 and 1997 data points, combined with projected capacity/demand dynamics in the individual technology segments. Because capacity in the leading-edge categories, which include linewidths of 0.35 micron and below, are forecast to remain in excess of demand through 2001, Dataquest is projecting steady declines in the prices for these wafers. Wafers at 0.5 micron to 1.0 micron will experience slightly down-to-flat pricing in 1998 and 1999 and a price rebound in 2000 and 2001 as demand is projected to exceed capacity in the lagging and senior categories.

A secondary influence on wafer prices is the relative position within the technology life cycle. When a new technology generation is first introduced on the foundry market, the initial users are typically performance-oriented buyers willing to pay a premium for the enhanced device speed afforded by the new technology. Later, as the technology moves into mainstream volume production, it attracts a broader range of users whose main concern is to improve the value/cost ratio of their products through a combination of die size reduction and increased functional density, both of which can be facilitated by a movement to smaller design rules. These are the value-oriented buyers, for whom lower wafer prices are an extremely important objective. As the technology matures, the mix of buyers shifts from the performance oriented to the value oriented, and with this shift comes a decrease in prices at the same time production volumes are increasing.

The technology life cycles of the leading-edge linewidths can be clearly seen in the plot of projected price-per-square-inch trends. Prices for a new technology are quite high at introduction and fall steeply in the next two years. It is also apparent from this comparison that the actual initial prices of 0.25-micron wafers in 1997 were considerably depressed, even lower than 0.35-micron wafers of only one year earlier, which is further evidence that 0.25-micron capacity is ramping ahead of demand. Initial prices in the range of $60 to $65 per square inch ($2,900 to $3,200 per 8-inch wafer) would be more consistent with the introduction of this technology in a market with a more balanced capacity and demand situation.

Figure 4-2
Projected Average SCM Price-per-Square-Inch Trends, 1996 to 2001



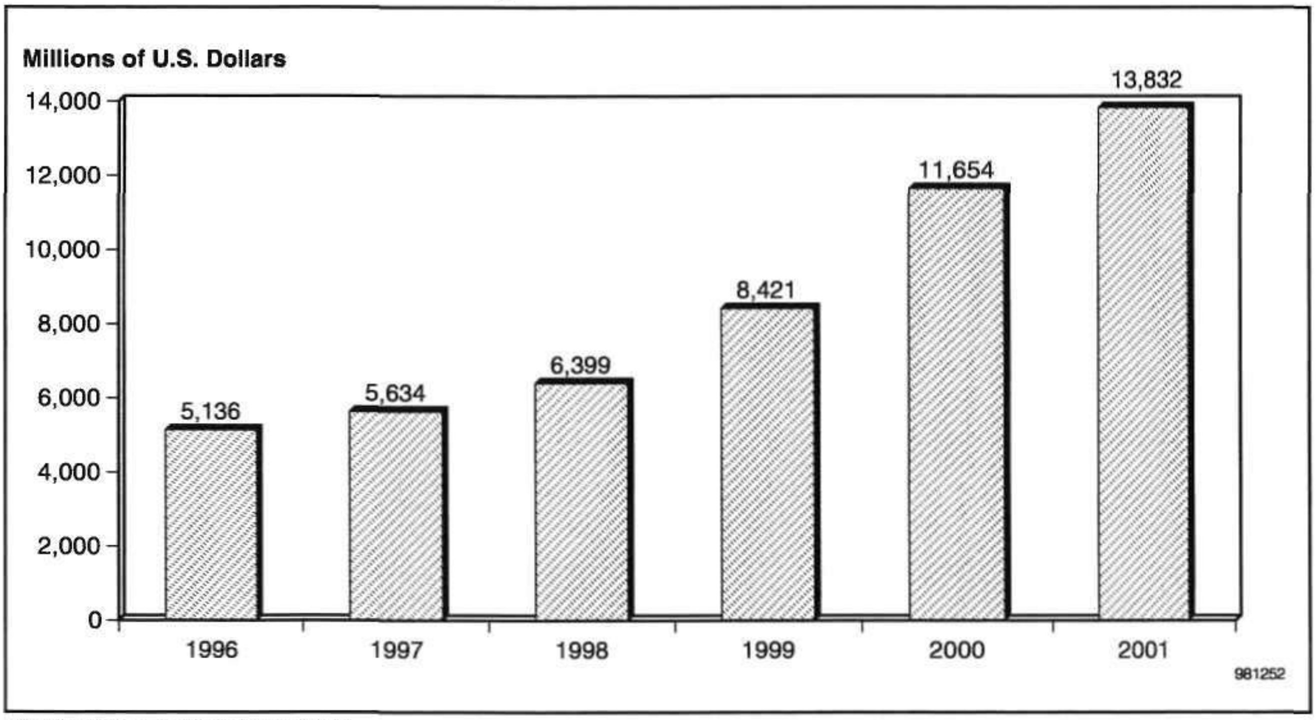
Source: Dataquest (February 1998)

SCM Market Forecast

Dataquest's forecast of the worldwide SCM market is presented in Figure 4-3. The market is projected to reach $13.8 billion in 2001, representing a CAGR of 21.9 percent. SCM market growth is expected to continue to outpace, by a substantial margin, the overall semiconductor market, which is forecast to grow at a compound annual rate of 16.2 percent during the same period.

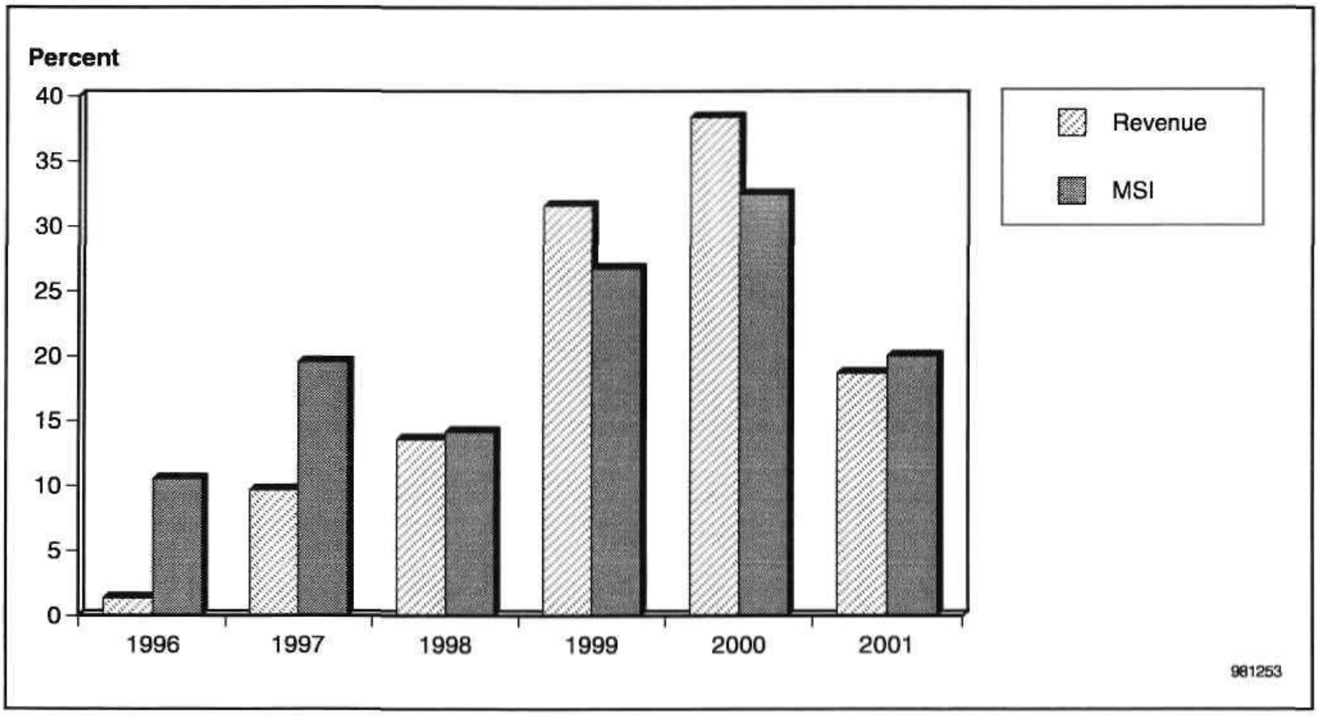
Figure 4-4 compares the sequential annual growth rates of revenue and MSI demand in the SCM market. The effect of strong downward price pressures can be clearly seen in the relative growth rates of 1996 and 1997. Despite strong demand growth in MSI terms, revenue growth was constrained to less than 2 percent in 1996 and an estimated 9.7 percent in 1997. The year 1998 will see a slowing of demand growth (in MSI) as the industry struggles to emerge from its current slump and burn off excess capacity. However, revenue growth is now on par with MSI growth, an indication of flat price-per-square-inch trends, on average. In spite of continued excess capacity, which can be expected to maintain downward pressure on prices through most of 1998, a shift in demand toward leading-edge technology, especially 0.35-micron, will begin to be felt in the average price-per-square-inch of foundry wafers this year.

Figure 4-3
Worldwide SCM Market Forecast, 1996 to 2001



Source: Dataquest (February 1998)

Figure 4-4
Annual Growth Rates of SCM Revenue and MSI, 1996 to 2001



Source: Dataquest (February 1998)

Demand will continue to show a trend toward the leading edge through 1999 and 2000, with 0.25 micron entering the picture in a real way. This movement will drive an increase in the average price per square inch for the market as a whole, even though a competitive pricing environment may persist, especially in the leading-edge segments where excess capacity is expected to be greatest. Thus we see revenue growth outpacing MSI growth by about 5 percent during this period. At the same time, MSI growth is very strong indeed, bolstered by accelerated demand and stable pricing in the semiconductor end-chip markets, which will be rebounding from a protracted period of slow growth and excess capacity. In short, the years 1999 and 2000 represent the next "boom cycle" of the semiconductor industry, and this effect will be amplified in the foundry market.

Following two years of exceptional growth in the foundry market, growth rates will moderate in 2001. It is during this period that Dataquest is expecting the industry to enter the next cyclical downturn as exuberant capital spending once again causes capacity to overtake demand and prices, especially in the DRAM market, begin to slide. The foundry market could still enjoy relatively robust growth, as shown in the figure, because of a couple of favorable influences. Fabless companies, which are completely reliant on foundries for their wafer manufacturing, will continue to grow, and they tend to produce more highly differentiated products that are less susceptible to the wild price swings of the DRAM market. As was seen in the last downturn, excess capacity and falling prices in the foundry market can lag the DRAM market by as much as a year. Also, uncertainty over the optimum timing of the migration to 300mm wafer fabrication will cause some IDMs to delay new fab projects to avoid building the first 300mm or the last 200mm wafer fab. Instead of building the new fabs, these IDMs will increase their usage of foundries in the short term, which will boost SCM demand in 2001.

Appendix A
Additional Forecast Data

Tables A-1 through A-3 show the SCM market worldwide by customer type, by region, and by technology segment. Tables A-4 through A-6 show worldwide SCM silicon demand by customer type, by region, and by technology segment.

Table A-1
Worldwide SCM Market by Customer Type
(Millions of U.S. Dollars)

	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
IDM	3,139	3,488	3,813	4,934	6,633	7,848	20.1
Fabless	1,832	1,952	2,342	3,167	4,575	5,507	24.6
Systems OEM	165	194	244	320	446	477	23.7
Total	**5,136**	**5,634**	**6,399**	**8,421**	**11,654**	**13,832**	**21.9**

Source: Dataquest (February 1998)

Table A-2
Worldwide SCM Market by Region (Millions of U.S. Dollars)

	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Americas	3,695	4,036	4,486	6,021	8,389	9,988	22.0
Japan	616	687	789	959	1,230	1,356	17.1
Europe, Africa, and Middle East	495	560	679	839	1,102	1,347	22.2
Asia/Pacific	330	351	445	602	933	1,141	28.2
Total	**5,136**	**5,634**	**6,399**	**8,421**	**11,654**	**13,832**	**21.9**

Source: Dataquest (February 1998)

Table A-3
Worldwide SCM Market by Technology Segment
(Millions of U.S. Dollars)

	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Leading/Mainstream Memory	901	1,003	1,118	1,465	1,952	2,222	19.8
Leading/Mainstream Logic	2,434	2,662	3,089	4,148	5,900	7,063	23.8
Lagging	1,576	1,733	1,958	2,508	3,395	4,053	20.8
Senior	225	236	234	300	407	494	17.0
Total	5,136	5,634	6,399	8,421	11,654	13,832	21.9

Source: Dataquest (February 1998)

Table A-4
Worldwide SCM Silicon Demand by Customer Type
(Millions of Square Inches)

	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
IDM	148	178	193	239	308	367	19.9
Fabless	63	74	94	124	173	212	27.5
Systems OEM	7	9	11	14	19	20	24.3
Total	**218**	**261**	**298**	**377**	**500**	**599**	**22.4**

Source: Dataquest (February 1998)

Table A-5
Worldwide SCM Silicon Demand by Region
(Millions of Square Inches)

	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Americas	157	185	206	266	355	427	22.3
Japan	27	34	40	47	58	65	18.9
Europe, Africa, and Middle East	23	29	34	41	51	63	22.1
Asia/Pacific	11	13	18	23	36	44	31.5
Total	**218**	**261**	**298**	**377**	**500**	**599**	**22.4**

Source: Dataquest (February 1998)

Table A-6
Worldwide SCM Silicon Demand by Technology Segment
(Millions of Square Inches)

	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Leading/Mainstream Memory	37	48	59	75	98	114	24.9
Leading/Mainstream Logic	76	92	112	148	203	247	26.7
Lagging	84	98	103	125	162	193	18.1
Senior	21	23	24	29	37	45	17.0
Total	**218**	**261**	**298**	**377**	**500**	**599**	**22.4**

Source: Dataquest (February 1998)

For More Information...

Inquiry Hotline	+1-408-468-8423
Internet address	scndinquiry@dataquest.com
Via fax	+1-408-954-1780
Dataquest Interactive	http://www.dataquest.com

Dataquest
A Gartner Group Company

DATAQUEST WORLDWIDE OFFICES

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

East Coast Research Center
Nine Technology Drive
P.O. Box 5093
Westborough, Massachusetts 01581-5093
United States
Phone: 1-508-871-5555
Facsimile: 1-508-871-6262

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

EUROPE
European Headquarters
Tamesis, The Glanty
Egham, Surrey TW20 9AW
United Kingdom
Phone: +44 1784 431 611
Facsimile: +44 1784 488 980

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

Dataquest Germany
Martin-Kollar-Strasse 15
D-81829 München
Germany
Phone: +49 89 42 70 4-0
Facsimile: +49 89 42 70 4-270

JAPAN
Japan Headquarters
Aobadai Hills 4-7-7
Aobadai
Meguro-ku, Tokyo 153
Japan
Phone: 81-3-3481-3670
Facsimile: 81-3-3481-3644

ASIA/PACIFIC
Asia/Pacific Headquarters
Suite 5904-7, Central Plaza
18 Harbour Road, Wanchai
Hong Kong
Phone: 852-2824-6168
Facsimile: 852-2824-6138

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

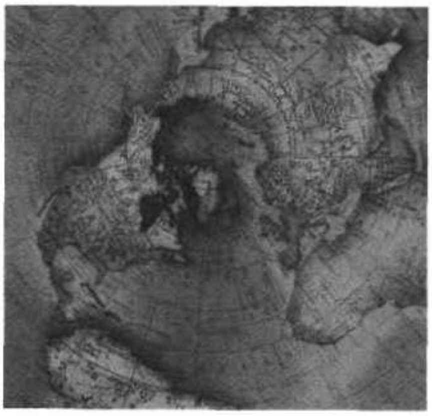
Dataquest Taiwan
11F-2, No. 188, Section 5
Nan King East Road
Taipei
Taiwan, R.O.C.
Phone: 8862-2756-0389
Facsimile: 8862-2756-0663

Dataquest Singapore
6 Temasek Boulevard, #26-02/03
Suntec City Tower 4
Singapore 038986
Phone: 65-333-6773
Facsimile: 65-333-6768

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

Dataquest Australia
80 Alfred Street
Milsons Point NSW 2061
Australia
Phone: 61-2-9941-4860
Facsimile: 61-2-9941-4868

Dataquest
A Gartner Group Company



Dataquest

Midyear 1998 Forecast: Semiconductor Contract Manufacturing

Market Trends

Program: Semiconductor Contract Manufacturing Services Worldwide
Product Code: SCMS-WW-MT-9802
Publication Date: October 19, 1998
Filing: Market Trends

Midyear 1998 Forecast: Semiconductor Contract Manufacturing

Market Trends

Program: Semiconductor Contract Manufacturing Services Worldwide
Product Code: SCMS-WW-MT-9802
Publication Date: October 19, 1998
Filing: Market Trends

Table of Contents

List of Figures

List of Tables

Chapter 1

Executive Summary

The scope of this forecast is defined to include contract manufacturing of semiconductor wafers, including "turnkey" foundry services, which combine "back-end" operations with "front-end" wafer fabrication.

Based on Dataquest's recent semiconductor contract manufacturing (SCM) market share survey, 1997 worldwide SCM revenue is estimated to be $5,178 million.

A redistribution of the regional splits is explained, in which some SCM sales in Asia/Pacific are moved to other regions to account for an error in reporting the sales by region.

Four distinct capacity segments are defined, which will be used to characterize the SCM market: leading-edge/mainstream memory, leading-edge/mainstream logic, lagging-edge, and senior.

Demand-side and supply-side research methodologies are reviewed, showing the primary sources of information and key assumptions applied to the forecast.

A list of definitions is included for terms used in this report and in other Dataquest publications on semiconductor contract manufacturing.

Significant trends include the following:

- Worldwide SCM capacity, measured by total silicon area, is projected to grow at a compound annual growth rate (CAGR) of 14.4 percent from 1997 to 2002. Capacity growth is led by the dedicated foundries, with a CAGR of 23.4 percent.
- Worldwide SCM demand, in terms of millions of square inches, will grow at a CAGR of 18.5 percent from 1997 to 2002. Demand growth is led by fabless semiconductor companies, with a CAGR of 20.6 percent, while integrated device manufacturer (IDM) demand still outpaces general industry growth with a CAGR of 16.2 percent.
- SCM demand segmentation favors the leading-edge/mainstream logic area, but not to the same extent as capacity.
- Excess capacity will become acute in 1998 and begin to improve in 1999, then continue to decrease in the years 2000 and 2001, with capacity shortages appearing in the senior segment.
- The SCM market is forecast to reach $12.3 billion in 2002, representing a CAGR of 19 percent.
- A competitive pricing environment in the SCM market will persist throughout 1999, driven by continued excess capacity; this condition will dampen revenue growth in the year despite a resumption of growth in SCM demand on an MSI basis.

- Competitive pricing pressures in the leading-edge segments can be expected to persist into the year 2000 as excess foundry capacity continues. However, an increase in average price per square inch for the market as a whole will be driven by a shift to leading-edge technology.
- The SCM market will experience exceptional growth in 2000 and 2001, when the foundry market will follow the overall semiconductor industry into a period of strong demand growth. The boom cycle is expected to continue through the year 2001 before industry capacity overshoots demand again in the year 2002.
- Demand for SCM services will be boosted in the year 2001 by IDMs that wish to avoid building the first 300mm or the last 200mm wafer fab.

Chapter 2
Introduction and Definitions

Highlights of This Chapter

The scope of this forecast is defined to include contract manufacturing of semiconductor wafers, including "turnkey" foundry services, which combine "back-end" operations with "front-end" wafer fabrication.

Based on Dataquest's recent SCM market share survey, 1997 worldwide SCM revenue is estimated to be $5,178 million.

A redistribution of the regional splits is explained, in which some SCM sales in Asia/Pacific are moved to other regions to account for an error in reporting the sales by region.

Four distinct capacity segments are defined, which will be used to characterize the SCM market: leading-edge/mainstream memory, leading-edge/mainstream logic, lagging-edge, and senior.

Demand-side and supply-side research methodologies are reviewed, showing the primary sources of information and key assumptions applied to the forecast.

A list of definitions is included for terms used in this report and in other Dataquest publications on semiconductor contract manufacturing (SCM).

Introduction to Semiconductor Contract Manufacturing

Semiconductor contract manufacturing (SCM) is defined for purposes of this report as wafer fabrication services provided by a semiconductor wafer foundry. At present, Dataquest limits the definition of SCM to the wafer processing part of semiconductor manufacturing, also known as "front-end" operations. Therefore, contract manufacturing of packaging, assembly, and test—or "back-end" operations—is excluded from this forecast. An exception to this rule is the case of the "turnkey" foundry, which provides the entire complement of manufacturing services, from wafer processing to packaging, assembly, and testing of finished integrated circuits (ICs) and, in some cases, drop-shipment to the end customer or distribution channel. Turnkey foundry services are included in our present forecast of the SCM market.

1997 SCM Market Estimates

During the most recent SCM market share survey, conducted during the spring of 1998, Dataquest determined that the size of the SCM market in the year 1997 was $5,178 million. The detailed findings of this survey may be found in the Dataquest report *1997 Semiconductor Contract Manufacturing Market Share Estimates*. This historical market data provides the basis for this forecast.

The SCM market structure development is and will continue to be directly related to the infrastructure for managing capacity generally in the semiconductor industry. Most of the attention in the last couple of years has been paid to the leading-edge and mainstream markets in which the fabless company and dedicated foundry suppliers have been dominant. However, these markets represent only one of four different silicon-based capacity segments of the semiconductor industry.

The Four Segments of Semiconductor Industry Capacity Infrastructure

In order to understand how the SCM market segmentation is likely to develop, it is critical to understand how and why the semiconductor industry has segmented into four subsegments of capacity. Each of these four subsegments has independent capacity supply-and-demand characteristics, as well as barriers to entry or conversion that are typical. There is some interaction among the four subsegments; however, the nature of the barriers requires some time lag for interactive characteristics to have an impact on the capacity.

Leading-Edge and Mainstream Memory Capacity

When the subject of memory is raised, DRAM comes to mind first. Indeed, more than 80 percent of the industry's memory capacity is used to produce DRAM, and for at least the past 20 years, DRAM has been a key driver for process technology. In 1997, the mainstream linewidth for DRAM production was 0.4 to 0.45 micron, with leading-edge at 0.35 to 0.32 micron and new products announced at 0.25 micron. Deep-UV lithography is starting to be implemented for critical layers.

The process flow characteristics of DRAM include three to four levels of polysilicon, but only two levels of metal. Unique to this class of capacity are the process flow and knowledge to make a storage capacitor. Process flows that are not typical include the widespread use of chemical mechanical planarization (CMP) and the process flow for creating a self-aligned silicide structure. Epitaxial silicon layers also are not typically used with DRAM.

The process flows included in this class of capacity for DRAM most directly match those used with flash memory and other nonvolatile memory devices. SRAMs can also be built easily using the process flow ingredients noted for this capacity class. However, without the self-aligned silicide flow to increase speed by means of a local interconnect, the SRAMs built in this type of fab would generally be limited to the commodity or slower SRAM markets.

Memory capacity fluctuates between 30 and 50 percent of the capital spending dollar, but averages about 40 percent overall. At the end of 1996, the memory class of capacity represented about 25 percent of overall worldwide silicon consumption and about 63 percent of capacity at below 0.5 micron.

Fabs in other capacity classes would have to add capital to align with leading-edge linewidths and to include capability for the unique storage capacitor and additional polysilicon levels in order to produce and compete effectively in the memory markets. This production market is one of the easier leading-edge areas to enter because the technology is well understood and easily purchased. Therefore barriers to entry are essentially limited to the availability of adequate capital.

Leading-Edge and Mainstream Logic Capacity

The leading-edge and mainstream logic capacity class has perhaps the broadest range of product classes that can be manufactured. For this reason, supply-and-demand analysis of individual types of products is not a practical exercise. In 1997, the mainstream linewidth for logic production was 0.45 to 0.55 micron, with leading-edge at 0.35 to 0.32 micron and new products announced at 0.25 micron. This linewidth range is nearly identical to the memory class, with the exception that the mainstream lags slightly. Deep-UV lithography is starting to be implemented for critical layers and at 0.25 micron could be used in roughly 40 to 50 percent of the mask layers.

The process flow characteristics of mainstream and leading-edge logic include two levels of polysilicon and three to six levels of metal. Process flows that typically exist in this class of capacity are widespread use of CMP, the process flow for creating a self-aligned silicide, and experience with the use of epitaxial silicon layers. Trench isolation techniques and process flows are starting to be required at the 0.25-micron level. The process flow and knowledge to make a storage capacitor have not typically existed in this class of fab capacity.

Virtually any kind of advanced logic or ASIC product can be manufactured in this kind of capacity. It is the capacity generally found within the dedicated foundry market today, primarily because the customer base of fabless companies competes in this product class. SRAMs can also be built using the process flow ingredients noted for this capacity class. Because of the existence of the self-aligned silicide flow to increase speed by means of a local interconnect, the SRAMs built in this type of fab would generally be for the fast SRAM markets.

Advanced microprocessors (MPUs) also could be produced in this class of capacity. Although this representation is simplistic, from a manufacturing perspective the MPU is really a collection of memory cells and wiring. In the mid-1980s, both Intel Corporation and Motorola Incorporated migrated the memory cells to the SRAM design, away from the DRAM cell, in order to increase processing speed. The increased area for an SRAM cell is not a large concern in MPU design. What emerged from these efforts is the fast SRAM market, where Motorola has been one of the key leaders.

Leading-edge logic capacity also fluctuates between 40 and 60 percent of the capital spending dollar (depending upon the DRAM investment cycle), but in raw dollar terms is fairly stable and countercyclical, averaging about 50 percent overall. At the end of 1997, the advanced/mainstream logic class of capacity represented about 34 percent of overall worldwide silicon consumption and also about 35 percent of capacity at below 0.5 micron.

Fabs in other capacity classes would have to add capital in order to align with leading-edge linewidths, and to include capability for the unique self-aligned silicide process, as well as additional metal levels and CMP, to produce and compete effectively in the advanced logic markets. This production market is one of the more difficult to enter, because the technology is specialized and not easily purchased. Therefore barriers to entry are high, but they can be hurdled if adequate capital and a technology partner or internal development are available. There is normally a significant time lag for this kind of conversion.

Lagging-Edge Technology Capacity and Product Segments

The lagging-edge capacity class also has a broad range of product classes that can be manufactured. In 1997, the mainstream linewidth for lagging-edge product production was 0.7 to 0.9 micron (but could be as high as 1.2-micron), with leading-edge at 0.55 to 0.6 micron and new products announced at 0.45-micron. The lithography to be employed is generally a mix of g-line and i-line.

The process flow characteristics of lagging-edge logic include one or two levels of polysilicon and two levels of metal. The process flow and knowledge to make a storage capacitor have not typically existed in this class of fab capacity. Process flows that are not typically included are any use of CMP and the process flow for creating a self-aligned silicide. Epitaxial silicon layers are also not typically used with DRAM. The storage capacitor process flow could be used but typically is not in this class of capacity.

The type of products that make up the bulk of this capacity class are analog, mixed-signal analog, microcontrollers, optoelectronics, older memory generations, and some low-end logic products.

Lagging-edge capacity represents only 5 to 7 percent of the capital spending dollar. At the end of 1997, the lagging-edge class of capacity represented about 17 percent of overall worldwide silicon consumption but only about 5 percent of capacity at below 0.5 micron and only for the most advanced mixed-signal capability.

Capacity additions are required for this class of capacity over time because the set of products are those in a growing market, but the way capacity is added is quite different from the approach used for leading-edge and mainstream products. Because the revenue generated per square inch of silicon is between 35 and 50 percent of that for leading-edge or mainstream products, suppliers cannot afford to spend much on manufacturing facilities to maintain profitability. Therefore the used equipment market is relied on heavily for adding new capacity. The other way capacity is added to this segment is by means of "trickle down" from older memory capacity, typically from the DRAM area. For example, most of the 0.5- to 0.6-micron capacity available now in Japan and Korea in this segment was producing 4Mb DRAMs in 1995.

Fabs in the leading-edge capacity classes would not have to add capital in order to migrate capacity to this segment, and thus manufacturing barriers to entry are not high. However, some product design barriers may exist, particularly in the area of analog and mixed-signal products, which may mean some delay in employing excess capacity.

Senior Technology Capacity and Product Segments

The senior technology capacity class has a relatively narrow range of product classes that can be manufactured, almost all of which are in the power and discrete areas. In 1997, the mainstream linewidth for senior technology production was 1.2 to 10.0 microns, with leading-edge at 0.9 to 1.0 micron and new products announced at 0.8 micron. The lithography to be employed is generally a mix of g-line steppers and projection aligners.

The process flow characteristics of senior technology are unique, including maybe one level of polysilicon and one level of aluminum metal on the front side, with backside metallization schemes that may include alloys of nickel or chromium. The process flow and knowledge to make a power or discrete device are very specialized, including knowledge of how to handle very heavily doped boron, arsenic, or antimony substrates, with epitaxial silicon thicknesses ranging from 10 to 250 microns. Leading-edge logic epitaxial silicon is typically 5 to 8 microns thick. Specialized deep diffusion processes are also part of the process flow.

The type of products that make up the bulk of this capacity class are bipolar power transistors, power MOSFETs, insulated gate bipolar transistors (IGBTs), power diodes, thyristors, small signal diodes, and smart power devices.

Senior technology capacity represents only 2 to 4 percent of the capital spending dollar. At the end of 1997, the senior technology class of capacity represents about 24 percent of overall worldwide silicon consumption (higher than the lagging-edge technology segment), and none of the capacity below 0.5 micron.

Capacity additions are required for this class over time, because the set of products is in a growing market, but the way capacity is added is different from the approaches used for other classes. Because the revenue generated per square inch of silicon is below that of even the lagging-edge capacity class, suppliers cannot afford to spend much on manufacturing facilities to maintain profitability. Therefore, the used equipment market is relied on almost exclusively for adding new capacity. Capacity additions by way of "trickle down" are also not typical, as the process flow requirements are so vastly different. Most new capacity is added by those companies already participating in the product markets.

Fabs in other capacity classes would have to add significant capital in order to align with capability for the unique process flow requirements, and additional equipment and specialties to produce and compete effectively in the power and discrete markets. There is also a product design barrier, which may mean some delay in employing excess capacity. Therefore the barriers to entry in this capacity class are actually quite high.

Forecast Methodology

Dataquest utilizes several sources of information in formulating a forecast for the SCM market. Because of Dataquest's breadth of coverage of the semiconductor and related industries, market research conducted in diverse areas can be leveraged for a highly informed perspective on the trends affecting the foundry market. In general, these sources are used to provide a baseline reference and to identify the most important trends that will influence the forecast:

- Annual survey of SCM service providers for total SCM revenue, technology split, product types, regional distribution, and sales by customer type (IDM, fabless, or system OEM)
- Annual survey of all worldwide semiconductor suppliers for market share, in which respondents are also asked to report total sales and purchases of SCM services for the year
- Foundry wafer pricing survey conducted three times per year
- Worldwide database of current and planned semiconductor wafer fabrication facilities (fab database), which is maintained with an annual survey of semiconductor manufacturers and quarterly updates based on public announcements of new projects, accelerated or delayed plans, and closures
- The Dataquest semiconductor market forecasts, by product type and applications segment
- Individual company interviews and additional information obtained in the course of interaction with the SCM supplier and user communities

Demand-Side Research

Demand for SCM services comes from three types of companies. Fabless semiconductor companies design and market semiconductor products, but because they do not have their own fabs, they rely entirely on foundries for the manufacture of their products. Integrated device manufacturers (IDMs) design, manufacture, and market semiconductor products, utilizing their own production facilities. However, these companies will often outsource a portion of their wafer production needs to foundries for a variety of reasons. System OEM companies are engaged in an electronic systems business, but they will often design a specific semiconductor device for use in their end product. Lacking semiconductor fabrication facilities, system OEMs, like fabless companies, rely completely on foundries to manufacture these semiconductor devices. Each of these demand segments has unique characteristics, and as a result, Dataquest adopts different approaches to forecasting the demand for each of them.

Fabless Semiconductor Companies

The fabless phenomenon arose from the dramatically lower capitalization requirements made possible by the emergence of the dedicated foundry. This development facilitated the birth and rapid growth of many fabless start-up companies, which no longer had to raise enough capital to build an entire wafer fab. The fabless sector, by its very definition, is highly dynamic, with many start-ups, many failures, and a few companies fortunate enough to hit upon a successful product and ride the wave as long as they can. It is impossible to predict with absolute certainty which companies among the fabless will be the winners and losers. We do know, however, that the fabless model is a success and that the growth of fabless companies as a whole is likely to outpace the semiconductor market.

In order to forecast the demand for foundry services from fabless companies, we have adopted a top-level approach, rather than a company-specific, bottom-up analysis. We have adopted this approach for the simple reason that there is so much churning in the fabless sector that the top players five years from now are likely to be quite different from the top players today. Based on historical penetration levels of fabless companies in the semiconductor application markets of data processing, communications, industrial, consumer, military/civil aerospace, and transportation, future penetration levels are projected. For the overall semiconductor market, the collective market share of fabless companies is projected to increase from 5.2 percent in 1997 to 8 percent by the year 2002.

Assumptions about the penetration levels of fabless companies in the semiconductor application markets combined with the forecast for these markets give a revenue forecast for fabless companies. By making a further assumption about the average revenue per square inch of silicon that these companies generate, we can arrive at a forecast of demand for processed silicon in millions of square inches per year. This particular ratio, which can be thought of as a silicon productivity metric, is a function of product type, technology, and pricing environment. Table 2-1 shows end-chip revenue per-square-inch trends for various product and technology segments.

These values have proved relatively stable over time. They are, of course, influenced by pricing swings in the end chip markets. In a competitive pricing environment, actual revenue per square inch will tend to be in the lower end of the ranges, whereas a stable pricing environment will support values in the upper end of the ranges. Since fabless companies are primarily in the MCU/ASIC/logic segment with a mix of leading-edge and mainstream technologies, we would expect values in the range of $100 to $115 per square inch. Our assumptions incorporate some variation within this range, which reflects changing pricing dynamics in the end chip markets in which these companies participate.

Table 2-1
End-Chip Revenue per Silicon Area by Product and Technology (Dollars per Square Inch)

	Leading-Edge	Mainstream	Lagging-Edge
MPU	300-600	150-250	90-150
MCU, ASIC, Logic	100-140	80-90	50-60
DRAM	80-90 (micron 130)	60-75	45-50
Power Discrete and Analog	30-35	~25	<15

Source: Dataquest (September 1998)

Integrated Device Manufacturers

By contrast, the situation is much more stable with the IDM companies. These companies are generally larger than their fabless counterparts, and they have a more established history in the semiconductor industry. In forecasting the SCM demand from IDMs, we can identify the largest users and model their future demand individually. The projected demands of the individual companies are summed to give total IDM demand.

Dataquest has identified the top 24 IDM users of SCM services worldwide, as shown in Table 2-2. These companies are the largest consumers of foundry-processed wafers among IDM companies, and they can be expected to continue to make up the greatest portion of IDM demand throughout the forecast period. At this time, IDM companies in the Asia/Pacific region are not active users of foundry services. Most of these companies were surveyed in December 1997 as part of Dataquest's preliminary semiconductor market share survey, and they were asked to estimate their total foundry purchases for the year 1997. Using this information as a starting point, spending patterns as a percentage of projected revenue have been modeled for each of these IDM companies.

Table 2-2
IDM SCM Users

North America	Japan	Europe
Advanced Micro Devices Inc.	Fujitsu	Philips
Analog Devices	Hitachi	Bosch
IBM Microelectronics	Matsushita Electric	STMicroelectronics
Intel	Mitsubishi	Siemens
LSI Logic	NEC Electronics	
Lucent Technologies	SANYO	
Motorola	Sharp	
National Semiconductor	Sony	
Rockwell	Toshiba	
Texas Instruments		
VLSI Technology		

Source: Dataquest (September 1998)

System OEM Companies

System OEM companies represent a small part of the overall demand for SCM services today, but their demand is expected to grow as more of these companies start to design their own IC solutions and rely on foundries to manufacture them. Dataquest has sized this segment of SCM demand based on present usage levels and projected growth.

Supply-Side Research

Suppliers of SCM services can be classified into two types: dedicated foundries and IDM foundries. Dedicated foundries rely almost exclusively on SCM services as their primary source of revenue and income. IDM foundries, in contrast, are primarily engaged in a chip business, and they sell a portion of their wafer fabrication capacity as a foundry. In reality, wafer foundries span a continuum of strategic orientations, with true dedicated foundries such as Taiwan Semiconductor Mfg. Co. (TSMC) and

Chartered Semiconductor Manufacturing Pte. Ltd. at one end and the more opportunistic DRAM manufacturer-turned-foundry at the other. In the end, it is not so much the classification of these suppliers that is important, but the accurate projection of available foundry capacity.

Our basic approach to determining the amount of capacity available on the SCM market is simply to add up the capacities of all the current and planned foundry fabs. To do so, we rely heavily on the Dataquest worldwide fab database, which lists all currently operating and planned future fabs throughout the world. The information in the database is maintained through an annual survey of semiconductor manufacturers and quarterly updates based on company announcements and other publicly available information. (The fab database is available in separate reports for each of the four regions: Americas; Japan; Europe, Middle East, and Africa; and Asia/Pacific.) In addition, the annual semiconductor market share survey provides a valuable reference point for the IDM foundries, which are asked to report the prior year's sales of foundry services. This information can be used to estimate the percentage of that company's total wafer capacity that was allocated to foundry services.

Dedicated Foundries

In order to represent more accurately the status of certain companies that are in the midst of a strategy transition, Dataquest has adopted a somewhat less rigid criterion for determining whether or not a company is classified as a dedicated foundry. Rather than requiring that 100 percent of revenue be from the sale of SCM services, if a company derives 75 percent or more of its revenue from SCM services and the company's strategy relies primarily on foundry services for future growth, then Dataquest will consider the company a dedicated foundry. This slightly broader definition allows the inclusion of such companies as United Microelectronics Corporation and Holtek Microelectronics Inc., whose omission would not result in a fair representation of the dedicated foundry segment.

Table 2-3 lists the 11 companies that have been identified as dedicated foundries for the purpose of this report. Note that there are no Japanese companies on the list. Also, the vast majority of the dedicated foundries are based in the Asia/Pacific region, with four of them located in Taiwan. Actually, this number is even higher since UMC Group includes three separate joint-venture companies in addition to UMC, all based in Taiwan. We have chosen to treat WaferTech, a joint-venture of TSMC and several fabless companies, as a separate entity because it is located in North America, and this treatment will facilitate a regional breakdown of foundry capacity.

IDM Foundries

The IDM companies identified as significant suppliers of SCM services are listed in Table 2-4. These companies represent those IDMs that have been historically active in the foundry market or that are expected to become active SCM suppliers in the future. Some companies, such as Nan Ya Technology, Powerchip, and Mosel Vitelic Inc., have only recently announced their intentions to participate in the foundry market, and their long-term commitment to the market remains to be seen. Nevertheless, they are included here in the interest of obtaining a comprehensive picture of the SCM capacity situation.

Table 2-3
Dedicated Foundry Service Providers

North America	Europe	Asia/Pacific
Orbit Semiconductor	Newport WAFERFAB Ltd.	Amkor Wafer Fabrication Services (Anam)
WaferTech	Tower Semiconductor Ltd.	Advanced Semiconductor Manufacturing Co. (ASMC)
UMC		Chartered
United Semiconductor Corp. (USC)		Holtek
United Integrated Circuit Corp. (UICC)		TSMC
United Silicon Inc. (USI)		UMC Group
		Worldwide Semiconductor Manufacturing Co. (WSMC)

Source: Dataquest (September 1998)

Table 2-4
IDM Foundry Service Providers

North America	Japan	Europe	Asia/Pacific
American Microsystems Inc.	Asahi Kasei Microsystems	Austria Mikro Systeme	Hyundai
IBM Microelectronics	Fujitsu	Philips	LG Semicon
IMP Inc.	Hitachi	STMicroelectronics	Mosel Vitelic
Lucent	Kawasaki Semiconductor		Nan Ya
Micrel Semiconductor Inc.	Matsushita		Powerchip
Mitel Corporation	Mitsubishi		Samsung
TI	Nippon Steel Semiconductor		Vanguard International Semiconductor
VLSI Technology	Oki		Winbond
	Ricoh		
	Rohm		
	SANYO		
	Seiko Epson (S-MOS)		
	Sharp		
	Toshiba		
	Yamaha		

Source: Dataquest (September 1998)

The main difference between estimating SCM capacity of IDM foundries and estimating capacity of dedicated foundries lies in the very definition of these two types. A dedicated foundry allocates all (or almost all, as we have discussed) of its available capacity to foundry services. Determining the SCM capacity of a dedicated foundry is a straightforward matter of adding up the capacities of its current and planned fabs. By contrast, the IDM foundry allocates only a portion of its total capacity to foundry services. Furthermore, this allocation percentage is variable, depending on market conditions for the company's IC products as well as the SCM market. At any point in time, an IDM must decide how to load its fabs in order to maximize profit, or in other words revenue per wafer (assuming that cost per wafer is relatively constant within a given fab). Therefore, when prices for the company's IC products fall, the company will increase the allocation of capacity to foundry services, and when prices are rising, the company will tend to shift capacity away from foundry services.

All of this movement of capacity between production of standard products and foundry services is not quite as complicated as it seems. The price swings in IC markets that influence the behavior of IDMs relative to foundry capacity allocation are themselves a function of capacity and demand. The balance of capacity and demand in the industry is cyclical in nature and tends to be dominated by the DRAM market. Excess DRAM capacity eventually finds its way into other IC markets, and especially the SCM market. Thus price declines, initially in DRAMs, spread to SRAM and other commodity memories, to logic ICs, and of course, to the foundry market, reflecting the general overcapacity in the industry, which is not limited to the DRAM market. These capacity cycles have been incorporated into the foundry capacity allocation assumptions applied to each of the IDM foundry suppliers.

Definitions

Key definitions are as follows:

- **Semiconductor contract manufacturing (SCM):** This is a service in which a supplier performs some or all of the semiconductor manufacturing operations under contract to a customer. In its broadest sense, SCM can encompass wafer fabrication, packaging/assembly, and testing of semiconductor products. For purposes of this study, the definition of SCM is limited to "front-end" wafer processing operations and does not include packaging, assembly, and testing services except for those that are provided by a SCM supplier as part of a "turnkey" manufacturing service.
- **Foundry purchase**: Foundry purchases can include unprobed wafers, probed wafers, tested wafers (known good die), or packaged chips, but must include the "front-end" wafer fabrication portion of the manufacturing process.
- **Turnkey foundry services:** These are semiconductor contract manufacturing services that include, in addition to basic wafer processing, the subsequent manufacturing operations of packaging/assembly, testing, and drop-shipment of finished IC products to the end customer or distribution channel. Turnkey services may include some or all of these additional steps.

- **Dedicated foundry:** Dedicated foundries are companies whose charter is to fabricate semiconductor products for other companies. Dataquest defines a dedicated foundry as one that derives 75 percent or more of its revenue from the sale of SCM services and has a strategy that relies primarily on the foundry business for future growth.
- **Integrated device manufacturer (IDM):** An IDM is a semiconductor supplier, merchant or captive, that manufactures its own products. The defining attribute of an IDM is the exclusive ownership and operation of one or more wafer fabrication facilities.
- **Fabless semiconductor company:** This is a merchant semiconductor supplier that designs and markets, but does not manufacture, its own semiconductor products. A fabless company is defined as one that obtains more than 75 percent of its wafers from outside sources.
- **System OEM:** A system OEM is an electronics equipment supplier that is neither a merchant nor captive semiconductor supplier but that designs semiconductor devices for its own internal use and outsources the manufacturing of such devices to a SCM supplier.
- **Company base:** This is the geographical region in which a company is based, determined by the location of the company's headquarters.
- **Region:** Except as defined for "company base," region refers to customer location—that is, the place from where the purchase order originates. Dataquest has defined four geographic regions: Americas; Japan; Europe, Middle East, and Africa; and Asia/Pacific. Note that this definition differs from the region of shipment in cases in which a foundry is instructed by the customer to ship wafers to another subcontractor for subsequent processing.

Chapter 3
SCM Capacity and Demand Analysis

Highlights of This Chapter

Worldwide SCM capacity, measured by total silicon area, is projected to grow at a CAGR of 14.4 percent from 1997 to 2002. Capacity growth is led by the dedicated foundries, with a CAGR of 23.4 percent.

Worldwide SCM demand, in terms of millions of square inches, will grow at a CAGR of 18.5 percent from 1997 to 2002. Demand growth is led by fabless semiconductor companies, with a CAGR of 20.6 percent, while IDM demand still outpaces general industry growth with a CAGR of 16.2 percent.

SCM demand segmentation favors the leading-edge/mainstream logic area, but not to the same extent as capacity.

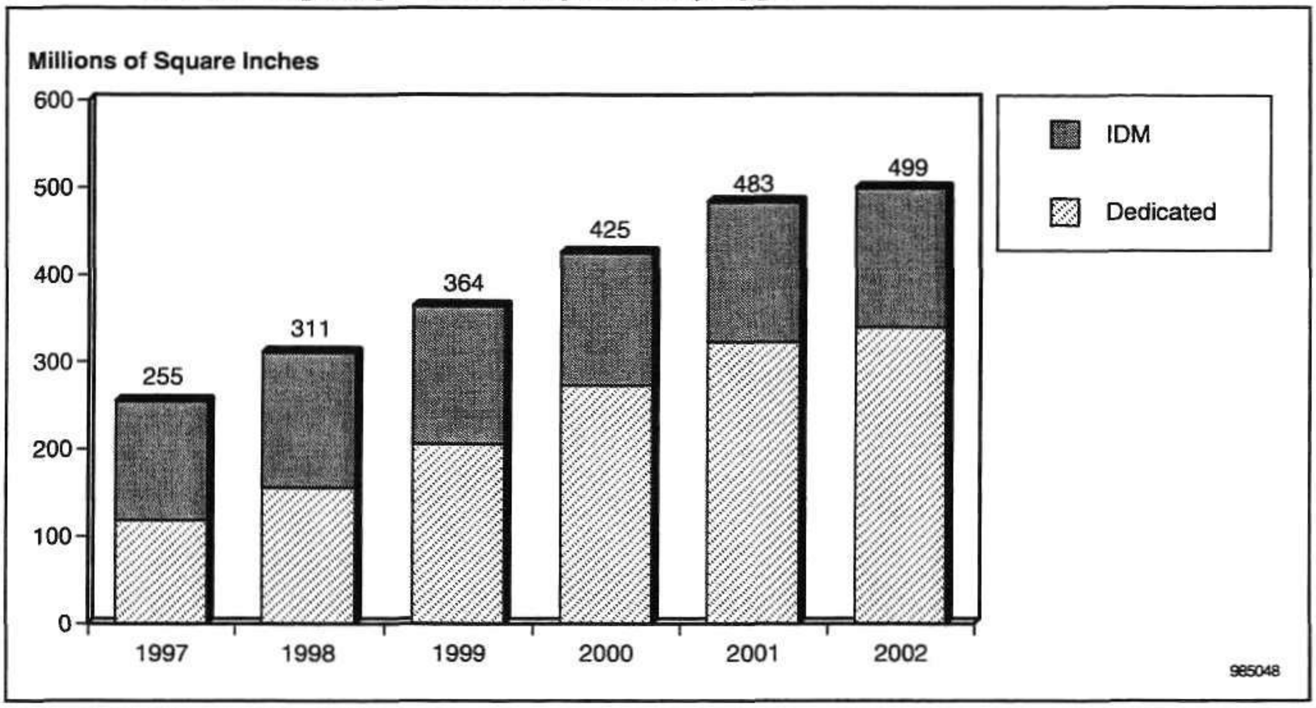
Excess capacity will become acute in 1998 and begin to improve in 1999, then continue to decrease in the years 2000 and 2001, with capacity shortages appearing in the senior segment.

SCM Capacity

The research methodology used to determine worldwide SCM capacity is discussed in Chapter 2. This chapter will present the results of that research and compare it to the demand for foundry services. Figure 3-1 shows the projected SCM capacity for both dedicated and IDM foundries, expressed in terms of silicon area, or millions of square inches (MSI). (MSI values can be converted to wafer equivalents by dividing by the wafer area: 27.4 square inches for a 150mm wafer, or 48.7 square inches for a 200mm wafer.) The total capacity is expected to grow at a CAGR of 14.4 percent from 1997 through 2002. Aggressive capital investment by the dedicated foundries is driving this growth in capacity, with a CAGR of 23.4 percent over the same period.

The five-year annual growth rate of IDM foundry capacity is expected to be much lower, at 3.2 percent. With a few exceptions, SCM capacity from IDM suppliers tends to be more opportunistic, used as a means to partly offset excess capacity in the markets for the company's standard products. As a result, the long-term growth in IDM foundry capacity is fairly low, even though there can be short-term increases caused by cyclical overcapacity in the industry at large. Dataquest assumes that the current period of general excess capacity will continue throughout 1998 and most of 1999. The years 2000 and 2001 are expected to be a period of balanced to short supply in most semiconductor markets, bringing stable prices and strong revenue growth. It is during this next "boom" cycle that IDM foundries can be expected to reduce their foundry capacity allocation in favor of standard products. This is a simple economic decision—in a firm pricing environment, the standard products will generally yield higher revenue per wafer than foundry work.

Figure 3-1
Worldwide SCM Capacity Forecast, by Foundry Type



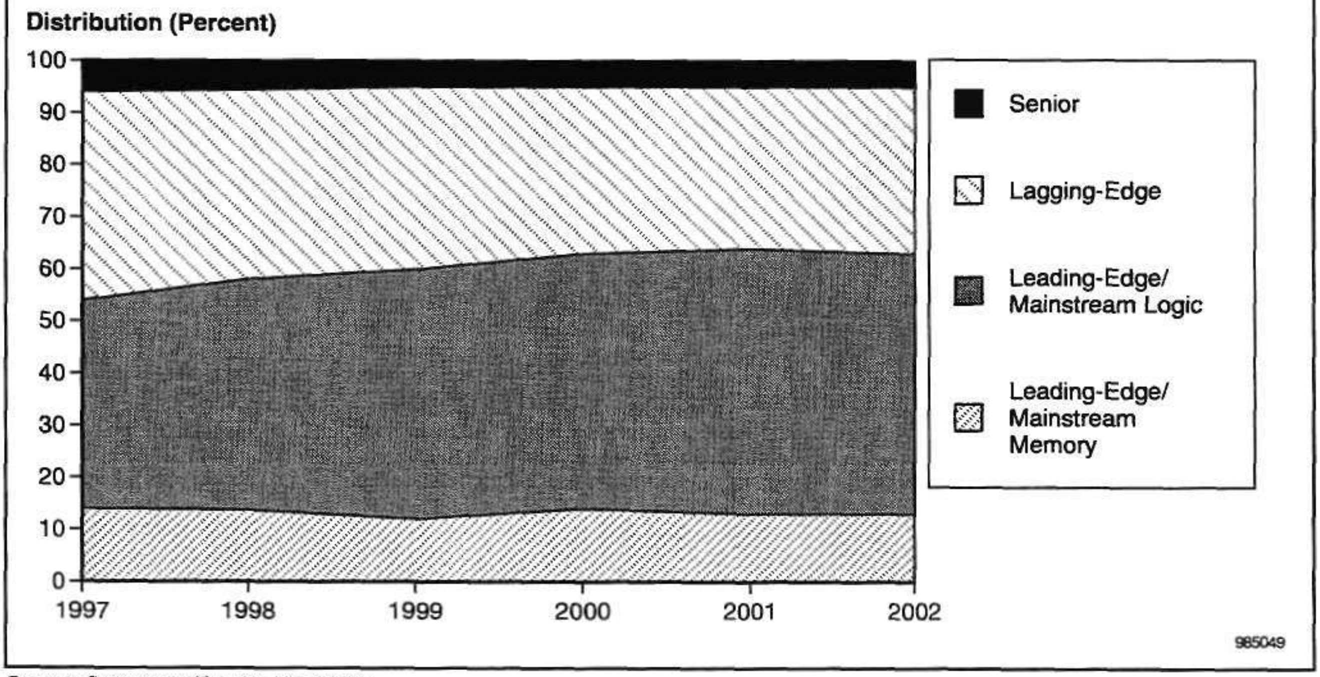
Source: Dataquest (September 1998)

SCM Capacity Segments

In the previous chapter, we defined four segments of semiconductor production capacity that can be applied to the SCM market: the leading-edge/mainstream memory, leading-edge/mainstream logic, lagging-edge, and senior capacity segments. Figure 3-2 illustrates how worldwide SCM capacity is distributed among these segments. Because of the way in which these segments are defined, dramatic shifts in capacity distribution should not be expected. For example, much of the 0.5-micron capacity would be classified as leading-edge in 1997, but it will be considered part of the lagging-edge category by the year 2001. These segment definitions account for the industry's continual march toward ever finer linewidths and are relatively independent of time.

Although the leading-edge/mainstream memory and senior segments exhibit no major shifts, there is a definite bias toward leading-edge/mainstream logic at the expense of lagging-edge capacity. This bias is due to the aggressive investment in leading-edge logic capacity on the part of the dedicated foundries. New foundry fab projects planned for 1998 and 1999 are predominantly 0.25 micron. Starting in 1999 or 2000 we will begin to see the first 0.18-micron foundry fabs. With investment patterns favoring the most advanced technology, a large amount of the growth in SCM capacity will be concentrated in the leading-edge/mainstream logic segment.

Figure 3-2
Distribution of SCM Capacity by Segment



Source: Dataquest (September 1998)

Meanwhile, as today's leading-edge fabs age, they will make the transition to the lagging-edge capacity class. What is evident in the forecast distribution of capacity is a "technology bubble" resulting from the rapid expansion of dedicated foundry capacity centered on the most advanced technologies.

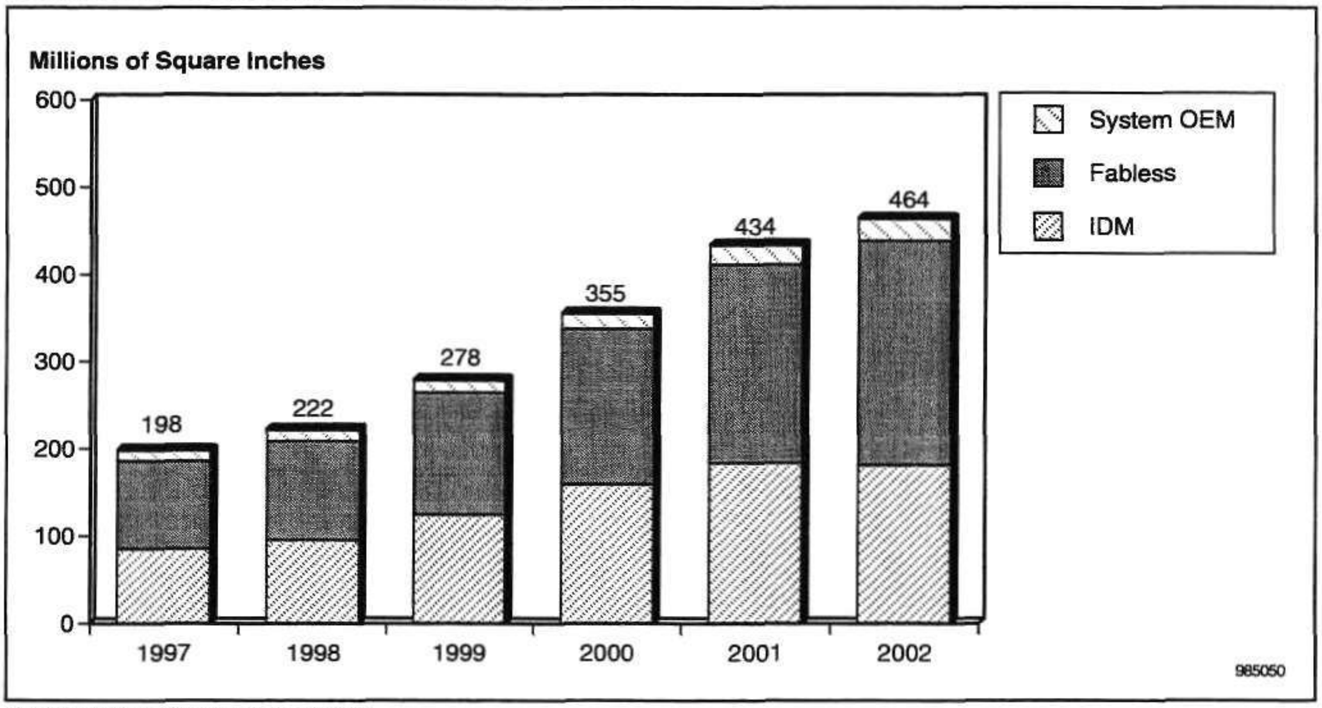
SCM Demand

Let us now turn our attention to the demand side of the SCM market. Trends are as follows:

- Following two years of strong growth, the next cyclical downturn in the semiconductor industry is forecast to occur in 2002. The SCM market will see a pause in demand growth and a resumption of downward price pressures.
- Uncertainty over the optimal timing of the transition to 300mm wafer manufacturing will cause many IDMs, wishing to avoid building the last 200mm fab or the first 300mm fab, to increase their level of outsourcing to foundries. This tendency will result in a surge in demand for SCM services from IDMs around 2001, and it will partly offset the cyclical downturn expected in that time frame.

Figure 3-3 shows forecast demand for SCM services expressed in terms of silicon MSI. Despite the fantastic growth that fabless semiconductor companies have experienced in recent years, they accounted for only 5.2 percent of worldwide semiconductor revenue in 1997. This forecast assumes that the fabless share of the semiconductor market will increase to 8 percent in the year 2002.

Figure 3-3
Worldwide SCM Silicon Demand Forecast



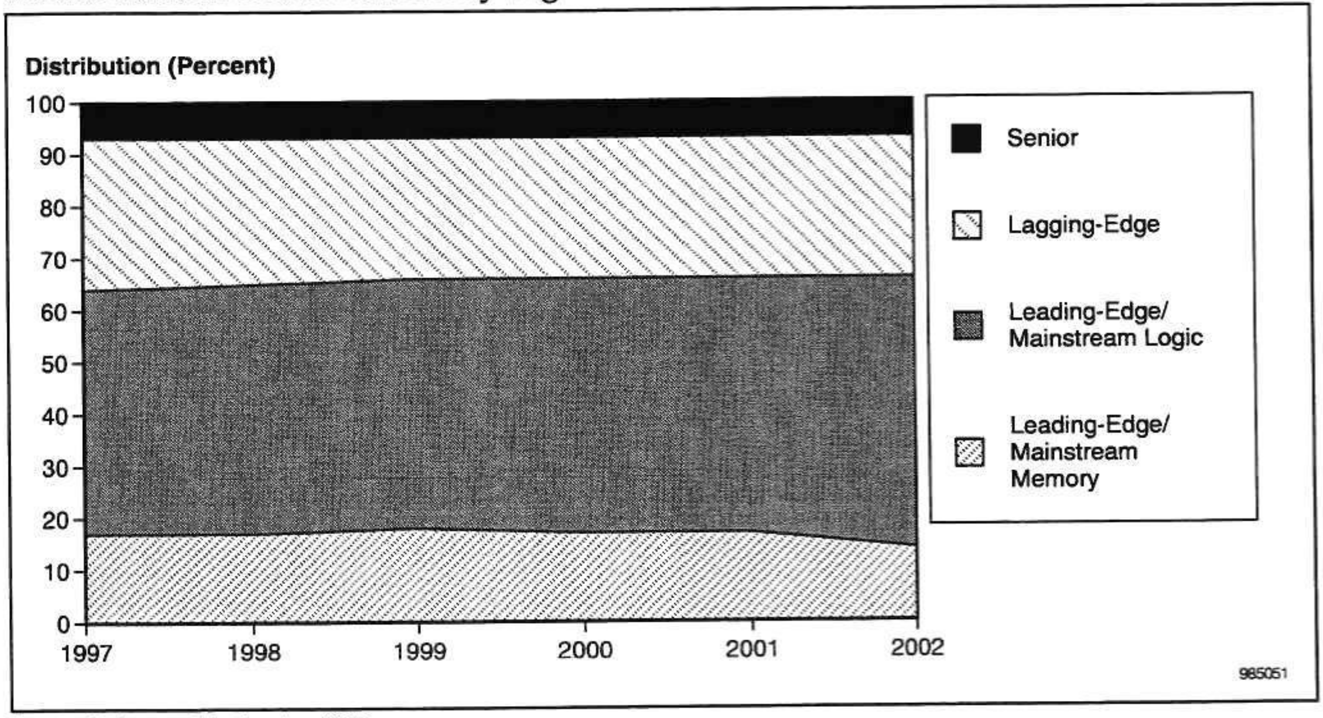
Source: Dataquest (September 1998)

Fabless companies, with their high growth rates, are very important to the future growth of the SCM market, but IDM companies provide the foundation upon which this growth will be built. Whereas the MSI demand from fabless companies will surge at a CAGR of 20.6 percent from 1997 to 2002, IDM demand will grow at a less dramatic pace, with a CAGR of 16.2 percent. In both cases, demand growth is outpacing the overall semiconductor market. With the trend toward greater levels of outsourcing of semiconductor production, IDM companies represent a very large market opportunity for foundries.

SCM Demand Segments

The same segmentation of capacity by technology classes has been applied to the demand side of the SCM market. Figure 3-4 depicts the distribution of forecast SCM demand by capacity segment. Again, the timeless nature of the segment definitions should provide a relatively constant mix over the five-year forecast period. As in the capacity analysis, we see little change in the split for the leading-edge/mainstream memory and senior segments. Also, there is an expansion of leading-edge/mainstream logic demand at the expense of the lagging-edge technology class. So, the trends in SCM demand segmentation appear similar to those of SCM capacity.

Figure 3-4
Distribution of SCM Demand by Segment



Source: Dataquest (September 1998)

SCM Capacity and Demand Analysis

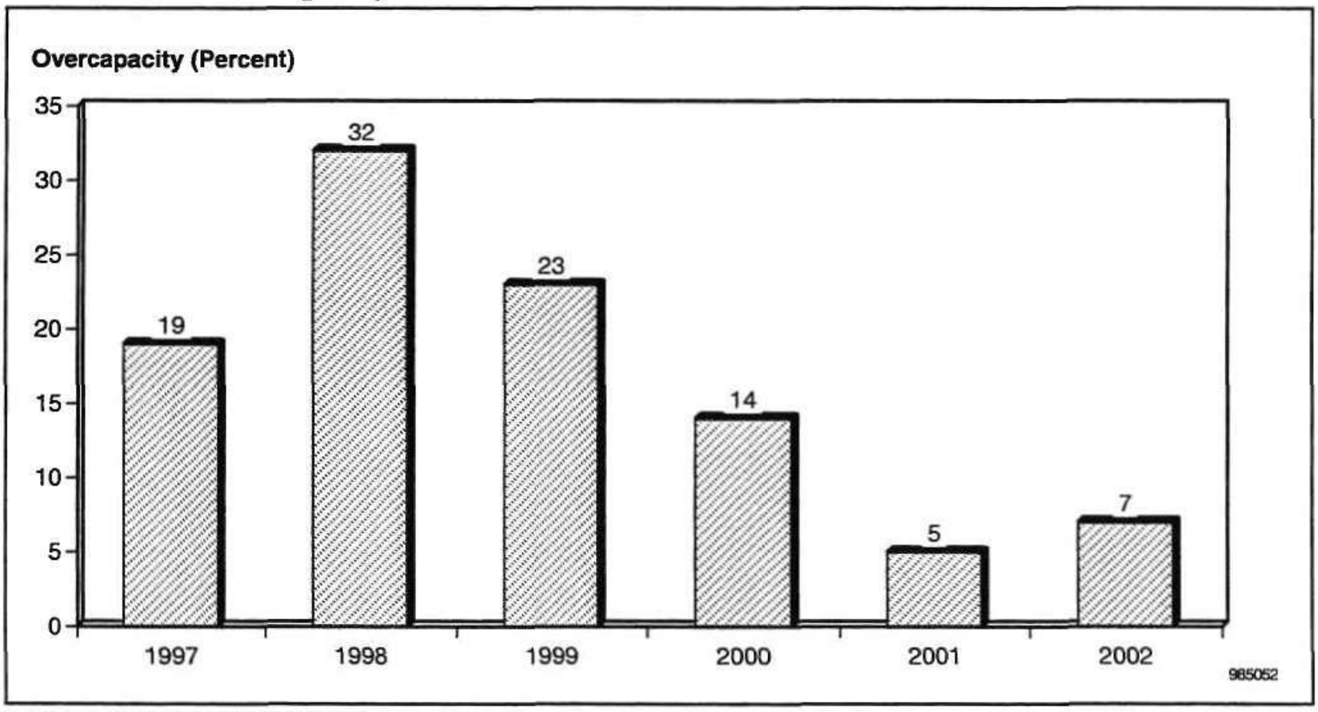
Determining the balance of capacity and demand is a fairly straightforward process of calculating the relative difference, expressed as a percentage, of the silicon capacity and demand values from the preceding analysis. There is one additional consideration, however. The SCM market is not perfectly efficient. Some time is necessary to match customer demand with supplier capacity, during which some or all of the following activities may take place:

- Ramping up of new production capacity
- Customer qualification of the manufacturing process
- Resolution of process development issues

Dataquest estimates that, on average, the time required for these activities runs from three to six months. The time required may be longer in some cases, but this is a reasonable assumption for the average case. In calculating the balance of capacity and demand, a "supply efficiency offset" of four months is applied to the projected capacity curve. This adjustment can be thought of as a four-month lead time on capacity, and it has the effect of reducing the calculated overcapacity or increasing the calculated undercapacity, depending on the market situation.

Figure 3-5 presents the projected balance of SCM capacity and demand through the year 2002. Any imbalance greater than 5 percent can be considered significant and will have a measurable impact on pricing. Significant excess capacity developed in 1997, concentrated in the leading-edge/mainstream logic and lagging-edge areas. Foundry oversupply has become acute in 1998. A resumption of demand growth that begins in 1999 becomes more apparent in the years 2000 and 2001, as excess capacity is reduced in these years.

Figure 3-5
Worldwide SCM Capacity versus Demand



Source: Dataquest (September 1998)

Chapter 4
SCM Market Forecast

Highlights of This Chapter

The SCM market is forecast to reach $12.3 billion in 2002, representing a CAGR of 19 percent.

A competitive pricing environment in the SCM market will persist throughout 1999, driven by continued excess capacity, and this environment will dampen revenue growth in the year despite a resumption of growth in SCM demand on an MSI basis.

Competitive pricing pressures in the leading-edge segments can be expected to persist into the year 2000 as excess foundry capacity continues. However, an increase in average price per square inch for the market as a whole will be driven by a shift to leading-edge technology.

The SCM market will experience exceptional growth in 2000 and 2001 when the foundry market will follow the overall semiconductor industry into a period of strong demand growth. The boom cycle is expected to continue through the year 2001 before industry capacity overshoots demand again in the year 2002.

Demand for SCM services will be boosted in the year 2001 by IDMs that wish to avoid building the first 300mm or the last 200mm wafer fab.

SCM Wafer Pricing Assumptions

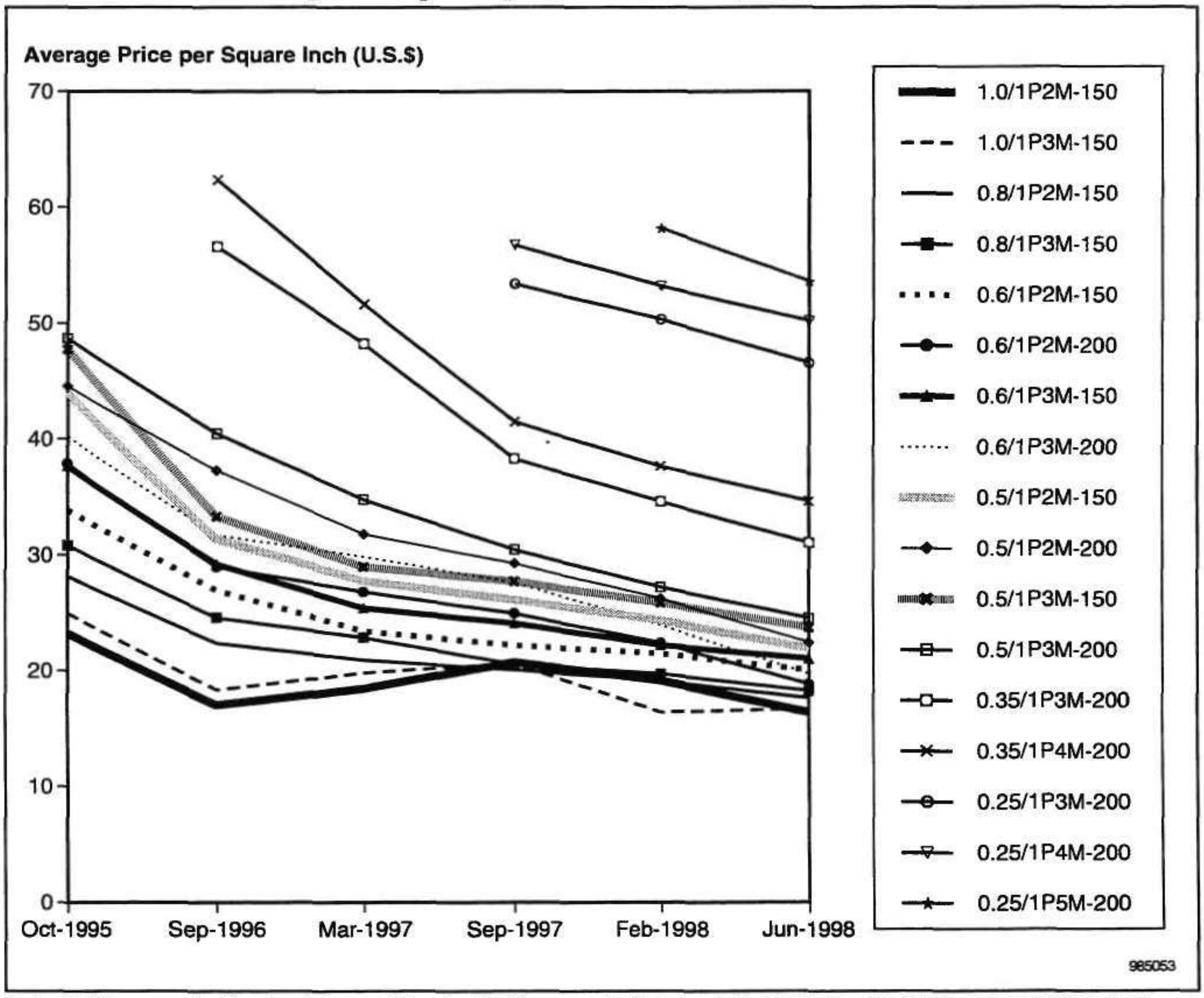
In the previous chapter we developed a forecast of demand for SCM services based on total silicon area, or MSI. In addition, we examined the projected relationship between capacity and demand for the four capacity classes. In order to make a forecast about the SCM market in dollar terms, we must make some assumptions about the average price per square inch for foundry wafers, and these assumptions will be influenced by the expected capacity/demand situation in each of the segments.

Historical Wafer Pricing Trends

In order to have a baseline from which to forecast future pricing movements within the foundry market, it is useful to examine the pricing trends of the past two years. In doing this, we should bear in mind that this particular period of time has been one of transition for the foundry market, resulting in a very dynamic pricing environment. The foundry market shares many of the characteristics of a commodity market, and foundry wafer prices have followed a trend similar to although not as extreme as that of DRAM prices over this period, lagging by about six to nine months.

Figure 4-1 shows a history of foundry wafer pricing from four surveys conducted over a period of almost three years. Wafer prices have been plotted as dollars per square inch in order to facilitate the comparison of prices across wafer sizes. A premium of 5 to 10 percent is typical for 200mm wafers because of the greater silicon usage efficiency afforded by their larger circumference. Otherwise, price-per-square-inch trends track pretty well within technology categories.

Figure 4-1
Historical SCM Average Price-per-Square-Inch Trends, October 1995 to June 1998



Note: 1P2M = one polysilicon level, two metal levels; 1P3M = one polysilicon level, three metal levels; 1P4M = one polysilicon level, four metal levels; 1P5M = one polysilicon level, five metal levels.
Source: Dataquest (September 1998)

The downward trend in wafer prices began in mid-1996, as the foundry market started to feel the effects of a growing surplus of capacity. Wafer prices for all technology categories had come down substantially by September 1996. Pricing pressure has continued through 1997, strongest at 0.35 micron and becoming progressively less severe toward the lagging edge of the technology spectrum.

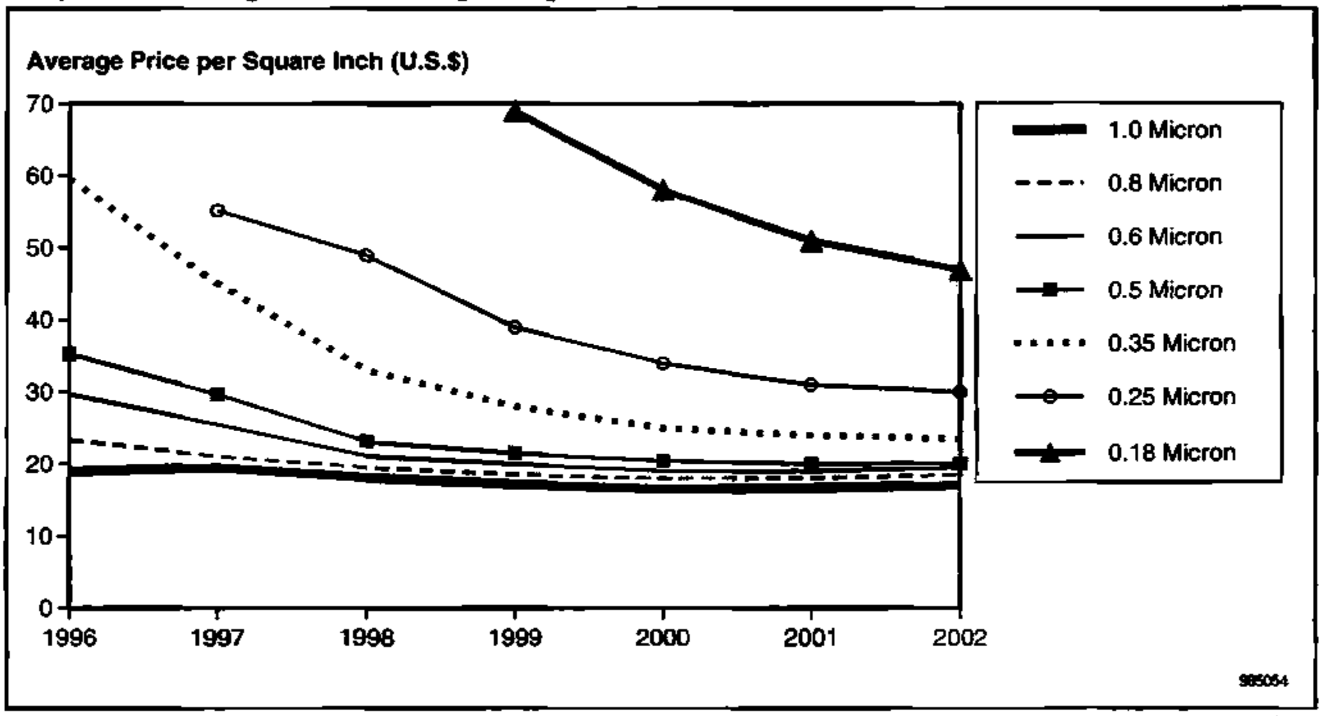
This pattern of strong price declines at the leading edge and more moderate declines, and even some increases, at the lagging edge is resulting in a convergence of the price-per-square-inch trends across technology categories. However, there remains a substantial premium for 0.35-micron wafers despite the fact that this category has seen the greatest price declines. And the introductory prices of 0.25-micron foundry wafers, although lower than expected, are still considerably higher than the rest of the market. A shift in demand toward the leading-edge technologies, as suggested in the demand projections of the previous chapter, could therefore provide some upward influence on the overall average price-per-square-inch trends in the SCM market, even in a competitive pricing environment.

Pricing Projections

Foundry wafer prices are primarily influenced by the relationship between capacity and demand. Although there is some opportunity for differentiation among foundries on the basis of service, semiconductor manufacturing capacity is essentially a commodity. This conclusion is supported by the recent history of foundry wafer prices we have just reviewed. Therefore, in projecting future pricing trends, we rely heavily on the capacity/demand analysis of the previous chapter. The pricing assumptions used in this forecast are plotted in Figure 4-2.

These pricing assumptions have been derived from a historical reference, which can be seen in the 1996 through 1998 data points, combined with projected capacity/demand dynamics in the individual technology segments. Because the leading-edge capacity categories, which include linewidths of 0.35 micron and below, are forecast to remain in excess of demand through the year 2001, we are projecting steady declines in the prices for these wafers. Wafers at 0.5 micron to 1.0 micron will experience slightly down-to-flat pricing movements in 1998 and 1999.

Figure 4-2
Projected Average SCM Price-per-Square-Inch Trends, 1996 to 2001



Note: 1P2M = one polysilicon level, two metal levels; 1P3M = one polysilicon level, three metal levels; 1P4M = one polysilicon level, four metal levels; 1P5M = one polysilicon level, five metal levels.
Source: Dataquest (September 1998)

A secondary influence on wafer prices is the relative position within the technology life cycle. When a new technology generation is first introduced on the foundry market, the initial users are typically performance-oriented buyers who are willing to pay a premium for the enhanced device speed afforded by the new technology. Later, as the technology moves into mainstream volume production, it attracts a broader range of users whose main concern is to improve the value/cost ratio of their product through a combination of die size reduction and increased functional density, both of which can be facilitated by a movement to smaller design rules. These are the value-oriented buyers, for whom purchasing wafers at lower prices is an extremely important objective. As the technology matures, the mix of buyers shifts from the performance-oriented to the value-oriented; with this shift comes a decrease in prices, while at the same time production volumes are increasing.

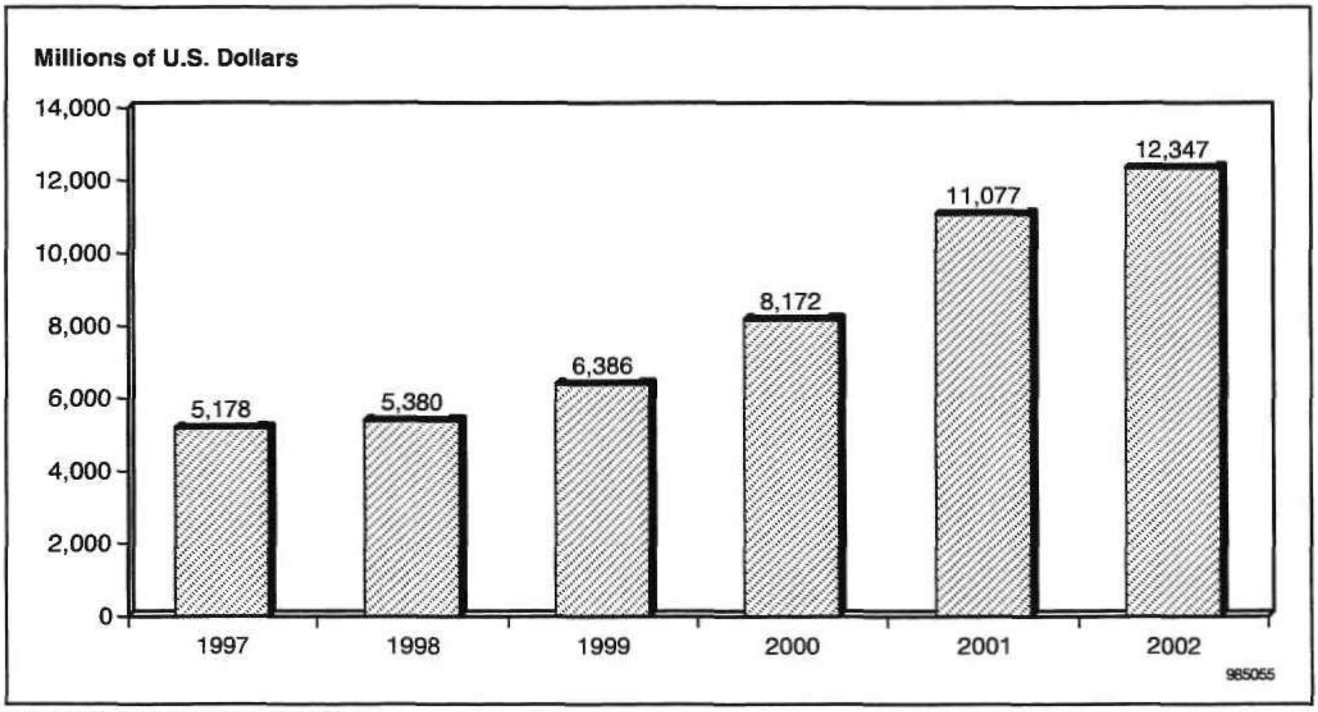
The technology life cycles of the leading-edge linewidths can be clearly seen in the plot of projected price-per-square-inch trends. Prices for a new technology are quite high at introduction and fall steeply over the following two years. It is also apparent from this comparison that the actual initial prices of 0.25-micron wafers in 1997 and 1998 are considerably depressed, even lower than 0.35-micron wafers of only one year earlier, which is further evidence that 0.25-micron capacity is ramping ahead of demand. Initial prices in the range of $60 to $65 per square inch ($2,900 to $3,200 per 8-inch wafer) would be more consistent with the introduction of this technology in a market with a better balance between capacity and demand.

SCM Market Forecast

Dataquest's forecast of the worldwide SCM market is presented in Figure 4-3. The market is projected to reach $12.3 billion in 2002, representing a CAGR of 19 percent. SCM market growth is expected to continue to outpace, by a substantial margin, growth in the overall semiconductor market.

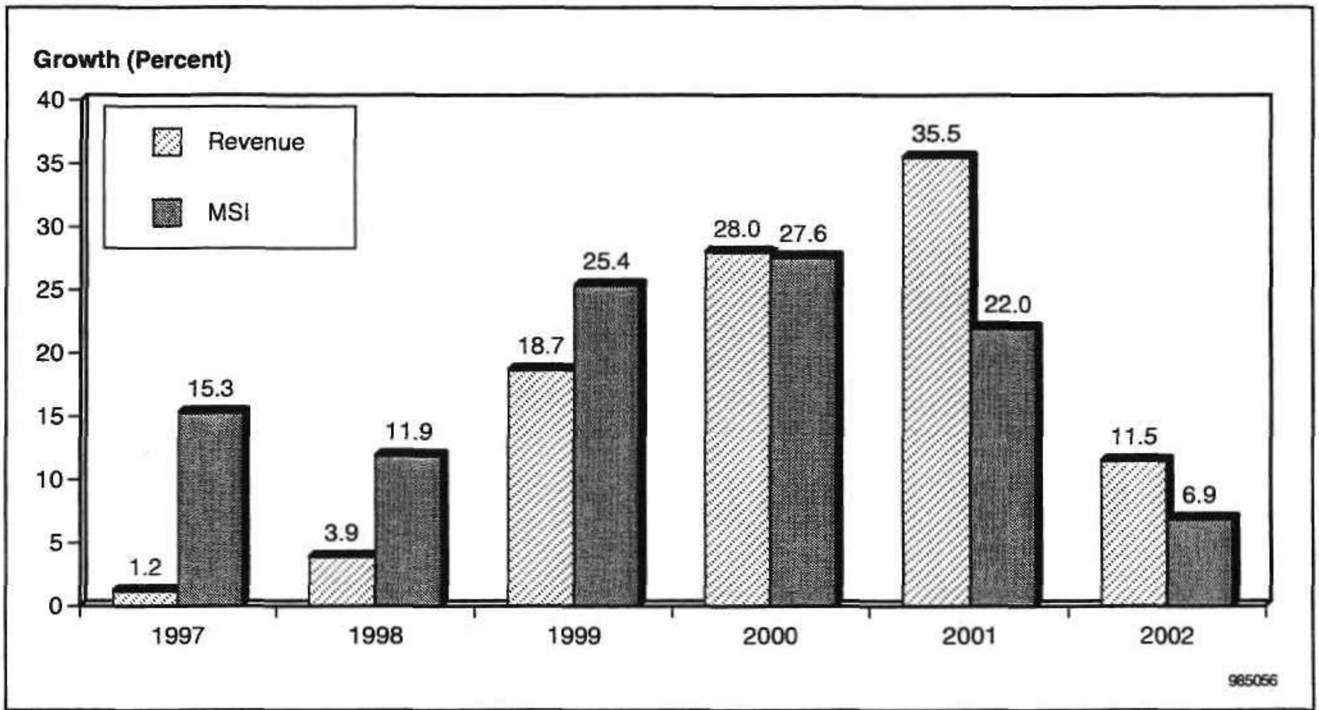
Figure 4-4 compares the sequential annual growth rates of revenue and MSI demand in the SCM market. The effect of strong downward price pressures can be clearly seen in the relative growth rates of 1997 and 1998, when, despite demand growth in MSI terms, revenue growth was constrained to less than 2 percent in 1997 and under 5 percent in 1998. The year 1999 will see a resumption of demand growth (in MSI terms) as the industry begins to emerge from its current slump and burn off excess capacity. However, revenue growth is now catching up with MSI growth, an indication of flattening price-per-square-inch trends, on average. In spite of continued excess capacity, which can be expected to maintain downward pressure on prices through most of 1999, a shift in demand toward leading-edge technology, especially 0.35 micron, will begin to be felt in the average price-per-square-inch of foundry wafers this year.

Figure 4-3
Worldwide SCM Market Forecast



Source: Dataquest (September 1998)

Figure 4-4
Annual Growth Rates of SCM Revenue and MSI



Source: Dataquest (September 1998)

Demand trending toward the leading edge will continue through 1999 and 2000, with 0.25-micron wafers entering the picture in a real way. This movement will drive an increase in the average price per square inch for the market as a whole, even though a competitive pricing environment may persist, especially in the leading-edge segments where excess capacity is expected to be greatest. Thus we see revenue growth on par with MSI growth during this period. At the same time, MSI growth is very strong indeed, bolstered by accelerated demand and stable pricing in the semiconductor end chip markets, which will be rebounding from a protracted period of slow growth and excess capacity. In short, the years 2000 and 2001 represent the next "boom cycle" of the semiconductor industry, and this effect will be amplified in the foundry market.

Following two years of exceptional growth in the foundry market, growth rates will moderate in the year 2002. It is during this period that Dataquest is expecting the industry to enter the next cyclical downturn, as exuberant capital spending once again causes capacity to overtake demand, and prices, especially in the DRAM market, begin to slide. The foundry market could still enjoy relatively robust growth, as shown in the chart, because of a couple of favorable influences. Fabless companies, which are completely reliant on foundries for their wafer manufacturing, will continue to grow, and they tend to produce more highly differentiated products that are less susceptible to the wild price swings of the DRAM market. As we saw in the last downturn, excess capacity and falling prices in the foundry market can lag the DRAM market by as much as a year. Also, uncertainty over the optimal timing of the migration to 300mm wafer fabrication will cause some IDMs to delay new fab projects, wishing to avoid building the first 300mm or the last 200mm wafer fab. Instead of building the new fabs, these IDMs will increase their usage of foundries in the short term, which will boost SCM demand in the year 2001.

Appendix A
Additional Forecast Data

Table A-1
Worldwide SCM Market by Customer Type (Millions of U.S. Dollars)

	1997	1998	1999	2000	2001	2002	CAGR (%) 1997-2002
IDM	1,735	1,816	2,289	3,074	3,936	3,908	17.6
Fabless	3,114	3,244	3,758	4,677	6,565	7,755	20.0
System OEM	329	320	340	420	575	683	15.7
Total	**5,178**	**5,380**	**6,386**	**8,172**	**11,077**	**12,347**	**19.0**

Source: Dataquest (September 1998)

Table A-2
Worldwide SCM Market by Region (Millions of U.S. Dollars)

	1997	1998	1999	2000	2001	2002	CAGR (%) 1997-2002
Americas	3,740	3,877	4,491	5,715	7,797	9,040	19.3
Japan	604	651	799	1,025	1,281	1,042	11.5
Europe	417	431	571	763	980	1,066	20.7
Asia/Pacific	417	422	526	669	1,019	1,199	23.5
Total	**5,178**	**5,380**	**6,386**	**8,172**	**11,077**	**12,347**	**19.0**

Source: Dataquest (September 1998)

Table A-3
Worldwide SCM Market by Technology Segment (Millions of U.S. Dollars)

	1997	1998	1999	2000	2001	2002	CAGR (%) 1997-2002
Leading-Edge/Mainstream Memory	590	604	786	1,143	1,589	1,237	-
Leading-Edge/Mainstream Logic	3,204	3,386	3,958	4,831	6,689	7,979	-
Lagging-Edge	1,238	1,253	1,449	1,930	2,467	2,774	17.5
Senior	147	138	194	268	331	356	19.4
Total	**5,178**	**5,380**	**6,386**	**8,172**	**11,077**	**12,347**	**19.0**

Source: Dataquest (September 1998)

Table A-4
Worldwide SCM Silicon Demand by Customer Type (Millions of Square Inches)

	1997	1998	1999	2000	2001	2002	CAGR (%) 1997-2002
IDM	85.9	96.2	124.7	159.7	184.4	181.8	16.2
Fabless	100.6	113.3	139.7	178.3	227.2	256.8	20.6
System OEM	11.9	12.5	14.0	17.5	22.0	25.0	16.1
Total	**198.3**	**222.0**	**278.4**	**355.4**	**433.5**	**463.6**	**18.5**

Source: Dataquest (September 1998)

Table A-5
Worldwide SCM Silicon Demand by Region (Millions of Square Inches)

	1997	1998	1999	2000	2001	2002	CAGR (%) 1997-2002
Americas	132.0	147.3	181.6	233.9	288.8	322.0	19.5
Japan	33.2	38.8	48.5	57.5	63.6	54.0	10.2
Europe	19.6	21.1	28.8	38.3	45.1	47.2	19.2
Asia/Pacific	13.5	14.7	19.6	25.8	36.0	40.4	24.6
Total	**198.3**	**222.0**	**278.4**	**355.4**	**433.5**	**463.6**	**18.5**

Source: Dataquest (September 1998)

Table A-6
Worldwide SCM Silicon Demand by Technology Segment (Millions of Square Inches)

	1997	1998	1999	2000	2001	2002	CAGR (%) 1997-2002
Leading-Edge/Mainstream Memory	34.0	37.7	49.1	62.1	73.1	63.8	-
Leading-Edge/Mainstream Logic	93.2	107.8	134.6	170.3	213.4	242.7	-
Lagging-Edge	56.7	61.5	74.8	97.4	116.1	124.6	17.1
Senior	14.5	15.0	19.9	25.6	31.0	32.5	17.6
Total	**198.3**	**222.0**	**278.4**	**355.4**	**433.5**	**463.6**	**18.5**

Source: Dataquest (September 1998)

For More Information...

Inquiry Hotline	+1-408-468-8423
Internet address	scndinquiry@dataquest.com
Via fax	+1-408-954-1780
Dataquest Interactive	http://www.dataquest.com

DATAQUEST WORLDWIDE OFFICES

NORTH AMERICA

Worldwide Headquarters
Dataquest/Gartner Group
251 River Oaks Parkway
San Jose, California 95134-1913
United States
Phone: +1-408-468-8000
Facsimile: +1-408-954-1780

East Coast Research Center
Gartner Group Lowell
900 Chelmsford Street
Tower Two, Floor Nine
Lowell, Massachusetts 01851
United States
Phone: +1-978-323-6900
Facsimile: +1-978-323-6933

EUROPE

European Headquarters
Gartner Group Ltd.
Tamesis, The Glanty
Egham, Surrey TW20 9AW
United Kingdom
Phone: +44-1784-431-611
Facsimile: +44-1784-488-980

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

Dataquest Germany
Martin-Kollar-Strasse 15
D-81829 München
Germany
Phone: +49-89-42-70-4-0
Facsimile: +49-89-42-70-4-270

JAPAN

Japan Headquarters
Aobadai Hills 4-7-7
Aobadai
Meguro-ku, Tokyo 153-0042
Japan
Phone: +81-3-3481-3670
Facsimile: +81-3-3481-3644

ASIA/PACIFIC

Asia Headquarters
Gartner Group Hong Kong
Suite 5904-7, Central Plaza
18 Harbour Road
Wanchai
Hong Kong
Phone: +852-2824-6168
Facsimile: +852-2824-6138

Pacific Headquarters
Gartner Group Pacific
80 Alfred Street - 6th Floor
Milsons Point, NSW 2061
Australia
Phone: +61-2-9941-4860
Facsimile: +61-2-9941-4868

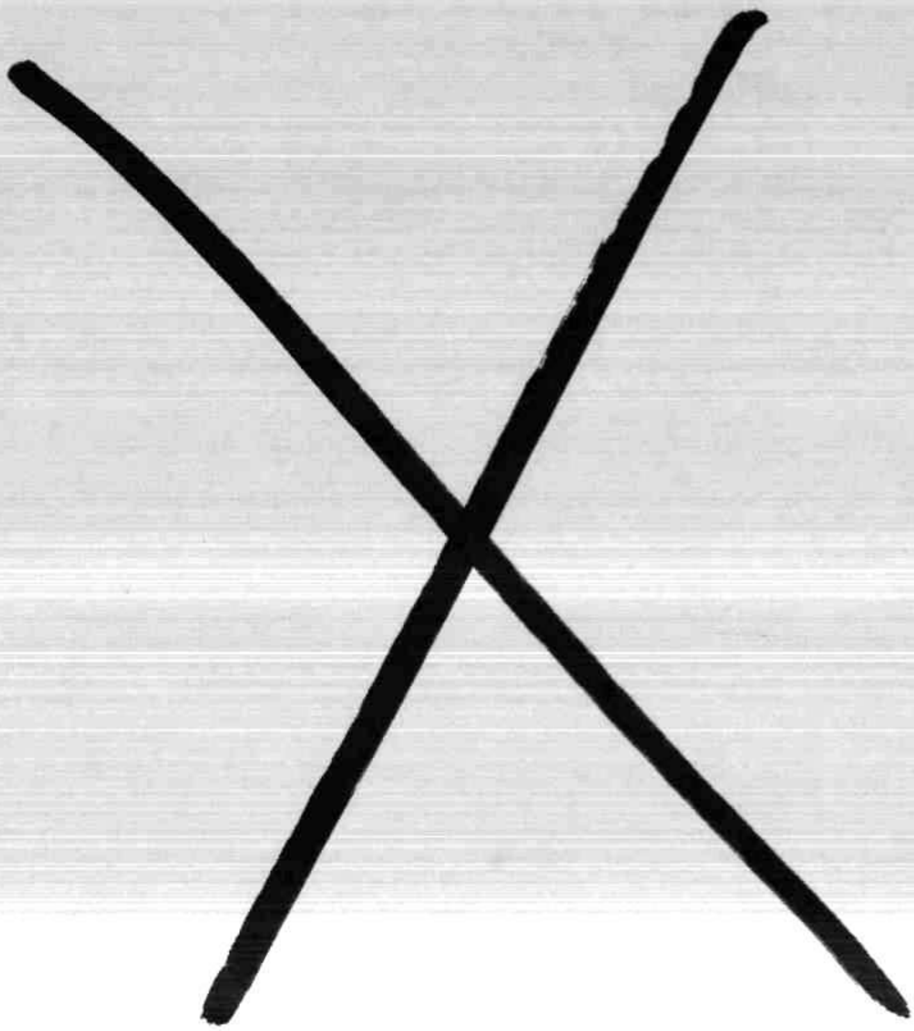
Korea
Dataquest Korea
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: +82-2-551-1331
Facsimile: +82-2-551-1330

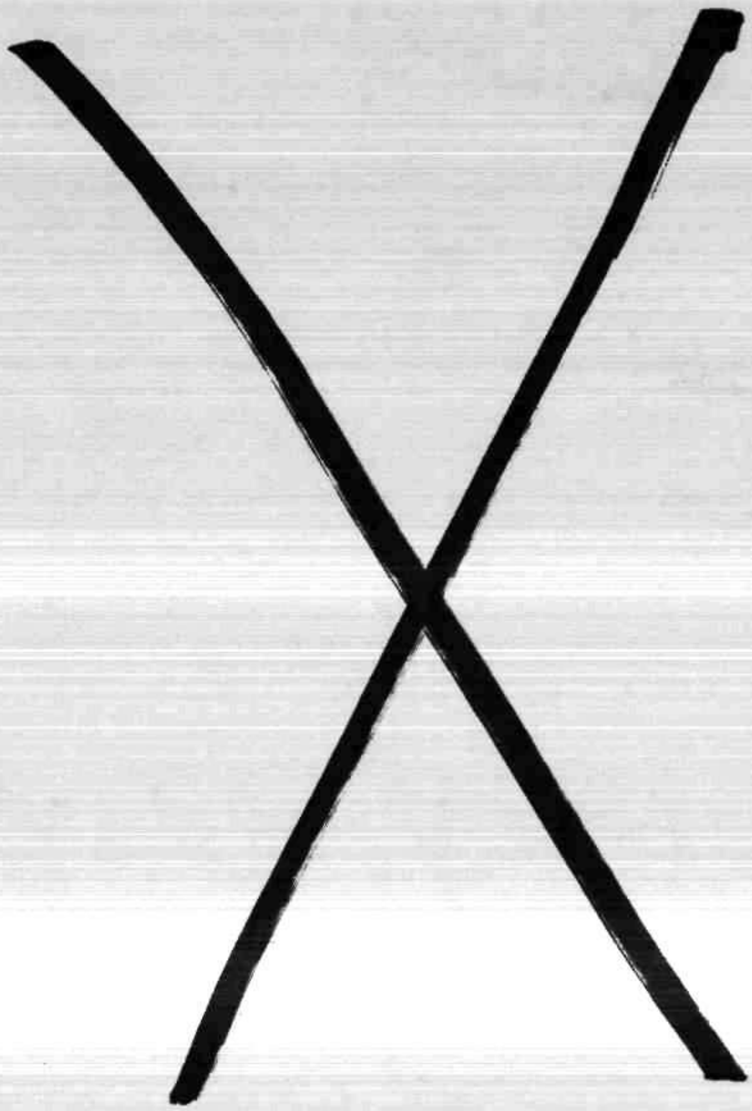
Taiwan
Gartner Group Taiwan Ltd.
11F-2, 188, Section 5
Nan King East Road
Taipei 105
Taiwan R.O.C.
Phone: +886-2-2756-0389
Facsimile: +886-2-2756-2663/4122

Thailand
Gartner Group Thailand Ltd.
29 Vanissa Building, 12F
Soi Chidlom, Ploenchit Road
Pathumwan, Bangkok 10330
Thailand
Phone: +662-655-0577
Facsimile: +662-655-0576

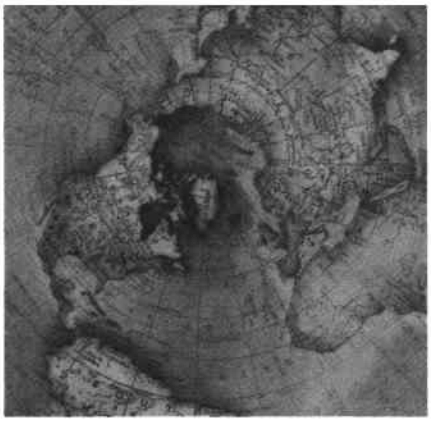
Singapore
Gartner Group Advisory (S) Pte Ltd.
6 Temasek Boulevard #26-02/03
Suntec City Tower 4
Singapore 038986
Phone: +65-333-6773
Facsimile: +65-333-6787

Dataquest
A Gartner Group Company





Market Statistics



Dataquest

1997 Semiconductor Contract Manufacturing Market Share Estimates

Market Statistics

Program: Semiconductor Contract Manufacturing Services Worldwide
Product Code: SCMS-WW-MS-9801
Publication Date: September 21, 1998
Filing: Market Statistics

1997 Semiconductor Contract Manufacturing Market Share Estimates

Market Statistics

Program: Semiconductor Contract Manufacturing Services Worldwide
Product Code: SCMS-WW-MS-9801
Publication Date: September 21, 1998
Filing: Market Statistics

Table of Contents

List of Tables

Chapter 1
Executive Summary

Overview of the 1997 SCM Market Share Study

Research Objectives

- To quantify the worldwide market for SCM (foundry) services in 1997, in terms of revenue and number of wafers shipped
- To rank SCM service providers by their shares of the 1997 foundry market
- To determine the relative size of various segments of the foundry market, categorized by geographic region, customer type, process technology, design interface, and level of foundry service
- To characterize the differences and similarities among the two types of SCM service providers: dedicated (pure-play) foundries and integrated device manufacturers (IDMs)

Methodology

The cornerstone of this research is Dataquest's annual survey of SCM service providers. A total of 55 companies, comprising 10 dedicated foundries and 45 IDMs, were surveyed for their 1997 sales of SCM services. Of the 55 companies, 42 responded to the survey, representing 73 percent of total worldwide foundry revenue. Foundry sales of the remaining companies were estimated based on information obtained from annual reports, press announcements, company promotional literature, and other public sources. In addition, these estimates were cross-checked against a foundry capacity analysis of each company to ensure consistent results.

Companies were asked to report their total revenue from shipments of SCM (foundry) wafers during calendar year 1997, as well as the number of wafers of each diameter that were shipped. In addition, companies were asked to confirm previously reported or estimated 1996 revenue. A series of questions in the survey requested breakdowns of foundry sales, as a percentage of revenue, within various categories.

Region of Sale

The definition of regional distribution of sales has special significance in the SCM market. Most of the companies that rely on foundries for wafer fabrication also use contract manufacturers for the packaging, assembly, and test phases of IC production, commonly referred to as the back-end operations. As a result, a large portion of the foundries' shipments are directed to these back-end contract manufacturers for subsequent processing. In some cases, the finished product is then drop-shipped to the end customer or to a distribution channel, never returning to the original foundry customer.

For purposes of characterizing the market for SCM services, the location of the foundry customer is more important than the region to which the wafers are shipped. In other words, the regional segmentation of the market should reflect the origins of the purchase orders for foundry services, not necessarily where the wafers are being sent for back-end processing. After applying this definition for region of sale, the resulting market statistics will provide a more accurate indication of where the greatest opportunities lie for SCM service providers.

The majority of back-end contract manufacturers are located in the Asia/Pacific region. Therefore, the initial survey responses resulted in a very high concentration of foundry sales to this region, reflecting a substantial amount of wafers being shipped from the foundries directly to back-end contract manufacturers. This result, while not surprising, was inconsistent with the preceding definition and with our knowledge of foundry demand in the Asia/Pacific region, which is almost entirely composed of an emerging fabless semiconductor community on the island of Taiwan. The SCM revenue estimates into the Asia/Pacific region were adjusted to be consistent with estimated demand, and the balance of revenue was reallocated to the other regions in the same proportions as reported in the initial survey responses.

Highlights and Key Findings

- For the year 1997, the market for SCM services amounted to $5,178 million, representing a rather anemic 1.2 percent increase over 1996. Pricing pressures, resulting from widespread oversupply, limited revenue growth.
- Taiwan Semiconductor Mfg. Co. (TSMC) maintained its position as the No. 1 SCM supplier, with almost 30 percent of the worldwide market for foundry services. The closest competitor was IBM with 11 percent market share.
- The Americas region accounted for 72 percent of the total demand for SCM services in 1997, reflecting the success of fabless semiconductor companies and a steadily increasing use of foundries on the part of IDM companies in the region.
- Dedicated, or "pure-play," foundries captured 44 percent of the market for SCM services in 1997, compared to 41 percent in 1996.
- Fabless semiconductor companies represented the largest segment of the foundry market in 1997, at 60 percent, with IDMs accounting for 34 percent and system OEM companies making up the remaining 6 percent of the worldwide market.
- Customers continue to transfer designs to foundries predominantly at the mask or GDS-II (or equivalent) tape level, with these two categories combining for 92 percent of worldwide SCM revenue in 1997.
- More than 60 percent of 1997 SCM revenue was attributable to wafers processed to linewidths of 0.5 micron and below, reflecting a migration of designs to leading-edge technologies as well as the higher average wafer prices associated with these technologies.

Chapter 2
Market Statistics Tables

Tables 2-1 through 2-17 provide detailed market statistics from Dataquest's annual survey of SCM service providers.

Table 2-1
Historical Sales Revenue from Shipments of SCM (Foundry) Wafers to the World, 1993 to 1997 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	CAGR (%) 1993-1997
Surveyed North American Companies						
Allegro MicroSystems	-	-	3	5	5	NM
Allied Signal Aerospace	-	-	-	-	18	NM
Applied Micro Circuits Corporation	-	-	1	2	3	NM
American Microsystems Inc.	50	62	77	110	71	9.2
Calogic Corporation	-	-	-	-	2	NM
GMT Microelectronics Corporation	-	-	2	2	5	NM
IBM Microelectronics	47	240	320	450	570	86.6
IC Works	-	15	18	20	-	NM
IMP	-	46	50	32	30	NM
LinFinity Microelectronics	-	-	-	-	1	NM
Lucent Technologies	-	-	45	30	36	NM
Micrel Semiconductor	10	18	23	23	8	-4.7
Mitel Corporation	-	-	25	20	20	NM
National Semiconductor Corporation	-	-	-	-	6	NM
Orbit Semiconductor	27	32	44	50	70	26.9
Raytheon Company	-	-	1	1	1	NM
SenSym	-	-	-	-	1	NM
Texas Instruments	20	30	30	15	17	-4.0
VLSI Technology	-	7	7	16	2	NM
North American Companies	154	450	646	776	866	54.0
Surveyed Japanese Companies						
Asahi Kasei Microsystems	20	22	25	30	149	65.2
Fujitsu	75	60	50	46	64	-4.0
Hitachi	20	15	12	9	5	-29.3
Kawasaki Semiconductor	85	70	60	55	50	-12.4
Matsushita	47	30	49	86	50	1.3
Mitsubishi	130	80	32	24	41	-24.9
NEC	50	40	33	28	10	-33.3
New Japan Radio Company	10	10	11	14	6	-12.8
Nippon Steel Semiconductor	340	320	266	18	3	-68.6
Oki	130	85	35	28	58	-18.3
Ricoh	15	20	45	55	21	8.3

Table 2-1 (Continued)
Historical Sales Revenue from Shipments of SCM (Foundry) Wafers to the World, 1993 to 1997 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	CAGR (%) 1993-1997
Rohm	18	30	25	28	17	-2.1
SANYO	37	46	72	138	75	19.4
Seiko Epson	220	250	260	230	126	-12.9
Sharp	135	160	192	236	253	17.0
Sony	5	6	8	9	2	-20.5
Toshiba	430	450	479	184	41	-44.3
Yamaha	32	38	40	46	7	-32.4
Japanese Companies	1,799	1,732	1,694	1,264	977	-14.2
Surveyed European Companies						
Austria Mikro Systeme	-	-	38	23	38	NM
Newport Wafer Fab Limited	-	14	30	32	30	NM
STMicroelectronics	30	50	75	69	80	27.8
Thesys Microelectronics	-	6	34	17	10	NM
Tower Semiconductor	37	57	100	98	126	35.8
European Companies	82	150	277	239	284	36.4
Surveyed Asia/Pacific Companies						
ASMC (Shanghai)	0	15	30	40	59	NM
Anam Semiconductor	-	-	-	-	1	NM
Hyundai Electronics Company	-	-	-	-	18	NM
Chartered Semiconductor Manufacturing	95	180	285	420	450	47.5
Daewoo	-	-	4	8	-	NM
Hualon Microelectronics Corporation	-	15	15	16	20	NM
Holtek Microelectronics	-	14	17	63	74	NM
LG Semicon	240	320	567	337	320	7.5
Samsung	-	24	30	50	25	NM
Taiwan Semiconductor Mfg. Co.	480	750	1,085	1,435	1,529	33.6
United Microelectronics Corporation Group	134	165	262	331	493	38.5
Winbond Electronics Corporation	30	60	155	138	62	19.9
Asia/Pacific Companies	996	1,543	2,450	2,838	3,051	32.3
Surveyed Worldwide Companies						
Surveyed Companies	2,999	3,852	5,067	5,117	5,178	14.6
Other Companies	97	68	-	-	-	NM
Total Market	**3,096**	**3,920**	**5,067**	**5,117**	**5,178**	**13.7**

NM = Not meaningful
Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (August 1998)

Table 2-2
Top 15 Companies' Sales Revenue from Shipments of SCM (Foundry) Wafers to the World (Millions of U.S. Dollars)

1997 Rank	1996 Rank	Company	1996	1997	Growth (%) 1996-1997	Market Share (%) 1997
1	1	TSMC	1,435	1,529	6.6	29.5
2	2	IBM Microelectronics	450	570	26.7	11.0
3	5	UMC Group	331	493	48.9	9.5
4	3	Chartered Semiconductor Mfg.	420	450	7.1	8.7
5	4	LG Semicon	337	320	-5.0	6.2
6	6	Sharp	236	253	7.1	4.9
7	25	Asahi Kasei Microsystems	30	149	396.7	2.9
8	7	Seiko Epson	230	126	-45.1	2.4
9	12	Tower Semiconductor	98	126	28.3	2.4
10	14	STMicroelectronics	69	80	15.9	1.5
11	9	SANYO	138	75	-45.5	1.5
12	15	Holtek	63	74	17.5	1.4
13	11	American Microsystems Inc.	110	71	-35.5	1.4
14	18	Orbit Semiconductor	50	70	40.0	1.4
15	20	Fujitsu	46	64	38.2	1.2
		Total Top 15 for 1997	**4,043**	**4,449**	**10.1**	**85.9**
		Other Companies	**1,074**	**728**	**-32.2**	**14.1**
		Total Market	**5,117**	**5,178**	**1.2**	**100.0**

Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (August 1998)

Table 2-3
Top 15 Companies' Sales Revenue from Shipments of SCM (Foundry) Wafers to the Americas Region (Millions of U.S. Dollars)

1997 Rank	1996 Rank	Company	1996	1997	Growth (%) 1996-1997	Market Share (%) 1997
1	1	TSMC	961	1,040	8.1	27.8
2	2	IBM Microelectronics	428	485	13.3	13.0
3	5	UMC Group	255	399	56.7	10.7
4	3	Chartered Semiconductor Mfg.	357	396	10.9	10.6
5	4	Sharp	227	245	8.2	6.6
6	NA	Asahi Kasei Microsytems	-	149	NA	4.0
7	6	Seiko Epson	184	91	-50.6	2.4
8	7	SANYO	132	74	-44.4	2.0
9	10	American Microsystems Inc.	88	64	-27.4	1.7
10	15	Orbit Semiconductor	45	60	32.2	1.6
11	12	STMicroelectronics	59	56	-4.5	1.5
12	NA	Kawasaki Semiconductor	-	50	NA	1.3
13	11	Matsushita	86	50	-42.4	1.3
14	21	Oki	21	49	130.9	1.3
15	NA	Mitsubishi	-	41	NA	1.1
		Total Top 15 for 1997	**2,843**	**3,248**	**14.2**	**86.8**
		Other Companies	**821**	**493**	**-40.0**	**13.2**
		All Companies	**3,664**	**3,740**	**2.1**	**100.0**

NA = Not available or not applicable
Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (August 1998)

Table 2-4
Top 15 Companies' Sales Revenue from Shipments of SCM (Foundry) Wafers to the Japan Region (Millions of U.S. Dollars)

1997 Rank	1996 Rank	Company	1996	1997	Growth (%) 1996-1997	Market Share (%) 1997
1	1	LG Semicon	297	286	-3.4	47.4
2	2	TSMC	72	168	134.4	27.8
3	NA	Fujitsu	NA	60	NA	10.0
4	4	Seiko Epson	32	23	-29.4	3.8
5	NA	Lucent	NA	13	NA	2.1
6	10	UMC Group	7	10	NA	1.6
7	12	Oki	7	9	29.0	1.4
8	11	Sharp	9	8	-19.7	1.3
9	14	Tower Semiconductor	5	6	28.3	1.0
10	3	Ricoh	36	6	-82.7	1.0
11	19	Winbond	1	5	259.8	0.8
12	8	Toshiba	18	4	-77.6	0.7
13	NA	Yamaha	NA	2	NA	0.4
14	13	NEC	6	2	-64.6	0.3
15	NA	Allegro MicroSystems	NA	2	NA	0.2
		Total Top 15 for 1997	**489**	**604**	**23.5**	**99.9**
		Other Companies	**137**	**0**	**-99.5**	**0.1**
		Total Market	**627**	**604**	**-3.0**	**100.0**

NA = Not available or not applicable
Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (August 1998)

Table 2-5
Top 15 Companies' Sales Revenue from Shipments of SCM (Foundry) Wafers to the Europe Region (Millions of U.S. Dollars)

1997 Rank	1996 Rank	Company	1996	1997	Growth (%) 1996-1997	Market Share (%) 1997
1	1	TSMC	258	168	-34.9	40.4
2	4	IBM Microelectronics	23	57	153.3	13.7
3	2	ASMC (Shanghai)	28	35	26.4	8.5
4	7	Austria Mikro Systeme	18	28	59.7	6.8
5	3	Newport Wafer Fab Limited	24	27	12.5	6.5
6	12	Tower Semiconductor	11	26	144.9	6.3
7	9	UMC Group	30	25	-17.3	5.9
8	8	Seiko Epson	14	13	-8.4	3.0
9	11	Orbit Semiconductor	5	10	96.0	2.4
10	NA	STMicroelectronics	-	8	NA	1.9
11	5	American Microsystems	22	4	-83.9	0.9
12	NA	TI	-	3	NA	0.6
13	18	Mitel	2	2	0	0.5
14	NA	National	-	2	NA	0.4
15	15	SANYO	3	2	-45.5	0.4
		Total Top 15 for 1997	**437**	**409**	**-6.4**	**98.0**
		Other Companies	**60**	**19**	**-67.4**	**4.7**
		Total Market	**496**	**417**	**-16.0**	**100.0**

NA = Not available or not applicable
Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (August 1998)

Table 2-6
Top 15 Companies' Sales Revenue from Shipments of SCM (Foundry) Wafers to the Asia/Pacific Region (Millions U.S. Dollars)

1997 Rank	1996 Rank	Company	1996	1997	Growth (%) 1996-1997	Market Share (%) 1997
1	1	TSMC	144	153	6.6	36.7
2	2	UMC Group	40	59	48.9	14.2
3	3	Chartered Semiconductor Mfg.	50	54	7.1	12.9
4	NA	IBM Microelectronics	-	29	NA	6.8
5	NA	LG Semicon	-	21	NA	5.0
6	5	Tower Semiconductor	12	19	60.3	4.5
7	7	Winbond	21	16	-25.1	3.7
8	9	STMicroelectronics	10	16	54.6	3.8
9	4	Holtek	9	11	17.5	2.7
10	10	Hualon Microelectronics	3	10	212.5	2.4
11	NA	Hyundai	-	10	NA	2.3
12	NA	Samsung	-	5	NA	1.2
13	NA	American Microsystems Inc.	-	4	NA	0.9
14	NA	Austria Mikro Systeme	-	2	NA	0.5
15	NA	NEC	-	2	NA	0.5
		Total Top 15 for 1997	**289**	**409**	**41.6**	**98.16**
		Other Companies	**41**	**8**	**-81.3**	**1.84**
		Total Market	**330**	**417**	**26.4**	**100.00**

NA = Not available or not applicable
Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (August 1998)

Table 2-7
Sales Revenue from Shipments of SCM (Foundry) Wafers by Company Base into Each Region, 1996 and 1997 (Millions of U.S. Dollars)

	1996	1997	Growth (%) 1996-1997
North American Companies			
Americas	702	734	4.6
Japan	3	14	375.9
Europe	57	81	41.3
Asia/Pacific	14	37	162.9
Worldwide	776	866	11.7
Japanese Companies			
Americas	954	844	-11.5
Japan	239	114	-52.3
Europe	48	16	-66.5
Asia/Pacific	22	2	-91.0
Worldwide	1,264	977	-22.7
European Companies			
Americas	156	148	-5.1
Japan	5	6	20.0
Europe	52	90	73.1
Asia/Pacific	25	39	56.0
Worldwide	239	284	18.7
Asia/Pacific Companies			
Americas	1,851	2,013	8.8
Japan	379	469	23.9
Europe	338	229	-32.2
Asia/Pacific	269	339	26.0
Worldwide	2,838	3,051	7.5
All Companies			
Americas	3,664	3,740	2.1
Japan	627	604	-3.6
Europe	496	417	-15.9
Asia/Pacific	331	417	26.0
Worldwide	5,117	5,178	1.2

Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (August 1998)

Table 2-8
Distribution of Sales Revenue from Shipments of SCM (Foundry) Wafers by Company Base into Each Region, 1996 and 1997 (Percent)

	1996	1997
North American Companies		
Americas	90.0	85.0
Japan	0.4	2.0
Europe	7.0	9.0
Asia/Pacific	2.0	4.0
Worldwide	100.0	100.0
Japanese Companies		
Americas	75.0	86.0
Japan	19.0	12.0
Europe	4.0	2.0
Asia/Pacific	2.0	0.2
Worldwide	100.0	100.0
European Companies		
Americas	65.0	52.0
Japan	2.0	2.0
Europe	22.0	32.0
Asia/Pacific	11.0	14.0
Worldwide	100.0	100.0
Asia/Pacific Companies		
Americas	65.0	66.0
Japan	13.0	15.0
Europe	12.0	8.0
Asia/Pacific	9.0	11.0
Worldwide	100.0	100.0
All Companies		
Americas	72.0	72.0
Japan	12.0	12.0
Europe	10.0	8.0
Asia/Pacific	6.0	8.0
Worldwide	100.0	100.0

Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (August 1998)

Table 2-9
Sales Revenue from Shipments of SCM (Foundry) Wafers by Company Type into Each Region, 1996 and 1997 (Millions of U.S. Dollars)

	1996	1997	Growth (%) 1996-1997
Dedicated Foundry Companies			
Americas	1,481	1,625	9.8
Europe	339	268	-20.9
Asia/Pacific	211	229	8.4
Japan	77	175	127.6
Worldwide	2,107	2,296	9.0
IDM Companies			
Americas	2,183	2,115	-3.1
Europe	158	149	-5.6
Asia/Pacific	120	188	57.2
Japan	550	430	-21.9
Worldwide	3,010	2,882	-4.3
All Companies			
Americas	3,664	3,740	2.1
Europe	496	417	-16.0
Asia/Pacific	331	417	26.1
Japan	627	604	-3.6
Worldwide	5,117	5,178	1.2

Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (August 1998)

Table 2-10
Distribution of Sales Revenue from Shipments of SCM (Foundry) Wafers by Company Type into Each Region, 1996 and 1997 (Percent)

	1996	1997
Dedicated Foundry Companies		
Americas	70	71
Europe	16	12
Asia/Pacific	10	10
Japan	4	7
Worldwide	100	100
IDM Companies		
Americas	73	73
Europe	5	5
Asia/Pacific	4	7
Japan	18	15
Worldwide	100	100
All Companies		
Americas	72	72
Europe	10	8
Asia/Pacific	6	8
Japan	12	12
Worldwide	100	100

Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (August 1998)

Table 2-11
Sales Revenue from Shipments of SCM (Foundry) Wafers by Company Type into Each Customer Type, 1997

	Revenue (U.S.$M)	Distribution (%)
Dedicated Foundry Companies		
Fabless Semiconductor Companies	1,390	61
IDM (IC Companies with Fabs)	872	38
System/OEM Customers	34	1
All Customer Types	2,296	100
IDM Companies		
Fabless Semiconductor Companies	1,724	60
IDM (IC Companies with Fabs)	863	30
System/OEM Customers	295	10
All Customer Types	2,882	100
All Companies		
Fabless Semiconductor Companies	3,114	60
IDM (IC Companies with Fabs)	1,735	34
System/OEM Customers	329	6
All Customer Types	5,178	100

Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (August 1998)

Table 2-12
Sales Revenue from Shipments of SCM (Foundry) Wafers by Company Type and Design Interface, 1997

	Revenue (U.S.$M)	Distribution (%)
Dedicated Foundry Companies		
Masks	1,604	70
GDS-2 Tape (or Equivalent)	589	26
High-Level Design Language (VHDL or Verilog)	25	1
Net-List plus Foundry-Owned Nonproprietary Cell Libraries	47	2
Net-List plus Foundry-Owned Proprietary Cell Libraries	30	1
All Designs	2,296	100
IDM Companies		
Masks	1,197	42
GDS-2 Tape (or Equivalent)	1,356	47
High-Level Design Language (VHDL or Verilog)	153	5
Net-List plus Foundry-Owned Nonproprietary Cell Libraries	151	5
Net-List plus Foundry-Owned Proprietary Cell Libraries	25	1
All Designs	2,882	100
All Companies		
Masks	2,801	54
GDS-2 Tape (or Equivalent)	1,945	38
High-Level Design Language (VHDL or Verilog)	178	3
Net-List plus Foundry-Owned Nonproprietary Cell Libraries	198	4
Net-List plus Foundry-Owned Proprietary Cell Libraries	55	1
All Designs	5,178	100

Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (August 1998)

Table 2-13
Sales Revenue from Shipments of SCM (Foundry) Wafers by Company Type and Process, 1997

	Revenue (U.S.$M)	Distribution (%)
Dedicated Foundry Companies		
CMOS	2,220	97
BiCMOS	22	1
Bipolar	42	2
Other	13	1
All Processes	2,296	100
IDM Companies		
CMOS	2,760	96
BiCMOS	76	3
Bipolar	21	1
Other	24	1
All Processes	2,882	100
All Companies		
CMOS	4,980	96
BiCMOS	98	2
Bipolar	63	1
Other	37	1
All Processes	5,178	100

Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (August 1998)

Table 2-14
Sales Revenue from Shipments of SCM (Foundry) Wafers by Company Type and Linewidth, 1997

	Revenue (U.S.$M)	Distribution (%)
Dedicated Foundry Companies		
1.0 Micron or Greater	324	14
0.8 to 1.0 Micron	233	10
0.6 to 0.8 Micron	630	27
0.5 to 0.6 Micron	502	22
0.35 to 0.5 Micron	608	26
Less than 0.35 Micron	NA	NA
All Linewidths	2,296	100
IDM Companies		
1.0 Micron or Greater	402	14
0.8 to 1.0 Micron	227	8
0.6 to 0.8 Micron	187	6
0.5 to 0.6 Micron	630	22
0.35 to 0.5 Micron	1,364	47
Less than 0.35 Micron	73	3
All Linewidths	2,882	100
All Companies		
1.0 Micron or Greater	726	14
0.8 to 1.0 Micron	459	9
0.6 to 0.8 Micron	817	16
0.5 to 0.6 Micron	1,131	22
0.35 to 0.5 Micron	1,972	38
Less than 0.35 Micron	73	1
All Linewidths	5,178	100

NA = Not applicable or not available
Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (August 1998)

Table 2-15
Sales Revenue from Shipments of SCM (Foundry) Wafers by Company Type and Number of Metal Levels, 1997

	Revenue (U.S.$M)	Distribution (%)
Dedicated Foundry Companies		
1 Metal Level	235	10
2 Metal Levels	1,235	54
3 Metal Levels	786	34
4 Metal Levels	41	2
5 or More Metal Levels	NA	NA
All Metal Levels	2,296	100
IDM Companies		
1 Metal Level	583	20
2 Metal Levels	1,185	41
3 Metal Levels	983	34
4 Metal Levels	128	4
5 or More Metal Levels	3	0
All Metal Levels	2,882	100
All Companies		
1 Metal Level	818	16
2 Metal Levels	2,420	47
3 Metal Levels	1,769	34
4 Metal Levels	169	3
5 or More Metal Levels	3	0
All Metal Levels	5,178	100

NA = Not available or not applicable
Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (August 1998)

Table 2-16
Sales Revenue from Shipments of SCM (Foundry) Wafers by Company Type and Foundry Service, 1997

	Revenue (U.S.$M)	Distribution (%)
Dedicated Foundry Companies		
Unprobed Wafers	1,156	50
Probed Wafers	545	24
Tested Wafers (Known Good Die)	381	17
Packaged Chips	214	9
All Foundry Services	2,296	100
IDM Companies		
Unprobed Wafers	1,381	48
Probed Wafers	582	20
Tested Wafers (Known Good Die)	224	8
Packaged Chips	695	24
All Foundry Services	2,882	100
All Companies		
Unprobed Wafers	2,538	49
Probed Wafers	1,127	22
Tested Wafers (Known Good Die)	604	12
Packaged Chips	909	18
All Foundry Services	5,178	100

Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (August 1998)

Table 2-17
Sales Revenue from Shipments of SCM (Foundry) Wafers by Company and Product Type, 1997

	Revenue (U.S.$M)	Distribution (%)
Dedicated Foundry Companies		
ASIC	172	7
Logic/Micro	1,346	59
Mixed-Signal	209	9
Analog	95	4
DRAM	138	6
SRAM	232	10
Flash	5	0
Others	102	4
All Product Types	2,296	100
IDM Companies		
ASIC	403	14
Logic/Micro	1,575	55
Mixed-Signal	219	8
Analog	36	1
DRAM	313	11
SRAM	38	1
Flash	270	9
Others	27	1
All Product Types	2,882	100
All Companies		
ASIC	575	11
Logic/Micro	2,920	56
Mixed-Signal	428	8
Analog	131	3
DRAM	450	9
SRAM	271	5
Flash	275	5
Others	129	2
All Product Types	5,178	100

Note: Some columns may not add to totals shown because of rounding.
Source: Dataquest (August 1998)

For More Information...

Inquiry Hotline	+1-408-468-8423
Internet address	scndinquiry@dataquest.com
Via fax	+1-408-954-1780
Dataquest Interactive	http://www.dataquest.com

 71210

Dataquest

A Gartner Group Company

DATAQUEST WORLDWIDE OFFICES

NORTH AMERICA

Worldwide Headquarters
Dataquest/Gartner Group
251 River Oaks Parkway
San Jose, California 95134-1913
United States
Phone: +1-408-468-8000
Facsimile: +1-408-954-1780

East Coast Research Center
Gartner Group Lowell
900 Chelmsford Street
Tower Two, Floor Nine
Lowell, Massachusetts 01851
United States
Phone: +1-978-446-0006
Facsimile: +1-978-323-6933

EUROPE

European Headquarters
Gartner Group Ltd.
Tamesis, The Glanty
Egham, Surrey TW20 9AW
United Kingdom
Phone: +44-1784-431-611
Facsimile: +44-1784-488-980

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

Dataquest Germany
Martin-Kollar-Strasse 15
D-81829 München
Germany
Phone: +49-89-42-70-4-0
Facsimile: +49-89-42-70-4-270

JAPAN

Japan Headquarters
Aobadai Hills 4-7-7
Aobadai
Meguro-ku, Tokyo 153-0042
Japan
Phone: +81-3-3481-3670
Facsimile: +81-3-3481-3644

ASIA/PACIFIC

Asia Headquarters
Gartner Group Hong Kong
Suite 5904-7, Central Plaza
18 Harbour Road
Wanchai
Hong Kong
Phone: +852-2824-6168
Facsimile: +852-2824-6138

Pacific Headquarters
Gartner Group Pacific
80 Alfred Street - 6th Floor
Milsons Point, NSW 2061
Australia
Phone: +61-2-9941-4860
Facsimile: +61-2-9941-4868

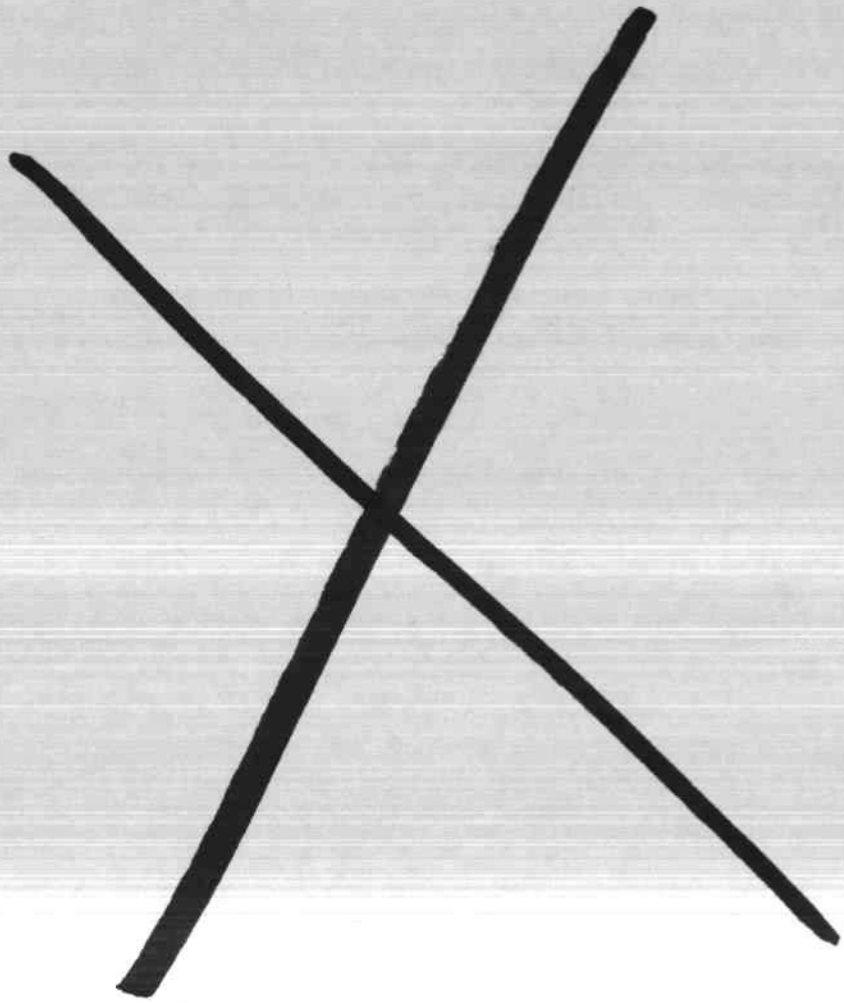
Korea
Dataquest Korea
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: +82-2-551-1331
Facsimile: +82-2-551-1330

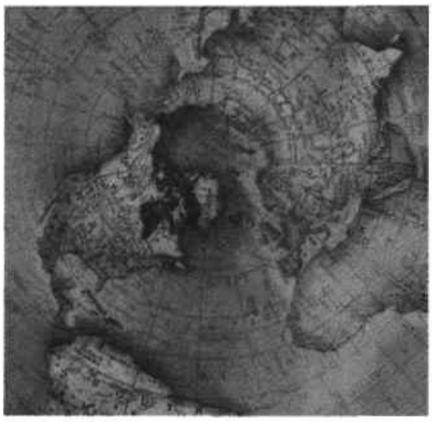
Taiwan
Gartner Group Taiwan Ltd.
11F-2, 188, Section 5
Nan King East Road
Taipei 105
Taiwan R.O.C.
Phone: +886-2-2756-0389
Facsimile: +886-2-2756-2663/4122

Thailand
Gartner Group Thailand Ltd.
29 Vanissa Building, 12F
Soi Chidlom, Ploenchit Road
Pathumwan, Bangkok 10330
Thailand
Phone: +662-655-0577
Facsimile: +662-655-0576

Singapore
Gartner Group/DQ Research Pte Ltd.
6 Temasek Boulevard #26-02/03
Suntec City Tower 4
Singapore 038986
Phone: +65-333-6773
Facsimile: +65-333-6787

Dataquest
A Gartner Group Company





Dataquest

1998 Fabless Semiconductor Company Directory

Focus Report

Program: Semiconductor Contract Manufacturing Services Worldwide
Product Code: SCMS-WW-FR-9801
Publication Date: December 21, 1998
Filing: Reports

1998 Fabless Semiconductor Company Directory

Focus Report

Program: Semiconductor Contract Manufacturing Services Worldwide
Product Code: SCMS-WW-FR-9801
Publication Date: December 21, 1998
Filing: Reports

Table of Contents

List of Figures

List of Tables

Chapter 1
Introduction

In recent years, the success of the fabless business model, supported by the complementary foundry business model, has become well established. Fabless semiconductor companies now represent 5.2 percent of the worldwide semiconductor market, and they are expected to continue to outpace the industry for the foreseeable future. (The Dataquest document "1997 Fabless Semiconductor Review," SCMS-WW-DP-9805, June 1998, analyzes fabless semiconductor company revenue and application markets.) The importance of this sector cannot be overstated, and the relationship between fabless semiconductor companies and growth in demand for foundry services is fundamental.

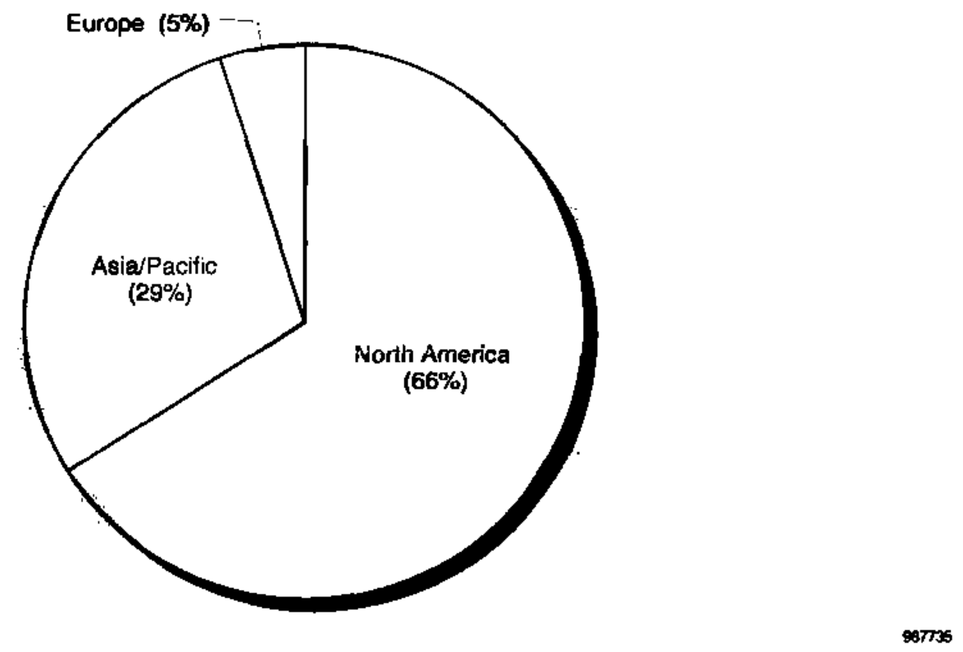
The number of fabless semiconductor companies is also growing. For the 1998 Fabless Directory, Dataquest has identified about 230 fabless semiconductor companies around the world. Although many of these companies have attained a level of prominence in the industry, many more are relative newcomers, usually privately held, for which abundant information is not always available. The purpose of this report is to provide a directory of companies in the emerging fabless sector, along with some essential facts, such as company address, a brief description of product offerings, 1997 revenue (if available), stock symbol (if applicable), and the year the company was founded. It is hoped that the report will serve as a guide to the very dynamic fabless sector and provide a launching pad for further research into the fabless semiconductor companies.

Dataquest obtained the information in this directory through a combination of direct and secondary research. Using our extensive semiconductor and fab databases as sources, surveys were sent to about 200 companies that were believed to fit the criteria for a fabless company. Dataquest defines a fabless semiconductor company as one that designs and markets its own semiconductor products but relies on external sources for 75 percent or more of its wafer production needs. The resulting database of fabless companies was then augmented by secondary research of company literature, Web sites, and other sources of publicly available information about the companies.

Silicon Valley: The Fabless Hot Spot

There is no doubt about it—Silicon Valley is the center of the universe for the fabless semiconductor sector. Figure 1-1 shows the relative distribution of fabless semiconductor companies throughout regions of the world (excluding Japan). The vast majority of fabless companies are headquartered in North America, and almost all of those are located in Santa Clara County, California. The fabless phenomenon got its start in Silicon Valley, and there it has flourished. Although this report is not intended to examine the development of the fabless sector, it is safe to say that a large talent pool and access to venture capital were major contributors in the rise of fabless companies in the region.

Figure 1-1
Distribution of Fabless Semiconductor Companies by Headquarters Location



Source: Dataquest (November 1998)

There is a healthy community of fabless semiconductor companies growing up in Taiwan, reflected in the large slice of the pie (over one-quarter) attributed to the Asia/Pacific region. In fact, all but a handful of these companies are located in Taiwan, right next door to the world's leading dedicated foundries. Coincidence? Not likely. This is a geographically desirable relationship and one that can be expected to grow, provided enough technical talent can be found to feed it.

Dataquest Perspective

The large number of fabless semiconductor companies in this directory is a testament to the success of the foundry and fabless business models. Concentration of capital in the large fabs of foundry companies has dramatically lowered the cost of entry into the semiconductor market for dozens of fabless start-up companies. Division of R&D investment has given fabless companies a time-to-market advantage by allowing them to focus their efforts on product design and systems integration issues while the foundries take care of process technology development. Dataquest believes the fabless-foundry model will continue to grow in importance, and it will dramatically change the complexion of semiconductor manufacturing in the future.

Chapter 2
Directory of Fabless Semiconductor Companies

Tables 2-1, 2-2, and 2-3 list fabless semiconductor companies in North America, Europe, and Asia/Pacific.

Table 2-1
North American Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	Initial Public Offering	Stock Symbol	1997 Semiconductor Revenue	Product and Market
Canada					
ATI Technologies Inc., 33 Commerce Valley Drive East, Thornhill, ONT L3T 7N6	1985	1993	ATY.TO	438	Graphics accelerators, multimedia accelerators
Focam Technology, 3050 Cartier Blvd. West, Laval, QUE H7V 1J4	1992			-	Analog, digital, and mixed-signal ASICs, cell libraries
Genesis Microchip Inc., 200 Town Centre Blvd., Suite 400, Markham, ONT L3R 8G5	1987	1998	GNSSF	15	ICs for high-performance, graphics/visualization and imaging
PMC-Sierra Semiconductor, 105-8555 Baxter Place, Burnaby, BC V5A 4V7	1983	1991	PMCS	127	ICs for broadband infrastructure, LAN, and net access or user interface; ATM, SONET/SDH, TI/EI, and Ethernet
V3 Semiconductor Inc., 250 Consumers Road, Suite 901, North York, ONT M2J-4V6	1994	1998	VVVI	2	Chipsets for embedded systems market
Matrox Graphics, Inc. C128, 1055 Saint Regis Blvd., Dorval, QUE H9P 2T4	-	-	-	-	PC graphics accelerators
MOSAID Technologies Inc., 11 Hines Road, Kanata, ONT K2K 2X1	-	1995	MSD.TO	-	Memory ICs: DRAM, ASM, HDRAM
Tundra Semiconductor Corporation, 603 March Road, Kanata, ONT K2K 2M5	1995		-	-	Bus bridging for embedded data communications and telecommunications
United States					
3D Labs Inc., 26081 Avenue Hall, Valencia, CA 91355-1241	1994	-	-	-	3-D graphic processors and accelerators and software for multimedia, CAD, simulation, virtual reality, interactive TV, and video games
3Dfx Interactive Inc., 4435 Fortran Drive, San Jose, CA 95134	1994	1997	TDFX	-	Multimedia and 3-D graphic accelerators
8x8 Inc., 2445 Mission College Blvd., Santa Clara, CA 95054	1987	1997	EGHT	62	Compression and decompression ICs
Actel, 955 East Arques Ave., Sunnyvale, CA 94086	1987	1993	ACTL	156	FPGAs

Table 2-1 (Continued)
North American Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	Initial Public Offering	Stock Symbol	1997 Semiconductor Revenue	Product and Market
Adaptec Inc., 691 S. Milpitas Blvd., Milpitas, CA 95035	1981	1986	ADPT	238	I/Os, accelerators, and controllers for multimedia, database backup, and networking
Admos Inc., 2345 Harris Way, San Jose, CA 95131	1991	-	-	-	DSPs for sound add-in cards, motherboards, sound controllers, and musical instruments
Advanced Hardware Architectures, 2365 NE Hopkins Court, Pullman, WA 99163-5601	1988	-	-	14	Coprocessors for error correction coding and data compression
Alesis Semiconductor Corporation, 12509 Beatrice Street, Los Angeles, CA 90066	1996	-	-	-	Studio electronics, mostly R&D
Alliance Semiconductor, 3099 North First Street, San Jose, CA 95134	1985	1993	ALSC	70	Flash, SRAMs, and DRAMs for high-performance memory and memory intensive logic products
Altera, 101 Innovation Drive, San Jose, CA 95134	1983	1988	ALTR	631	PLDs
AMP Sensors, 470 Friendship Road, Harrisburg, PA 17111	1941	1982	AMP	-	Sensors
Aptek Williams, 700 NW 12th Avenue, Deerfield Beach, FL 33442	1982	1995	WMCO	60	Thick-film hybrid circuits, sensors, and controls for trucking and automotive applications.
Aptix Corporation, 2880 North First Street, San Jose, CA 95134	1989	-	-	-	FPICs and prototyping systems for digital wireless communications
Aptos Semiconductor, 2254 North First Street, San Jose, CA 95131	1993	-	-	-	SRAMs, high-speed miniprocessors, speech and speaker recognition, neuralnet technology circuits, SRAM
Arithmos Inc., 2730 San Tomas Expwy., Suite 210, Santa Clara, CA 95051-0952	1993	-	-	-	ICs for flat panel monitors
Arizona Microtek, 225 East First Street, Suite 107, Mesa, AZ 85201-6700	1985	-	-	-	ASICs, analog, digital and mixed-signal; ECL standard products
Armedia Inc., 830 Hillview Court, Suite 280, Milpitas, CA 95035	1987	-	-	-	Custom ICs, MPEGs
Array Microsystems Inc., 987 University Ave., Los Gatos, CA 95030	1990	-	-	-	Video compression and decompression products

Table 2-1 (Continued)
North American Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	Initial Public Offering	Stock Symbol	1997 Semiconductor Revenue	Product and Market
Auctor Corporation , 2401 Walsh Ave., 2nd Floor, Santa Clara CA 95051	1987	-	-	-	Power logic controllers for PCs
Aura Vision Corporation, 47865 Fremont Blvd., Fremont, CA 94538	1992	-	-	-	Multimedia ICs
Aureal Semiconductor, 4245 Technology Drive, Fremont, CA 94538	1990	1997	AURL	2	Audio ICs for 3-D audio technology
BasiConcepts, Inc., 312 West First Street, Suite 201, Sanford, FL 32771	1996	-	-	-	Programable analog microcontrollers and recognition devices for solving control and pattern recognition problems
Benchmarq Microelectronics, Inc. (Subsidiary of Unitrode), 7 Continental Blvd., Merrimack NH 3054	1989	1995	BHE	325	Battery management products, NVSRAM products, RTC products, mixed-signal (analog and digital) ICs
Broadcom, 16251 Laguna Canyon Road, Irvine, CA 92618	1991	1998	BRCM	37	Mixed-signal ICs; highly integrated, system-level silicon solutions for high-speed transmission of data over existing communications infrastructure
Catalyst Semiconductor, 1250 Borregas Ave., Sunnyvale, CA 94089	1985	1993	CATS	40	EEPROMs, NVRAMs, and flash memories
C-Cube Microsystems, 1778 McCarthy Blvd., Milpitas, CA 95035	1988	1994	CUBE	171	Processors, decoders, and encoders for video and still images in consumer electronics, computers, and communications
Chip Express, 2323 Owen Street, Santa Clara, CA 95054	1989	-	-	31	High-performance ASICs
Chromatic Research Inc., 615 Tasman Drive, Sunnyvale, CA 94089-1707	1993	-	-	-	Media processor
Chrontel Inc., 2210 O'Toole Avenue, San Jose, CA 95131-1326	1987	-	-	-	Mixed-signal ICs for graphics, video, and audio, high-performance clocks
Cirrus Logic Inc., 3100 W. Warren Avenue, Fremont, CA 94538-6423	1984	1988	CRUS	880	Multimedia, communications, mass storage, and data acquisition ICs

Table 2-1 (Continued)
North American Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	Initial Public Offering	Stock Symbol	1997 Semiconductor Revenue	Product and Market
Cisco Systems' SONET/SDH Transport Group subsidiary—Skystone Systems of Ottawa, ONT	-	-	-	-	Highly integrated "system-on-a-chip solutions" for synchronous optical networks, a new technology used to carry data in high-capacity backbone networks
Clare Micronix Integrated Systems (A Division of C.P. Clare Corporation), 145 Columbia, Aliso Viejo, CA 92656-1490	1983	-	CPCL	158	ASICs
Clarkspsur Design Inc., 100 Park Center Plaza, Suite 501, Saratoga, CA 95113	1988	-	-	-	DSP core for modems, voice mail, and disk drives
CORSAIR Memory, 4437 Enterprise Street, Fremont CA 94538	1994	-	-	-	DRAM memory for PCs
CPU Technology Inc., 4900 Hopyard Road, Suite 300, Pleasanton, CA 94588	1989	-	-	-	Compatible MPUs, fully operational virtual models of entire systems, automated technology for system testing and verification
CREE Research Inc., 4600 Silicon Drive, Durham, NC 27703	1987	1993	CREE	27	Power semiconductors and optoelectronics using silicon carbide technology
Cubic Memory, 27 Janis Way, Scotts Valley, CA 95060	-	-	-	-	High-density, small-footprint memory and IC products, flash-SRAM stacks
DataPath Systems Inc. (DPS), 2334 Walsh Ave., Santa Clara, CA 95051	-	-	-	-	CMOS and BiCMOS mixed-signal VLSI circuits
Diamond Multimedia Systems Inc., 2880 Junction Ave., San Jose, CA 95134-1922	1982	1995	DIMD	443	Graphics accelerators, DVD, and video phone kits
DSP Group, Inc., 3120 Scott Blvd., Santa Clara, CA 95054	1987	1994	DSPG	62	Digital signal processing ICs for digital speech
Dynachip, 1255 Oakmead Pkwy., Sunnyvale, CA 94086	-	-	-	-	FPGAs
Emulex, 3535 Harbor Blvd., Costa Mesa, CA 92626	1979	1990	EMLX	57	Communication processors, LANs and WANs, fibre channel technology

Table 2-1 (Continued)
North American Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	Initial Public Offering	Stock Symbol	1997 Semiconductor Revenue	Product and Market
Enable Semiconductor, 1381 McCarthy Blvd., Milpitas, CA 95035	1995	-	-	-	Mixed-signal ICs for low power/low voltage and high-speed CMOS memory solutions for the low power/low voltage market; Fast Ethernet LAN chips.
ESS Technology Inc., 48401 Fremont Blvd., Fremont, CA 94538	-	1995	ESST	245	Highly integrated, mixed-signal ICs for multimedia
Etec Microsystems, 26460 Corporate Ave., Hayward, CA 95035-7413	-	-	-	-	Microcomponents
Evans and Sutherland, 600 Komas Drive, Salt Lake City, UT 84108	1968	-	-	-	Multimedia and 3-D graphics
EXAR Corporation, 48720 Kato Road, Fremont, CA 94538	1971	1985	EXAR	102	Analog, digital, mixed-signal communication and SCF ICs
Exponential Technology, 2001 Gateway Place, Suite 610 West, San Jose, CA 95110-1013	1993	-	-	32	Microprocessors for high-performance power PCs
Galileo Technology, Ltd., 142 Charcot Avenue, San Jose, CA 95131	1993	1997	GALTF	10	Core logic WAN interface devices
Gatefield Corporation (Formerly known as Zycad Corp), 47100 Bayside Pkwy., Fremont, CA 94538-9942	1981	1984	GATE	16	FPGAs
GlobeSpan Semiconductor, Inc., 100 Schulz Drive, Red Bank, NJ 07701	1996	-	-	-	Power-efficient transceiver chipsets for RADSL, ADSL, HDSL, MSDSL, and SDSL telecommunications equipment
Hittite Microwave, 21 Cabot Road, Woburn, MA 1801	1985	-	-	-	RF and microwave applications
ICT Inc., 2123 Ringwood Avenue, San Jose, CA 95131	1983	-	-		PLDs
I-Cube Inc., 2605 S. Winchester Blvd., Campbell CA 95008	1990	-	-	-	ASIC switch sets and DSCs for telecommunications, networking, high-end multimedia

Table 2-1 (Continued)
North American Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	Initial Public Offering	Stock Symbol	1997 Semiconductor Revenue	Product and Market
Information Storage Devices Inc. (ISD), 2045 Hamilton Avenue, San Jose, CA 95125	1987	1995	ISDI	48	High-density storage and mixed-signal ICs for voice recording and playback, and batteryless message storage
Integrated Circuit Systems Inc. (ICS), 2435 Blvd. of the Generals, P.O. Box 968, Valley Forge, PA 19482-0968	1976	1991	ICST	95	LAN/WAN mixed-signal ICs and ASICs for multimedia and data communications; FPGA frequency timing generators
Integrated Telecom Technology Inc. (IgT), 18310 Montgomery Village, Gaithersburg, MD 20879	1991	-	-	-	Memory, microcomponents, logic, mixed-signal, linear, discretes, ATM switches, LAN, some software
Intellon Corporation, 5100 W. Silver Springs Blvd., Ocala, FL 34482	1989	-	-	-	Technology for low-cost wireless networks: Spread Spectrum Carrier technology in integrated circuits (ICs) for communications over power line and RF media
Irvine Sensors Corporation, 3001 Red Hill Avenue, Bldg. 3, Costa Mesa, CA 92626	1980	1982	IRSN	14	3-D, analog, and mixed-signal; stacked chips: DRAM tall stacks, short stacks, and modules, SRAM short stacks, and flash memory short stacks and modules; image processing and smart sensing devices and ICs: analog mixed-signal and low power; IRDA transceiver modules; MEMS sensors
IXYS Corporation, 3540 Bassett Street, Santa Clara, CA 95054	1983	-	-	-	MOSFETs, IGBTs, FREDs, smart power ICs, thyristors, rectifiers, and diodes for the motion control and power conversion industries
Jato Technologies, 505 E. Huntland Drive, Suite 550, Austin, TX 78752	1996	-	-	-	10/100/1000 Ethernet controllers
Jaymar Semiconductor Inc., 13845 Alton Pkwy., Suite B, Irvine, CA 92718	1992	-	JMAR	1	Gate arrays
Lattice Semiconductor, 5555 Northeast Moore Court, Hillsboro, OR 97124-6421	1983	1990	LSCC	242	ISP logic devices and E2CMOS PLDs for communications, data processing, computer peripherals, instrumentation, industrial controls, and military systems

Table 2-1 (Continued)
North American Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	Initial Public Offering	Stock Symbol	1997 Semiconductor Revenue	Product and Market
Level One Communications Inc., 9750 Goethe Road, Sacramento, CA 95827	1985	1993	LEVL	156	ASSPs: mixed-signal ICs for networks, wireless, cable, telephony, digital Internet access, LANs, WANs, high-speed transmissions
LightSpeed Semiconductor, Corp., 151 Sonora Court, Sunnyvale, CA 94086	1995	-	-	-	High-performance, high-density ASICs that enable customers to get into production rapidly
Logic Devices Inc., 1320 Orleans Drive, Sunnyvale, CA 94089	1983	1990	LOGC	14	High-performance, digital ICs: DSPs and SRAMs
MediaMatics, 48430 Lakeview Blvd., Fremont, CA 94538	-	-	-	-	Multimedia and MPEG
Medianix Semiconductor Inc., 100 View Street, Suite 101, Mountain View, CA 94043	1994	-	-	3	Digital signal processors for consumer audio applications
Melexis Inc., 15 Sutton Road, Webster, MA 1570	1989	-	MLX	-	High-volume Hall Effect sensors and power transistor arrays, microcontrollers, tags, pressure sensors
Micro Linear Corp, 2092 Concourse Drive, San Jose, CA 95131	1983	1994	MLIN	62	High-performance analog and mixed-signal ICs for communications, computer, and industrial markets (bipolar, CMOS, BiCMOS) for networks, video, power supply, battery management, motor controllers
Micro Networks, 324 Clark Street, Worcester, MA 1606	1969	-	-	-	Analog and digital ICs, high-precision frequency oscillators, custom microelectronics
MMC Networks, 1134 E. Arques Ave., Sunnyvale, CA 94086	1992	1997	MMCN	22	Network processor chipsets
MoSys Incorporated, 1020 Stewart Drive, Sunnyvale, CA 94086	1991	-		-	Memory ICs: SRAM, DRAM, MDRAM for PC graphics
Music Semiconductors Inc., 254B Mountain Ave., Hackettstown, NJ 7840	1986	-	MUSIC	-	Advanced semiconductor devices that accelerate crucial functions within network switching and routing systems and application-specific standard products)

Table 2-1 (Continued)
North American Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	Initial Public Offering	Stock Symbol	1997 Semiconductor Revenue	Product and Market
Ncube, 110 Marsh Drive, Suite 200, Foster City, CA 94404-1184	1983	-	-	-	Switched digital video (SDV) or hybrid fiber/coax (HFC) for home delivery via ATM/SONET networks, for interactive multimedia
NeoMagic Corporation, 3260 Jay Street, Santa Clara, CA 95054	1993	1997	NMGC	41	Multimedia accelerators for notebook computers
NetLogic Microsystems Inc., 465 Fairchild Dr, Suite 101, Mountain View, CA 94043	1996	-	-	-	Content-Addressable Memories; Semiconductor ICs and subsystems for networking
Nu Vision Technologies Inc. (a Subsidiary of Vikay Industrial), 1815 NW 169th Place, Bldg. 3060, Beaverton, OR 97006	1994	-	-	-	3-D technology for PC games
NVidia Corp., 3535 Monroe Street, Santa Clara, CA 95051	1993	-	-	-	Multimedia accelerator ICs for PCs for 2-/3-D graphics
Oak Technology, 139 Kifer Court, Sunnyvale, CA 94086	1987	1995	OAKT	163	High-performance semiconductors and related software solutions for the optical storage, consumer electronics, and office equipment markets
Onchip Systems, 1190 Coleman Ave, San Jose, CA 95110	-	-	-	-	Linear and mixed-signal ICs and VCAs and music/synth chips
OPTi Inc., 1440 McCarthy Blvd., Milpitas, CA 95035	1989	1993	OPTI	68	Core logic USB and LCD controllers for PCs, notebooks
Oxford Micro Devices, 273 Canal Street, Suite 600, Shelton, CT 6484	1987	-	-	1	Video digital signal processor chips; embedded fingerprint capture and verification systems
Paradigm Technology Inc., 694 Tasman Drive , Milpitas, CA 95035	1987	1995	PRDM	12	High-speed, high-density SRAM semiconductor devices for memory needs of networks, workstations, advanced modems, and complex military/ aerospace applications
Peregrine Systems Corporation, 6175 Nancy Ridge Drive, San Diego, CA 92121	1990	-	-	-	High-performance RF ICs and ASICs for Rahard satellite industries and wireless industries
Performance Semiconductor, 630 East Weddell Drive, Sunnyvale, CA 94089-1751	-	-	-	-	SRAMs

Table 2-1 (Continued)
North American Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	Initial Public Offering	Stock Symbol	1997 Semiconductor Revenue	Product and Market
Pericom Semiconductor, 2380 Bering Drive, San Jose, CA 95131	1990	1997	PSEM	49	High-performance digital and mixed-signal ICs for PCs, workstations, peripherals, and networking
Photobit, 135 N. Los Robles Ave., 7th Floor, Pasadena, CA 91101	-	-	-	-	CMOS, APS
Power Integrations, 477 N. Mathilda Ave., Sunnyvale, CA 94086	1988	1997	POWI	44	High-voltage analog ICs for AC-to-DC power conversion
Power Semiconductors, Inc., 6352 Corte del Abeto, Suite F, Carlsbad, CA 92009	1968	-	-	-	Power semiconductors
Purdy Electronics, 720 Palomar Ave., Sunnyvale, CA 94086	1995	-	-	-	LEDs, LCDs for computers, medical, and industrial instrumentation
QLogic Corp. , 3545 Harbor Blvd., Costa Mesa, CA 92626	1980	1994	QLGC	73	SCSI and fibre channel initiators and hard disk controllers for high-end HDD, minicomputers, workstations and servers
QT Optoelectronics (Formerly Known as Quality Technologies Corporation), 610 N. Mary Avenue, Sunnyvale, CA 94086	1990	-	-	54	Opto couplers; LEDs; infrared emitters, switches, detectors
QUALCOMM Incorporated, 6455 Lusk Blvd., San Diego, CA 92121-2779	1985	1991	QCOM	-	Digital wireless communications products and technologies
Quality Semiconductor , 851 Martin Avenue, Santa Clara, CA 95050-2903	1988	1994	QUAL	63	High-performance logic (FCT) and logic-intensive specialty memory ICs (RAMs) for networking, PCs, workstations
Quantum Effect Design (QED), 3255-3 Scott Blvd., Suite 200, Santa Clara, CA 95054	-	-	-	-	Embedded RISC
QuickLogic Corp., 1277 Orleans Drive, Sunnyvale, CA 94089-1138	1988	-	-	29	FPGAs
Raycer Graphics (Formerly Known as Silicon Engines), 2585 East Bayshore Road, Palo Alto, CA 94303	1986	-	-	-	High-performance parallel processors for visual computing systems
Real 3D Inc., 12506 Lake Underhill Road, MP811, Orlando, FL 32825	1996	-	-	-	Multimedia and 3-D

Table 2-1 (Continued)
North American Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	Initial Public Offering	Stock Symbol	1997 Semiconductor Revenue	Product and Market
Rendition Inc. (Division of Micron Technology), 999 East Arques Ave., Sunnyvale, CA 94086	1993		MU	-	2-/3-D and video graphics processors for PCs
RF Monolithics, Inc., 4441 Sigma Road, Dallas, TX 75244	1979	1994	RFMI	42	SAW devices and RF modules for low-power wireless, high-frequency timing, and telecommunications applications
Rise Technology Company, 2451 Mission College Blvd., Santa Clara, CA 95054	1993	-	-	-	x86 CPU solutions and CPU-centric products
RocketChips Inc., 7400 Metro Blvd., Suite 100, Edina, MN 55439-2311	-	-	-	-	High-performance mixed-signal and analog IP cores and ASSPs for the communications markets (Gigabit Ethernet, fibre channel, IEEE 1394, data conversion and wireless)
S3 Inc., 2801 Mission College Blvd., Santa Clara, CA 95052	1989	1993	SIII	437	Multimedia graphic accelerator solutions for desktop and mobile computers
SanDisk Corporation, 140 Caspian Court, Sunnyvale, CA 94089	1988	1995	SNDK	125	Flash memory data storage products for industrial, communications, highly portable computing, consumer electronics applications
SCS Corporation, 10905 Technology Place, San Diego, CA 92127	1992	-	-	-	Radio frequency identification technology
SEEQ Technology, 47200 Bayside Pkwy., Fremont, CA 94538	1981	1983	SEEQ	31	LAN ICs for networking connectivity (controllers, media interface adapters, and transceivers)
Sensory Circuits Inc., 521 E. Wendell Drive, Sunnyvale, CA 94089	1994	-	-	-	Interactive speech ICs for speech recognition, speech and music synthesis, voice recording and playback, and speaker verification
SiCOM, 7585 E. Redfield Road, Scottsdale, AZ 85260	1985	-	-	-	ICs for wireless high-speed systems ASICS
Sigma Designs Inc., 46501 Landing Parkway, Fremont, CA 94538	1982	1982	SIGM	37	MPEG-1 and -2 decoders
Signal Processing Technologies, 4755 Forge Road, Colorado Springs, CO 80907	1983	-	-	-	Data conversion

Table 2-1 (Continued)
North American Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	Initial Public Offering	Stock Symbol	1997 Semiconductor Revenue	Product and Market
Silicon Image, 10131 Bubb Road, Cupertino, CA 95014	1995	-	-	-	ICs for flat panel displays, LCD
Silicon Magic Corporation, 4500 Great America Parkway, Santa Clara, CA 95054	1994	-	-	-	EDO DRAMs and SGRAMs for graphic/video applications; embedded DRAM single-chip solutions
Silicon Storage Technology Inc. (SST), 1171 Sonora Court, Sunnyvale, CA 94086	1989	1995	SSTI	75	EEPROMs and flash memories; compact flash cards
Siliconians, 4701 Patrick Henry Dr., Santa Clara, CA 95054	1995	-	-	-	ICs for wireless communications
Single Chip Systems Corp. (SCS), 10905 Technology Place, San Diego, CA 92127	1992	-	-	-	Interactive identification (I/I) in inventory control, asset management, document management and ticketing systems for high volume identification markets
Siquest Inc., 1731 Technology Drive, Suite 550, San Jose, CA 95110	1991	-	-		CMOS gate arrays, FPEG conversions for consumer electronics, telecommunications, and industrial controls and ATE
SiRF Technology, Inc., 3970 Freedom Circle, Santa Clara, CA 95054	1995	-	-	-	RF and digital signal processor chips for consumer GPS navigation and wireless communications markets
Space Electronics Inc., 4031 Sorrento Valley Blvd., San Diego, CA 92121	1992	-	-	12	Advanced function, highest density, monolithic, radiation-hardened ICs (memory and microprocessor) for spacecraft
Space Power Electronic, Inc. , 305 Jeffrey Lane, Glen Gardner, NJ 8826	1960	-	-		Microwave and discrete signal ICs
Spectra Diode Labs, 80 Rose Orchard Way, San Jose, CA 95134	-	-	-	17	Optoelectronic integrated circuits and high-power semiconductor lasers
Stanford Telecom, 1221 Crossman Ave., Sunnyvale, CA 94089	1973	1983	STII	153	Digital telecom for communications systems
Sun Microsystems, 901 San Antonio Road, Palo Alto, CA 94303	1982	1986	SUNW	-	SPARC

Table 2-1 (Continued)
North American Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	Initial Public Offering	Stock Symbol	1997 Semiconductor Revenue	Product and Market
Suni Imaging Microsystems, 185 East Dana Street, Mountain View, CA 94041	1995	-	-	-	CCD and CMOS imaging technologies
Swift Microelectronics Corporation, 1762 Technology Drive, Suite 228, San Jose, CA 95110	1992	-	-		Single mask, customization gate arrays
Synova, 1333 Gateway Drive, Suite 1017, Melbourne, FL 32901	1993	-	-	-	Turnkey ASIC solutions ranging from embedded MIPS core designs for space applications, to HDL core logic products, to engineering design and systems engineering services
TCS America, 1510 11th Street, Suite 102, Santa Monica, CA 90401	-	-	-	123	High-speed A S-shaped acceleration/deceleration pulse generator LSI, motion control ICs
TDK Semiconductor, 2642 Michelle Dr., Tustin CA 92780-7019	1972	-	TDK	-	Analog and mixed-signal ICs
Teltone Corporation, 22121 20th Avenue SE, Bothell, WA 98021	1968	1990	TTNC	10	DSPs, analog ICs for telecommunications
Terayon Corporation, 2952 Bunker Hill Lane, Santa Clara, CA 95054	1993	1998	TERN	2	ICs for network interface
The Engineering Consortium, Inc., 3000 Olcott Street, Santa Clara, CA 95054	-	-	-	-	Mixed-signal ICs for hearing devices, modems, and military smart power
The Western Design Center Inc. (WDC), 2166 E. Brown Road, Mesa, AZ 85213	1978	-	-	-	Microprocessors and microcontroller chips; developer boards
TranSwitch Corp., 3 Enterprise Drive, Shelton, CT 6484	1988	1995	TXCC	27	High-speed, mixed-signal and digital ICs for broadband telecommunications and data communications applications
Trident MicroSystems Inc., 189 N. Bernardo Ave., Mountain View, CA 94043-5203	1987	1992	TRID	144	Video/graphics, controller/chipsets, and multimedia video processors for IBM PCs
Tripath Technology, 3900 Freedom Circle, Suite #200, Santa Clara, CA 95054-1204	1995	-	-	-	Signal processing and its application to power electronic

Table 2-1 (Continued)
North American Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	Initial Public Offering	Stock Symbol	1997 Semiconductor Revenue	Product and Market
UTMC (a Subsidiary of United Technologies), 4350 Centennial Blvd., Colorado Springs, CO 80907	1980	-	-	-	Radiation-hardened ICs
Vadem Ltd., 1960 Zanker Road, San Jose, CA 95112	1983	-	-	-	Microprocessors, PCMCIA host adapters, and PC card controllers for portable systems; Windows CE solutions including reference designs, device driver development, and adaptation development tools
ViComp Technology Inc., 465 Fairchild Drive, Suite 201, Mountain View, CA 94043	1995	-	-	-	MPEGs in consumer and computer systems for video, PC multimedia, satellite, and cable receiver boxes, compressed video and audio data
Vivid Semiconductor Inc., 7400 West Detroit Street, Suite 100, Chandler, AZ 85226	1993	-	-	-	Extended voltage-range column drivers for LCD panels for notebook and CRT replacement flat panel displays
Wafer Scale Inc. (WSI), 47280 Kato Road, Fremont, CA 94538	1984	-	-	50	High-performance, field-programmable/MCU peripheral ICs (PSD microcontrollers, PROMs, EPROMs) for technologically advanced electronics companies
White Electronic Designs Corporation (A Division of Bowmar Instruments), One Research Drive, Westborough, MA 15810	1995	1996	WHT	-	High-density, high-performance memory devices for communications (SRAMs and monolithic devices) AMLCDs
Xilinx Inc., 2100 Logic Drive, San Jose, CA 95124	1984	1990	XLNX	612	FPGAs and CPLDs for computers peripherals, telecommunications, industrial control and instrumentation, and military markets
Zoran Corporation, 3112 Scott Blvd., Santa Clara, CA 95054	-	1995	ZRAN	34	High-performance DSPs for leading-edge compression solutions to high-volume PC and consumer applications (JPEGs, MPEGs, and Dolby Digital)
ZSP Corporation, 982 Walsh Ave., Santa Clara, CA 95050	1996	-	-	-	High-performance DSPs

Source: Dataquest (November 1998)

Table 2-2
European Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	1997 Semiconductor Revenue	Major Products
France			
TCS (Parent: Thomson-CSF), 38521 Saint Egreve, Calex, France	1985	80	Microprocessors, discretes, mixed-signal, linear, CMOS optical devices, ASIC, wireless data transmission chips
Israel			
Galileo Technology, Moshav Manof D.N. Misgav 20184 Israel	1993	13	High-performance RISC microprocesssors for data communications and imaging
Novacom Technologies Ltd., 4 Hacharoshet St. (P.O. Box 2660), Ra'anana 43657 Israel	1988	-	Standard-compliant IC products, single-chip PHY layer solutions for ATM and token-ring LANs
Norway			
Nordic VLSI, Vestre Rosten 81 7075, Tiller, Norway	1983	-	Analog mixed digital ASICs; intellectual property
Scotland			
Wolfson Microelectronics Ltd., Lutton Court, Bernard Terrace, Edinburgh EH8 9NX Scotland	1985	3	Analog and mixed-signal semiconductor interface products for high-growth consumer electronics applications such as digital imaging and PC audio
Sweden			
NetCore AB, Scheelevagen 32 223 63 Lund, Sweden	1997	-	Fast ATM switch (80 Gbps) for the WAN/LAN and telecom markets
Switzerland			
Xemics (Formerly Known as CSEM IC), Maladiere 71 Neuchatel CH-2007 Switzerland		-	Analog CMOS and BiCMOS; high-performance, mixed-mode signal processing ICs; low-power/low-voltage ICs
United Kingdom			
Oxford Semiconductor, 69 Milton Park Abingdon, Oxfordshire OX14 4RX UK	1992	-	Products for data communications
Pixel Fusion Ltd., 2440 The Quadrant Aztec West Bristol BS32 4AQ UK	1997	29	Processors that will deliver quality 3-D and 2-D graphics; design 3-D chips
VideoLogic UK Ltd., Home Park Estate, Kings Langley, Hertfordshire WD4 8LZ UK	1985	9	High-performance solutions for immersive 3-D graphics; graphic chips, graphic cards, 3-D accelerator sound cards, video cards, DVD playback and speakers
Vision Group, Aviation House, 31 Pinkhill, Edinburgh EH12 7BF UK	1990	-	IC imaging devices and cameras

Source: Dataquest (November 1998)

Table 2-3
Asia/Pacific Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	1997 Semiconductor Revenue	Major Products
Korea			
ASIC Plasa, 734-11, Yeoksam-dong Kangnam-gu, Seoul, Korea	1995	1	ASICs for peripherals, set-top boxes, LEDs, and decode ICs
CandS Technology, 41-2, Chungdam-dong, Kangnam-gu, Seoul, Korea	1993	12	ASICs for multimedia/communications, chipsets for pagers
Seodoo Logic, 647-5, Yeoksam-dong Kangnam-gu, Seoul, Korea	1990	9	Controllers for set-top boxes
Singapore			
Azfin Semiconductors Pte. Ltd., 31 Ubi Road 1, Aztech Building, Singapore 408694	1995	-	ASICs
Tritech Microelectronics Ltd., 5 Yishun Street 23 #05-01, Singapore 768442	1990	-	ASICs, ASSPs
Taiwan			
Acer Laboratories Inc., 5F, No. 156, Tung Hsing St. Taipei, Taiwan	1987	120	Core logic, ASICs, I/O peripherals, graphics, multimedia
ADM, 1F, No. 9, Industry Rd. 9, Science-Based Industrial Park, Taiwan	1997	-	Logic ICs, memory
Advance Reality Technology Inc., 3F, No. 609, Kuang Fu Rd. Sec. 1, Hsinchu City, Taiwan	1994	1	ASICs, gate array
Analog and Power, 5F, No. 2, Li Shin Rd. Science-Based Industrial Park, Hsinchu, Taiwan	1997	-	Logic ICs, memory
Analog Integrations Co., 4F, No. 9, Industry Rd. 9, Science-Based Industrial Park, Hsinchu, Taiwan	1992	3	Monolithic and hybrid analog ICs
Aplus Integrated Circuits Inc., 6F-3, No. 7, 75 Lane, Ta An Rd. Taipei, Taiwan	1992	3	Audio ICs
Aslic Microelectronics Co., 5F, No 317, Sung Chiang Rd. Taipei, Taiwan	1987	2	Consumer ICs, encoders, decoders
Avid Electronics, 4F, 11, Park Ave. II, Hsinchu Science-Based Industrial Park, Hsinchu, Taiwan	1996	2	Logic ICs, memory

Table 2-3 (Continued)
Asia/Pacific Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	1997 Semiconductor Revenue	Major Products
ASIX, 2F, No. 28, Industry E. Rd. Science-Based Industrial Park, Taiwan	1985	-	Logic ICs, memory
Best Integrated Technology Inc., 1F, 48, Park Ave. II, Science-Based Industrial Park, Hsinchu, Taiwan	1997	-	Logic ICs
Brilliance Technology, 2F, 40, Park Ave. II, Hsinchu Science-Based Industrial Park, Hsinchu, Taiwan	1996	2	Communications Ics
Chesen Electronics Co., 5F-2, No. 94, Pao Chung Rd., Hsin Tien City, Taiwan	1984	15	Communications ICs
Chip Design Technology Inc., 4F-3, No. 26, Wu Chuan 2nd Rd. Wu Ku Industry Dist. Wu Ku, Shing Chuang City, Taiwan	1985	5	ASICs
Davicom Semiconductor Inc., 4F, 17, Park Ave Rd. II, Science-Based Industrial Park, Hsinchu, Taiwan	1996	5	Communications ICs
Direction Technology Co., 5F, 9, Lane 24, Alley 68, Kang Fu Rd. Sec. 1, Shan Chung City, Taipei County, Taiwan	1997	2	Logic ICs
E-CMOS Co., 1F, No. 58, Park Ave. 2, Science-Based Industrial Park, Hsinchu, Taiwan	1987	5	Mouse controllers, ASICs
Elan Microelectronics Co., 7F-1, No. 9, Prosperity Rd. I, Science-Based Industrial Park, Hsinchu, Taiwan	1994	72	Neural-fuzzy ICs, DSPs, 8-bit MCUs, ASICs
Elecvision, 2F., No. 28, R&D II Rd. Science-Based Industrial Park, Hsinchu, Taiwan	1996	-	Logic ICs, memory
Eplus Co., 2F-2, No. 2, 253 Lane, Fu Shing S. Rd. Sec. 1, Taipei, Taiwan	1989	-	PIR
Etron Technology Inc., 1F, No. 1, Prosperity Rd. I, Science-Based Industrial Park, Hsinchu, Taiwan	1991	48	SRAMs, DRAMs, ASICs
Eureka, 3F., No. 7, Industry E. Rd. 9, Science-Based Industrial Park, Hsinchu, Taiwan	1995	-	Logic ICs, memory
Evermore, 2F, No. 7, R&D Rd. I, Science-Based Industrial Park, Hsinchu, Taiwan	1997	-	Logic ICs, memory
Etrend, 2F, No. 22, Industry Rd. 9, Science-Based Industrial Park, Hsinchu, Taiwan	1997	-	Logic ICs, memory

Table 2-3 (Continued)
Asia/Pacific Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	1997 Semiconductor Revenue	Major Products
F3, 2F, No. 7, Industry E. Rd. 7, Science-Based Industrial Park, Hsinchu, Taiwan	1997	-	Logic ICs, memory
Faraday Technology Co., 7F-3, No. 9, Prosperity 1 Rd., Science-Based Industrial Park, Hsinchu, Taiwan	1993	40	ASICs
G-Link Technology Co., 2F, 12, R&D Rd. II, Hsinchu Science-Based Industrial Park, Hsinchu, Taiwan	1995	15	DRAMs, SRAMs
Genesys, 10F, No. 11, Shen Ken, Taipei County, Taiwan	1997	-	Logic ICs, memory
GinJet Technology Co., No. 18-1, 76 Lane, Long Chiang Rd., Taipei Taiwan	1989	4	ASICs, monitor OSD, pager decoder/ encoder
Golden Technology Co., 4F, 221, Chung Yang Rd. Nan Kang District, Taipei, Taiwan	1997	-	Logic ICs
Holylite Microelectronics Co., 10F-2, No. 67, Chih Hu Rd., Hsinchu City, Taiwan	1992	-	Melody, analog ICs, mixed MOD
Hwa Mye Electronic Co. Ltd., 8F, No. 80, Sung Te Rd., Taipei, Taiwan	1988	3	ASICs
Inno Technology Ltd., 7F, No. 181, Yung Chi Rd. Taipei, Taiwan	1993	2	Consumer ICs
Integrated Silicon Solution (Taiwan) Inc., 1F, No. 10 Prosperity Rd. II, Science-Based Industrial Park, Hsinchu, Taiwan	1990	108	EEPROMs, flash, SRAMs, DSPs, voice EPROMs
Integrated Technology Express (Taiwan) Inc., 15F, 376, Sec. 4, Jen Ai Rd. Taipei, Taiwan	1996	43	Core logic
Media Tek, 1F, No. 13, Innovation Rd. I, Science-Based Industrial Park, Hsinchu, Taiwan	1997	-	Logic ICs, memory
Micro Advance Technology Co. Ltd., 8F, No. 26, 204 Lane, Sung San Rd. Taipei, Taiwan	1992	4	ASICs
Micro Electronic Co. Ltd., 5F-5, No 12, 609 Lane, Chung Shing Rd. Sec. 5, San Chung City, Taiwan	1991	-	ASICs
Micron Design Technology Ltd., 5F, 164-2, Lian Chan Rd. Chun Ho City, Taipei County, Taiwan	1997	-	Logic ICs
MOS Design Semiconductor Co., 6F-5, No. 10, 609 Lane, Chung Shin Rd. San Chung City, Taiwan	1988	12	Melody, sound effector

Table 2-3 (Continued)
Asia/Pacific Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	1997 Semiconductor Revenue	Major Products
MOSART Semiconductor Co., 11F-2, No. 33, Ming Shen Rd. Sec. 1, Pan Chiao City, Taiwan	1993	2	Communications and consumer ICs
Myson Technology Inc., No. 2, Industry E Rd. 3, Science-Based Industrial Park, Hsinchu, Taiwan	1991	35	ASICs, LAN ICs, bipolar ICs
N-One, Roon 106, No. 47, Park Ave. II, Science-Based Industrial Park, Hsinchu, Taiwan	1997	-	Logic ICs, memory
Novatek, 2F, No. 13, Innovation Rd. I, Science-Based Industrial Park, Hsinchu, Taiwan	1997	-	Logic ICs, memory
Princeton Technology Co., 2F, No. 233-1, Pao Chiao Rd. Hsin Tien City, Taiwan	1986	13	Remote controllers, encoder/decoder, audio ICs
Progate Group Co., 14F, No. 482, Chung Hsiao E. Rd. Taipei Taiwan	1991	2	ASICs
Realtek Semi. Co. Ltd., 1F, No. 11, Industry E Rd. 9, Science-Based Industrial Park, Hsinchu, Taiwan	1987	63	Video/graphic ICs, consumer ICs, LAN ICs, ASICs
Roco Enterprise Co., 2F, 33, Yung Chi Rd. Taipei, Taiwan	1985	1	Consumer ICs
SARC Technology Co., 15F-1, No. 159, Sung Te Rd. Taipei, Taiwan	1989	2	ASICs
Silicon-Based Technology Co., 1F, 23, R&D Rd. I, Hsinchu Science-Based Industrial Park, Hsinchu, Taiwan	1995	5	SRAMs
Silicon Interated Systems Co., 2F, No. 17, Innovation Rd. I, Science-Based Industrial Park, Hsinchu, Taiwan	1987	109	Core logic, ASICs
Silicon Touch, 2F, No. 8, Jian Shing Rd. Hsinchu City, Taiwan	1997	-	Logic ICs, memory
Sun Plus Technology Co. Ltd., 1F, No. 21, R&D Rd. II, Science-Based Industrial Park, Hsinchu, Taiwan	1990	45	DSPs, ASICs, consumer ICs, voice and music synthesizers, multimedia-related ICs
Syntek Semiconductor Co. Ltd., 1F, No. 40, Park Ave. II, Science-Based Industrial Park, Hsinchu, Taiwan	1981	42	Microcontrollers with LCD drivers
Taiwan Memory Technology Inc., No. 3, R&D Rd., I, Science-Based Industrial Park, Hsinchu, Taiwan	1993	61	DRAMs, SRAMs

Table 2-3 (Continued)
Asia/Pacific Fabless Companies (Revenue in Millions of U.S. Dollars)

	Year Founded	1997 Semiconductor Revenue	Major Products
Tamarack Microelectronics Inc., 16F-4, Fu Shing N. Rd. Taipei, Taiwan	1987	8	Hybrid ICs, ASICs, LAN chipsets
Tontek Design, 6F, 770, Chung Zan Rd. Chung Ho City	1986	2	Logic ICs
Topro, 6F, No. 130, Sui Wei Rd. Hsinchu City, Taiwan	1997	-	Logic ICs, memory
Unisonic Technology Co., 4F-2, 16, Lane 609, Chung Sing Rd. Sec. 5, San Chung City, Taipei, Taiwan	1990	2	Logic ICs
Utron Technology Inc., 1F, No. 11, R&D Rd. II, Science-Based Industrial Park, Hsinchu, Taiwan	1993	80	ASICs, SRAMs
VIA Technologies Inc., 8F, No. 533, ChunZan Rd. Hsin Tien City, Taiwan	1987	152	Core logic, ISA/PCI/PCMCIA LAN chips
Weltrend Semiconductor Inc., 2F, No. 24, Industry E. Rd. IX, Science-Based Industrial Park, Hsinchu, Taiwan	1989	12	Multisync monitor discriminator ICs, consumer ICs
Yuban Co., 5F, No. 29, Jen Ai Rd. Sec. 3, Taipei, Taiwan	1993	2	DRAMs, SRAMs

Source: Dataquest (November 1998)

For More Information...

Inquiry Hotline	+1-408-468-8423
Internet address	scndinquiry@gartner.com
Via fax	+1-408-954-1780
Dataquest Interactive	http://www.dataquest.com

74195

Dataquest

A Gartner Group Company

DATAQUEST WORLDWIDE OFFICES

NORTH AMERICA

Worldwide Headquarters
Dataquest/Gartner Group
251 River Oaks Parkway
San Jose, California 95134-1913
United States
Phone: +1-408-468-8000
Facsimile: +1-408-954-1780

East Coast Research Center
Gartner Group Lowell
900 Chelmsford Street
Tower Two, Floor Nine
Lowell, Massachusetts 01851
United States
Phone: +1-978-323-6914
Facsimile: +1-978-323-6933

EUROPE

European Headquarters
Gartner Group Ltd.
Tamesis, The Glanty
Egham, Surrey TW20 9AW
United Kingdom
Phone: +44-1784-431-611
Facsimile: +44-1784-488-980

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

Dataquest Germany
Martin-Kollar-Strasse 15
D-81829 München
Germany
Phone: +49-89-42-70-4-0
Facsimile: +49-89-42-70-4-270

JAPAN

Japan Headquarters
Aobadai Hills 4-7-7
Aobadai
Meguro-ku, Tokyo 153-0042
Japan
Phone: +81-3-3481-3670
Facsimile: +81-3-3481-3644

ASIA/PACIFIC

Asia Headquarters
Gartner Group Hong Kong
Suite 5904-7, Central Plaza
18 Harbour Road
Wanchai
Hong Kong
Phone: +852-2824-6168
Facsimile: +852-2824-6138

Pacific Headquarters
Gartner Group Pacific
80 Alfred Street - 6th Floor
Milsons Point, NSW 2061
Australia
Phone: +61-2-9941-4860
Facsimile: +61-2-9941-4868

Korea
Dataquest Korea
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: +82-2-551-1331
Facsimile: +82-2-551-1330

Taiwan
Gartner Group Taiwan Ltd.
11F-2, 188, Section 5
Nan King East Road
Taipei 105
Taiwan R.O.C.
Phone: +886-2-2756-0389
Facsimile: +886-2-2756-2663/4122

Thailand
Gartner Group Thailand Ltd.
29 Vanissa Building, 12F
Soi Chidlom, Ploenchit Road
Pathumwan, Bangkok 10330
Thailand
Phone: +662-655-0577
Facsimile: +662-655-0576

Singapore
Gartner Group Advisory (S) Pte Ltd.
6 Temasek Boulevard #26-02/03
Suntec City Tower 4
Singapore 038986
Phone: +65-333-6773
Facsimile: +65-333-6787

Dataquest
A Gartner Group Company