Semiconductor Industry Service
Newsletters 1990

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Research *Newsletter*

TECHNOLOGY STOCKS FALL TO BARGAIN BASEMENT LEVELS—SO WHAT?

*Sic transit gloria mundi.**
—Thomas à Kempis, 1420

DATAQUEST PERSPECTIVE

Stocks are down. Way down. Not since 1974 have technology stocks reached such depressed levels. This decline has important implications for the entire technology community.

Table 1 provides revenue, profit, and stock data for an arbitrary selection of US technology companies for August 23, 1990. This table provides information on companies of various industries, large and small, old and new, and gives a representative sample of some better known technology stocks.

Clearly, stocks have taken a beating, with most falling dramatically from their 52-week highs. Most of these stocks peaked during the summer. For example, two months ago, on Friday June 22, the *Wall Street Journal's* "Heard on the Street" headline was: "Pros Put Chips on Extended Run-Up in Semiconductors." On this date, Motorola hit its high for the year. In the ensuing weeks, share prices have tumbled.

Why? A confluence of several factors has caused Wall Street to lose confidence in technology companies:

- Concern over the general business environment including competition, especially foreign, and the ability of companies to deal with rapidly changing markets and falling prices
- Disappointing profits and profit outlook for companies (Margins are skinny.)
- Unpleasant surprises in second-quarter reports including several major companies such as Businessland, Digital Equipment, and Texas Instruments
- Concerns over recession and its effect on cyclical stocks
- The Mideast crisis and the perceived certainty of negative economic effects

Although the Dow Jones average has fallen about 16 percent from its high, technology stocks have fallen 30 to 50 percent, more or less. Companies with problems have been hammered—N.E.T. from 34.375 to 6.0, Businessland from 11.0 to 2.5, Oracle from 28.374 to 12.75, Adaptec from 24.0 to 11.25, Conner Peripherals from 31.0 to 20.75.

Companies with good earnings now have low P/E ratios—Chips & Technologies at 6, for example. Companies with low earnings have low market capitalization—for example, Texas Instruments at 36 percent. Many companies, such as Seagate, are priced below book value. Across the board, these low values for high-tech stocks are unprecedented.

IMPLICATIONS

It is not likely that this debacle will be reversed rapidly. Once burned, investors will be twice shy. Technology companies must adjust to the long-term consequences:

- Liquidity difficulties
- Increased acquisition and licensing activity
- Opportunity

*How swiftly pass the glories of the world.

0008044

TABLE 1
Technology Company
Financial Data and Stock Price

Company	Fiscal Year 1989 Revenue ($M)	Latest Revenue Second Quarter 1990 ($M)	Latest Profit Second Quarter 1990 ($M)	8/23/90 Stock Price ($)	Stock Price 12-Month High ($)	Number of Shares (Millions)	Market Capitalization ($M)	Market Capitalization as Percent of Revenue (Latest Quarter)	P/E Ratio (Latest Quarter)	Stock Price Percent Decline
Advanced Micro Devices Incorporated	1,105	268	(5.92)	5.500	11.375	82.10	452	42	-	52
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Chips & Technologies, Incorporated	218	82	6.29	10.375	25.500	15.28	159	48	6.30	59
Compaq Computer Corporation	2,876	862	104.28	45.250	67.875	39.40	1,783	52	4.27	33
Conner Peripherals Incorporated	705	304	26.65	20.750	31.000	45.50	944	78	8.86	33
Cypress Semiconductor Corporation	199	54	8.51	9.750	15.625	38.30	373	173	10.97	38
Digital Equipment Corporation	12,742	3,365	74.39	63.000	103.375	122.00	7,686	57	25.83	39
Hewlett-Packard Company	11,899	3,242	178.00	32.750	53.125	238.00	7,795	60	10.95	38
International Business Machines	62,710	16,495	1,410.00	97.250	123.125	581.10	56,512	86	10.02	21

(Continued)

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Integrated Device Technology Incorporated	181	49	0.26	4.125	10.875	25.50	105	54	101.14	62
Intergraph Corporation	860	254	16.55	14.000	23.500	53.90	755	74	11.40	40
Intel Corporation	3,127	968	170.69	32.500	52.000	188.80	6,136	158	8.99	38
Lotus Development Corporation	556	175	23.46	17.000	39.250	42.39	721	103	7.68	57
LSI Logic Corporation	547	160	6.20	8.375	13.000	41.10	344	54	13.88	36
Mentor Graphics Corporation	380	101	3.65	12.250	26.000	36.90	452	112	30.96	53
Micron Technology Incorporated	446	84	1.81	7.750	16.375	36.70	284	85	39.29	53
Motorola Incorporated	9,620	2,715	161.00	65.375	88.375	130.00	8,499	78	13.20	26
Octel Communications Corporation	87	36	4.94	17.250	27.750	15.20	262	181	13.27	38
Oracle Corporation	971	334	52.96	12.750	28.375	136.8	1,744	130	8.23	55
Quantum Corporation	446	163	17.34	14.500	25.750	27.59	400	61	5.77	44
Seagate Technology, Incorporated	2,413	668	29.69	9.125	19.750	51.78	472	18	3.98	54
Silicon Graphics Incorporated	264	120	11.20	24.000	40.875	17.20	413	86	9.21	41

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Silicon Valley Group Incorporated	131	47	0.43	6.625	13.750	10.20	68	36	39.29	52
Sun Microsystems Incorporated	1,765	700	49.10	26.000	37.125	85.20	2,215	79	11.28	30
Tandem Computers Incorporated	1,633	472	32.44	13.875	30.125	101.40	1,407	75	10.84	54
Texas Instruments Incorporated	6,522	1,592	11.00	26.750	44.000	84.9	2,271	36	51.62	39
VLSI Technology Incorporated	289	85	2.40	5.625	12.250	23.80	134	40	13.95	54
Varian Associates, Incorporated	1,344	344	(34.10)	28.750	34.750	19.90	572	42	-	17
Western Digital Corporation	992	294	9.48	9.250	14.875	29.10	269	23	7.10	38
Xerox Corporation	16,441	4,255	(254.00)	39.000	68.500	101.70	3,966	23	-	43

Source: Dataquest (September 1990)

Lack of Liquidity

Already, the decline in public stocks has led to the cancellation of IPOs. Clearly, current prices are not prices that companies want to, or can, take back to the market; it is likely that Sun, for example, will cancel its intended offering. Exacerbating the problem, the newly conservative banking industry is steering clear of (perceived) risky high-tech companies. This movement is already in evidence in the Northeast.

Capital will be increasingly scarce and conservation of capital must become a priority for most companies. Reminiscent of Peter Drucker's advice, "Sell the mailroom!", more and more nonessential or noncritical activities will be farmed out, especially those that are capital intensive—such as wafer fabs and MIS departments. More nonstrategic business units will be sold.

Companies that are not public, and some that are, will look more actively at non-market-financing alternatives including selling part or all of the companies. Entrepreneurs will think twice about wanting to be a public company. On the other side of the coin, low share prices make LBOs increasingly attractive. Going private could be a trend of the 1990s. Cash will be king.

Acquisitions

Loss of liquidity reduces the options of companies, and low share prices definitely will induce salivation among corporate predators. A large percentage of companies are priced significantly below key takeover benchmarks—such as one times revenue. Both seller and buyer activity is sure to increase. For those companies that view this activity as unwholesome, defense mechanisms will be studied and installed.

In the United States, cultural reluctance toward acquisitions is nonexistent. Friendly and unfriendly acquisition by corporate and financial interests inevitably will rise.

Will low share prices create a fire sale to foreign interests? Because foreign stock markets were hit hard and because foreign companies generally are reticent to indulge in international cross-cultural acquisitions of a predatory (unfriendly) nature, a fire sale to Asian interests is unlikely. Buyouts of this nature will be the exception rather than the rule; nevertheless, some activity is bound to occur. On the other hand, lack of domestic liquidity historically has sent companies abroad for financing—such as Amdahl—and this will happen again: More technology and ownership will go abroad.

Lack of financing alternatives will encourage companies to sell parts or pieces of themselves, or to license or sell technology at more attractive prices. Participation in these activities may be more attractive to foreign establishments.

Opportunity

Established companies—i.e., those with cash or a high stock price—will see ample opportunity for acquisitions of technology or other beneficial strategic arrangements with other companies. Indeed, we think that an effect of the stock slide will be to bring, by necessity, the US high-tech community closer as interests, assets, and technology are traded for mutual advantage.

Companies that have the lowest (perceived) stock prices relative to value can take heart. Now is the time to move with alacrity and rewrite stock options—a onetime chance to secure and lock in exceptional talent.

Some companies will take advantage of low share prices and below book values to buy back their own stock. Intel already announced its intention to do this, and other companies are sure to follow.

Bernadette Cesena
Frederick Zieber
Ralph Finley

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Research Newsletter

QUARTERLY ECONOMIC OUTLOOK: PERSIAN GULF CRISIS ADDS TO AN ALREADY LACKLUSTER ECONOMY

SUMMARY

Although the nearly three-month-old Persian Gulf crisis has further slowed what was an already sluggish rate of economic growth and increased the probability of recession, recession will likely be averted. The Dun & Bradstreet Corporation (D&B) forecasts US real gross national product (GNP) growth of 1.0 percent in 1990 and 1.9 percent in 1991 (see Figure 1). The crisis' adverse effects notwithstanding, the current slow-growth period may last longer than is implied ordinarily by a purely cyclical downturn. This possibility is because, independently of the Gulf crisis, *potential* GNP growth has fallen significantly in the past few years as a result of decelerating labor force and productivity growth. Given that high-technology companies continue to provide among the most productive investment solutions, *internationally* competitive companies should fare comparatively well during the next few years.

INTRODUCTION

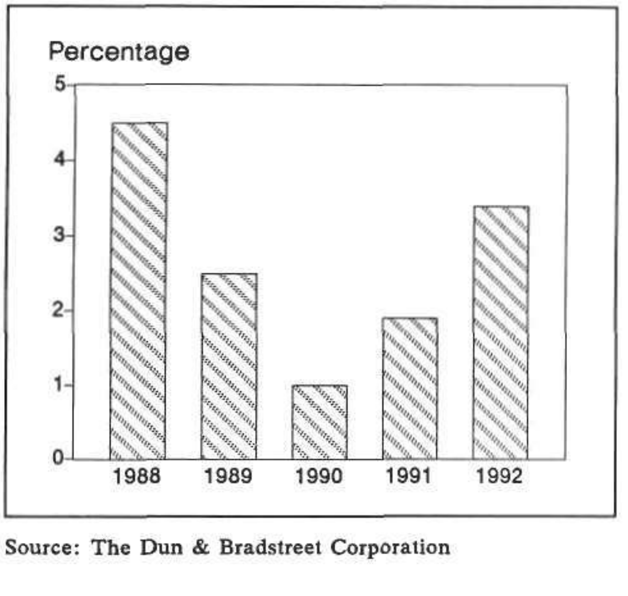
Iraq's invasion of Kuwait in August dramatically illustrated how vulnerable the world economy is to unexpected events. Despite an immediate response by the United Nations, other Arab countries, the United States, and the Western allies, many uncertainties about the short-range and long-range implications of the Persian Gulf crisis remain.

It is *possible* that the largest oil inventories in nine years, a slowing world economy, additional available oil-production capacity, and an unprecedented amount of international cooperation together can provide a sufficient shock absorber for lost Iraqi/Kuwaiti oil production. However, the current volatility in oil prices is obvious evidence that the final outcome remains unclear. Memories of previous recessions caused by earlier oil crises caused stock markets throughout the world to tumble in August.

Will these events push the US economy into recession in the near term? Probably not. Can we dismiss all the negative anecdotal evidence of economic weakness as misleading? Again, probably not. Will the oil crisis in the Middle East hurt the economy? Most definitely yes, but the redistributional effects of higher oil prices on income and economic growth are far more significant than the weakness caused directly by higher oil prices.

In the absence of an outright war or some other severe economic shock, most recession scenarios involve an especially adverse psychological reaction by consumers and producers, triggering cutbacks in spending. But whether a recession is

FIGURE 1
US Real GNP Growth Annual Percent Change



Source: The Dun & Bradstreet Corporation

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imminent may not be the right question to ask. Events in the Middle East may obscure a more important issue: *Is the current economic malaise the result of a "normal" business cycle downturn, or is there something else fundamentally wrong with the US economy?*

This newsletter addresses these issues, relying heavily upon the recent analyses of The Dun & Bradstreet Corporation (Dataquest's corporate parent). The newsletter provides some economic perspectives for business planners by reviewing current economic conditions and providing a framework for interpreting the impact of the unfolding events.

ARE WE IN A RECESSION? WHO CARES!

Perhaps the most often-asked question in the business community these days is, "Is the economy in a recession?" Technically speaking, a recession is defined as two consecutive quarters of declining real GNP. So whether the US economy currently is contracting is, and will continue to be for several months, a debatable point until the US Department of Commerce (DOC) releases statistics of *current* and short-term future business activity in the coming months. Whether or not the economy is in recession is a moot point: As a practical matter, there is no doubt that current economic conditions in the United States clearly are weak, as shown in the following:

- The unemployment rate has risen to 5.7 percent after remaining at nearly 5.0 percent for almost two years.
- Employment levels currently are about where they were at the beginning of the year.
- New orders for durable goods have fallen in four of the last eight months.
- Consumer spending barely has budged since the third quarter of 1989.

This same weakness shows up clearly in the following D&B economic statistics:

- Based on a third-quarter survey of fourth-quarter expectations, business expectations for higher sales have dropped to their lowest level since early 1983. D&B's sales optimism index has fallen to 50, which historically has been the dividing line between economic growth and recession. Expectations for new jobs and profit also are weak.
- Through mid-August of this year, business failures had risen 10.8 percent over the same period in 1989. Until this past April, failures had been declining since 1987. Most of this increase in failures occurred in the New England and Mid-Atlantic regions.
- During the first half of 1990, new incorporations were 3.4 percent below 1989 levels. Again, New England and the Mid-Atlantic states showed the most weakness. In addition, new incorporations in California were down 15.5 percent from year-earlier levels, signaling a slowdown in this heretofore fast-growing region.

WHAT THE PERSIAN GULF CRISIS MEANS TO THE US ECONOMY

Tensions in the Middle East add another layer of uncertainty to the economic outlook. According to many economists' models, the impact of $30 per barrel of oil (a high price, given current supply and demand conditions) is not very significant. Most economic forecasters have trimmed their original forecasts of real GNP by less than one-half a percentage point for 1990 and 1991. Similarly, future inflation rates were reestimated upward by about one-half a percentage point. Of course, if war breaks out in the Middle East or other circumstances drive the price of oil far above $30 per barrel, then in the words of many economists, "all bets are off."

There are many reasons why today's higher oil prices should not impact the economy as severely as did the oil shocks of 1974 and 1979, including the following:

- World oil inventories are relatively high.
- Some of the supply shortfall may be offset by other countries' pumping more oil—particularly Saudi Arabia, Mexico, and Venezuela.
- Stated as a percentage, the current oil-price increase is much less than in 1974 and 1979.
- OPEC economies now are much more geared toward importing goods from industrialized countries than in the 1970s. Thus, some of those petrodollars would be recirculated more quickly.
- Through efficiency gains, industrial economies use about 40 percent less energy per dollar of output than in 1979.
- The US economy was already experiencing accelerating inflation before the oil-price shocks of 1974 and 1979. By comparison, although inflation today is positive, it is not accelerating.

Unfortunately, economists' models do not perform very well in the presence of an "unexpected" geopolitical disturbance, particularly in the midst of one that continues to propagate copious amounts of uncertainty. Uncertainties in the Middle East contributed to a sharp drop in consumer confidence in August, according to data from the University of Michigan's Survey Research Center. When consumers lose confidence in the economy, they tend to postpone expenditure on big-ticket items such as vacations, food consumed away from home, apparel, and home electronics. This one-month plunge is not sufficient to conclude that a recession is imminent—it takes only two points to determine a line, but it takes several points to *estimate a trend*—but it certainly is a signal worth noting. This is especially true in view of the fact that we are entering the holiday buying season.

Similarly, D&B's business expectations survey provides an indicator of business confidence in the economy. When executives are confident about future business conditions, they tend to increase their companies' equipment investment spending. The D&B and University of Michigan surveys both point to an economy on the *cusp of recession*. In both cases, however, more data are needed to forecast more conclusively that a recession is imminent.

One distinguishing characteristic of the current situation is the wealth of the oil states and their willingness to underwrite some of the incremental costs of supporting US forces in the Middle East. President George Bush also is pressuring other oil-dependent allies such as the United Kingdom, France, Germany, and Japan to help foot the bill for these military operations. This financial support would, in effect, pump billions of dollars into the US economy through various categories of spending, such as for munitions, fuel for military support, wages for National Guard troops, and transportation services to ship large volumes of food and supplies thousands of miles.

LONG-TERM IMPLICATIONS

If the current standoff continues for any length of time, there will be other economic consequences. Increased military costs will hinder efforts to reduce the federal budget deficit. Increased expenditure for oil would add at least $25 billion in current dollars to the US trade deficit. Worldwide, increased expenditure and military energy will add to inflationary pressures, prompting interest rates to remain high or go higher still.

On the positive side, increased defense spending provides at least a temporary bailout of many defense-related industries. The volume of oil imports will be reduced, helping the trade deficit in real terms. Capital spending to develop domestic oil supplies will be modestly increased, partially reversing some of the 1986 declines in the oil patch regions caused by sub-$10-per-barrel oil. Consumers also will spend more for energy and energy conservation equipment. Although this type of spending will definitely "crowd out" purchases of other goods, overall consumer spending should decline only slightly.

POTENTIAL VERSUS ACTUAL ECONOMIC GROWTH

Although a near-term recession is possible, business planners cannot ignore their long-range responsibilities. In planning for the long term, an important concept of economic analysis is *potential* economic growth, which normally is viewed as the additional output that comes from an increasing labor force, plus the growth in productivity of this labor force. Thus, if the labor force grows 2 percent in a given year and productivity increases 1 percent, potential GNP increases by 3 percent. If actual GNP is less than potential GNP, then, by definition, unemployment is above its "natural" or equilibrium rate. When actual growth in actual GNP exceeds potential growth, unemployment is (temporarily) reduced below its natural rate, and inflation accelerates.

In recent years, the measurement of potential growth has been hampered by weakness in productivity measures, particularly in the services areas, and by some controversy about demographic trends in measuring the size of the labor force. Nevertheless, as seen in Table 1, potential GNP growth has been slowing markedly. In addition, the gap between potential and actual GNP has been narrowing.

The claim that the economy is operating near its full potential is confirmed in Figure 2, which shows recent unemployment and capacity utilization rates in the region of "full resource employment."

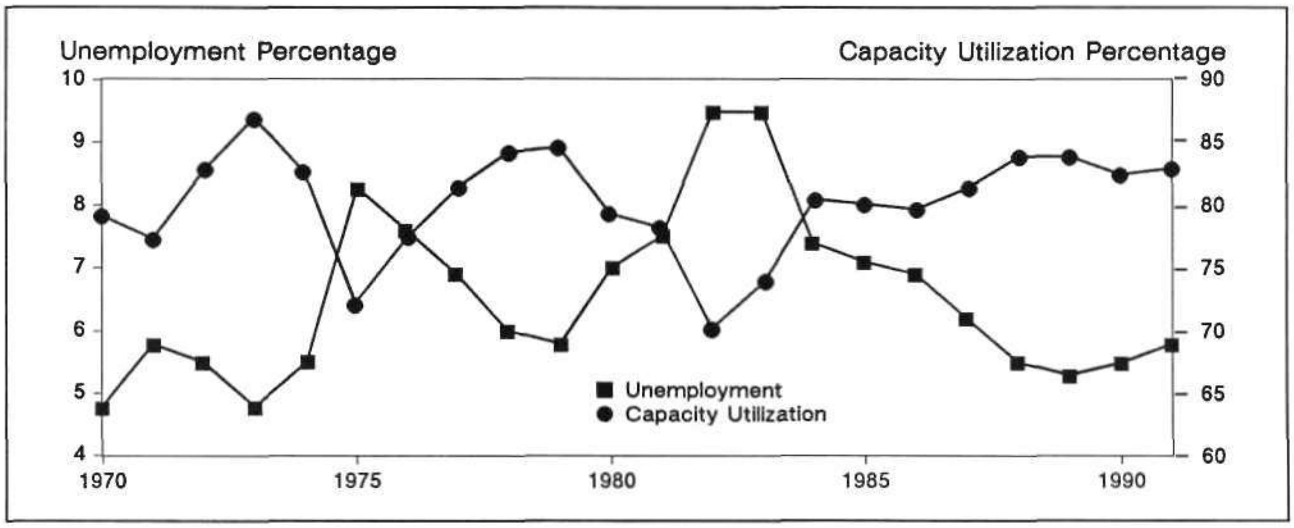
The Federal Reserve's policy of limiting demand to bring down the rate of inflation has been contributing to the recent slow rate of expansion. The approximately 1.5 percent rate of GNP growth during the first half of the year has been in line with the Fed's implicit goal for the current year.

TABLE 1
Potential versus Actual Real US GNP Growth

Year	Productivity (% Change)	Labor Force (% Change)	Potential GNP (% Change)	Actual GNP (% Change)	Unemployment Rate (%)
1986	2.1	2.1	4.2	2.7	6.9
1987	1.1	1.7	2.8	3.4	6.1
1988	2.1	1.5	3.6	4.5	5.4
1989	0.9	1.8	2.7	2.5	5.2
1990 (Est.)	0.5	1.1	1.6	1.0	5.5

Source: The Dun & Bradstreet Corporation

FIGURE 2
US Factor Utilization



Source: US Department of Commerce, US Department of Labor, The Dun & Bradstreet Corporation, Dataquest (October 1990)

The important point is that the current slow-growth period may last longer than is ordinarily implied by a purely cyclical downturn. Furthermore, for the past two years, much of the economic growth in the United States has been driven by external demand—that is, exports. Hence, a pickup of domestic demand could actually lead to an acceleration of inflation unless significant productivity gains can be made.

DATAQUEST CONCLUSIONS AND RECOMMENDATIONS

Dataquest believes that the chances of a recession are substantial, but this outcome still is not the odds-on favorite. The negative economic factors associated with the crisis in the Persian Gulf are probably not enough to cause a recession *at this stage of development*. The most significant risks associated with this disturbance are psychological. Steep declines in consumer and business sentiment can provoke a recession very quickly. Although declines in sentiment have indeed occurred as an immediate response to the Gulf crisis, we must wait to see if they move to the lower levels that typically are associated with pending recessions.

Whether we are in a recession or about to enter one is almost irrelevant. For many sectors, real declines have occurred and the strong growth of the recent years has disappeared, and it may be naive to blame these downturns on events in the Persian Gulf or an adverse turn in the business cycle. Potential GNP growth has fallen precipitously in the past few years as labor force and productivity growth have decelerated. Labor force growth is influenced heavily by participation rates, whose growth will be hindered by adverse demographic factors in the coming years. In particular, the baby-boom generation's maturity will be only partially offset by young recruits to the labor force, which means that increases in potential economic growth will be most influenced by improvements in productivity. Without productivity gains, potential GNP growth may be only about 2.0 percent. So, the current 1.0 to 1.5 percent actual GNP growth may be almost as good as we can expect over the next few years.

For electronic systems and semiconductor manufacturers, there is a silver lining to this otherwise gloomy outlook. Some years ago, very large scale (semiconductor) integration ushered in a period of unprecedented growth in workplace productivity. Now, granted, past high-technology investment has raised the rate-of-return hurdle for future incremental additions to the capital stock. By the same token, however, the most-productive investments continue to come from technologies that rely increasingly on electronic systems and semiconductors. In an environment where economic growth is fueled primarily by productivity growth, high-technology businesses will have a distinct advantage over industries that offer relatively less-productive investment solutions.

Dataquest cautions its clients not to misconstrue this positive outlook to mean that doing business and making a profit in the future are going to become easier. Much of the most easily accessible opportunities have been taken: When was the last time you walked into a workplace where the information systems were not at least partially automated? As high technology matures, it will inevitably become more pervasive and generic. *Internationally competitive* manufacturers that deliver the most cost-effective and productive investment solutions will be the ones to come out intact and strong on the other side of the expected economic doldrums.

Terrance A. Birkholz

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Cypress Semiconductor Corporation	199	54	8.51	9.750	15.625	38.30	373	173	10.97	38
Digital Equipment Corporation	12,742	3,365	74.39	63.000	103.375	122.00	7,686	57	25.83	39
Hewlett-Packard Company	11,899	3,242	178.00	32.750	53.125	238.00	7,795	60	10.95	38
International Business Machines	62,710	16,495	1,410.00	97.250	123.125	581.10	56,512	86	10.02	21

(Continued)

TABLE 1 (Continued)
Technology Company
Financial Data and Stock Price

Company	Fiscal Year 1989 Revenue ($M)	Latest Revenue Second Quarter 1990 ($M)	Latest Profit Second Quarter 1990 ($M)	8/23/90 Stock Price ($)	Stock Price 12-Month High ($)	Number of Shares (Millions)	Market Capitalization ($M)	Market Capitalization as Percent of Revenue (Latest Quarter)	P/E Ratio (Latest Quarter)	Stock Price Percent Decline
Integrated Device Technology Incorporated	181	49	0.26	4.125	10.875	25.50	105	54	101.14	62
Intergraph Corporation	860	254	16.55	14.000	23.500	53.90	755	74	11.40	40
Intel Corporation	3,127	968	170.69	32.500	52.000	188.80	6,136	158	8.99	38
Lotus Development Corporation	556	175	23.46	17.000	39.250	42.39	721	103	7.68	57
LSI Logic Corporation	547	160	6.20	8.375	13.000	41.10	344	54	13.88	36
Mentor Graphics Corporation	380	101	3.65	12.250	26.000	36.90	452	112	30.96	53
Micron Technology Incorporated	446	84	1.81	7.750	16.375	36.70	284	85	39.29	53
Motorola Incorporated	9,620	2,715	161.00	65.375	88.375	130.00	8,499	78	13.20	26
Octel Communications Corporation	87	36	4.94	17.250	27.750	15.20	262	181	13.27	38
Oracle Corporation	971	334	52.96	12.750	28.375	136.8	1,744	130	8.23	55
Quantum Corporation	446	163	17.34	14.500	25.750	27.59	400	61	5.77	44
Seagate Technology, Incorporated	2,413	668	29.69	9.125	19.750	51.78	472	18	3.98	54
Silicon Graphics Incorporated	264	120	11.20	24.000	40.875	17.20	413	86	9.21	41

(Continued)

TABLE 1 (Continued)
Technology Company
Financial Data and Stock Price

Company	Fiscal Year 1989 Revenue ($M)	Latest Revenue Second Quarter 1990 ($M)	Latest Profit Second Quarter 1990 ($M)	8/23/90 Stock Price ($)	Stock Price 12-Month High ($)	Number of Shares (Millions)	Market Capitalization ($M)	Market Capitalization as Percent of Revenue (Latest Quarter)	P/E Ratio (Latest Quarter)	Stock Price Percent Decline
Silicon Valley Group Incorporated	131	47	0.43	6.625	13.750	10.20	68	36	39.29	52
Sun Microsystems Incorporated	1,765	700	49.10	26.000	37.125	85.20	2,215	79	11.28	30
Tandem Computers Incorporated	1,633	472	32.44	13.875	30.125	101.40	1,407	75	10.84	54
Texas Instruments Incorporated	6,522	1,592	11.00	26.750	44.000	84.9	2,271	36	51.62	39
VLSI Technology Incorporated	289	85	2.40	5.625	12.250	23.80	134	40	13.95	54
Varian Associates, Incorporated	1,344	344	(34.10)	28.750	34.750	19.90	572	42	-	17
Western Digital Corporation	992	294	9.48	9.250	14.875	29.10	269	23	7.10	38
Xerox Corporation	16,441	4,255	(254.00)	39.000	68.500	101.70	3,966	23	-	43

Source: Dataquest (September 1990)

Lack of Liquidity

Already, the decline in public stocks has led to the cancellation of IPOs. Clearly, current prices are not prices that companies want to, or can, take back to the market; it is likely that Sun, for example, will cancel its intended offering. Exacerbating the problem, the newly conservative banking industry is steering clear of (perceived) risky high-tech companies. This movement is already in evidence in the Northeast.

Capital will be increasingly scarce and conservation of capital must become a priority for most companies. Reminiscent of Peter Drucker's advice, "Sell the mailroom!", more and more nonessential or noncritical activities will be farmed out, especially those that are capital intensive—such as wafer fabs and MIS departments. More nonstrategic business units will be sold.

Companies that are not public, and some that are, will look more actively at non-market-financing alternatives including selling part or all of the companies. Entrepreneurs will think twice about wanting to be a public company. On the other side of the coin, low share prices make LBOs increasingly attractive. Going private could be a trend of the 1990s. Cash will be king.

Acquisitions

Loss of liquidity reduces the options of companies, and low share prices definitely will induce salivation among corporate predators. A large percentage of companies are priced significantly below key takeover benchmarks—such as one times revenue. Both seller and buyer activity is sure to increase. For those companies that view this activity as unwholesome, defense mechanisms will be studied and installed.

In the United States, cultural reluctance toward acquisitions is nonexistent. Friendly and unfriendly acquisition by corporate and financial interests inevitably will rise.

Will low share prices create a fire sale to foreign interests? Because foreign stock markets were hit hard and because foreign companies generally are reticent to indulge in international cross-cultural acquisitions of a predatory (unfriendly) nature, a fire sale to Asian interests is unlikely. Buyouts of this nature will be the exception rather than the rule; nevertheless, some activity is bound to occur. On the other hand, lack of domestic liquidity historically has sent companies abroad for financing—such as Amdahl—and this will happen again: More technology and ownership will go abroad.

Lack of financing alternatives will encourage companies to sell parts or pieces of themselves, or to license or sell technology at more attractive prices. Participation in these activities may be more attractive to foreign establishments.

Opportunity

Established companies—i.e., those with cash or a high stock price—will see ample opportunity for acquisitions of technology or other beneficial strategic arrangements with other companies. Indeed, we think that an effect of the stock slide will be to bring, by necessity, the US high-tech community closer as interests, assets, and technology are traded for mutual advantage.

Companies that have the lowest (perceived) stock prices relative to value can take heart. Now is the time to move with alacrity and rewrite stock options—a onetime chance to secure and lock in exceptional talent.

Some companies will take advantage of low share prices and below book values to buy back their own stock. Intel already announced its intention to do this, and other companies are sure to follow.

Bernadette Cesena
Frederick Zieber
Ralph Finley

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Research Newsletter

DATAQUEST'S OUTLOOK FOR 1990 AND 1991: SLOWING BUT POSITIVE GROWTH

INTRODUCTION

Each year, in the third quarter, Dataquest reexamines its near-term forecasts. Additionally, a number of Dataquest industry services perform a midyear survey to verify predicted trends. This newsletter, which combines information from a variety of Dataquest services, presents a summary of our near-term industry forecasts and the results of our ongoing examination of major high-technology industries. We begin with an examination of the current US economic outlook, followed by an overview of semiconductors, business and technical computers, computer storage, electronic printers, display terminals, CAD/CAM/CAE, personal computer software, and telecommunications.

US ECONOMIC OUTLOOK, SEPTEMBER 1990: THE SKY IS NOT FALLING

GNP Economic Outlook

Contrary to popular belief, the sky is not falling; nor is it expected to do so anytime soon. That is, although the rate of real economic growth has been decelerating over the past several months, no recession is forecast. In the wake of Iraq's invasion of Kuwait, The Dun & Bradstreet Corporation (D&B) forecasts real gross national product (GNP) growth of 1.3 percent in 1990, down from 2.5 percent forecast for the year in April; 2.8 percent in 1991, down from 3.4 percent; and 2.9 percent in 1992, down from 3.0 percent.

The unemployment rate is at 5.6 percent, lower than this rate was for any year from 1974 to 1987. Factory capacity utilization is more than 83 percent, exceeded in only 6 of the past 20 years. These measurements reflect relatively tight labor and product markets; there is little slack in the economy. Recent slowing of economic growth is a result of the Fed's policy of limiting aggregate demand to lower the rate of inflation.

The rise in world oil prices is not likely to push the economy into recession. Indeed, if world oil prices—currently just over $30 per barrel (bbl)—settle at about $27 bbl during the next 12 months, which is a likely scenario, GNP would decrease by one-half of 1 percent. Similarly, should the recent oil price increase stick, this would slice, at the most, about one-half of 1 percentage point from economic growth.

Capital Spending

Spending that can be postponed (e.g., business capital investment and consumer durables expenditure) shows the greatest exposure to the recent slowdown in overall economic growth. Indeed, as of August, D&B's forecast of real growth of business equipment investment is 1.6 percent in 1990, down from 4.9 percent forecast in April; and 6.8 percent in 1991, down from 9.0 percent. Similarly, real growth of consumer durables expenditure has been revised down to 0.6 percent in 1990, from 2.8 percent in April; and to 1.1 percent in 1991, down from 3.4 percent. Note that real growth in these areas is forecast to remain positive. Almost without exception, real investment spending growth is negative during a recession. Not all investment spending will be postponed; projects that will be postponed are the marginal ones—that is, those projects that are not sufficiently profitable, given the expectation of slower real economic growth.

US Electronics Production and Economic Outlook

Capital spending on electronics equipment has not been immune to recent economic slowing.

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Indeed, for US electronics equipment as a whole, 3-month-ended-orders growth has shown a decelerating trend compared with earlier figures; from 10.3 percent in January 1990 down to 6.2 percent in July 1990. July 1990 12-month-ended- and year-to-date-shipments growth figures are in the 6 to 7 percent range.

THE SEMICONDUCTOR EQUIPMENT, MANUFACTURING, AND MATERIALS MARKET

Dataquest anticipates that a silicon wafer shortage will occur in the 1990 to 1991 time frame, with ramifications likely to last until 1992. An explanation for this occurrence is that few new capital investments were made in the area of silicon wafer manufacturing since 1985. One consequence of this material shortage is increased lead times to semiconductor manufacturers. Dataquest does not expect this material undersupply to affect the semiconductor market adversely; the market presently is oversupplied. Yet, such a shortage may influence the strategic alliances of wafer suppliers and semiconductor manufacturers, especially second-tier semiconductor manufacturers that have not yet built long-term relationships with material suppliers.

SEMICONDUCTOR DEVICES

The PC market represents the single largest microcomponent application for the microcomponent device market. So far, the year 1990 has been characterized by high demand for 386SX and 386DX processors. Recently, reports indicate that an oversupply of these processors may exist. Additionally, some PC logic chip set vendors are experiencing a slowdown in PC AT chip set demand, particularly for 286 AT products. Combined, these indicators point to a slowdown in microcomponent revenue in the fourth quarter of 1990, possibly carrying over into the first quarter of 1991.

In the logic device market, major ASIC players experienced strong bookings in the past months, whereas standard microcomponent products (i.e., PC chip sets and graphics controllers) encountered a soft, lackluster market. The weakness in the standard product market can be attributed to two factors: an increase in competition and a shift in demand. Dataquest expects the strong bookings for ASIC devices to carry forth into the first half of 1991, primarily because of the long lead times of these products.

Dataquest anticipates that the memory device market will have extremely competitive pricing for 1Mb, 4Mb, and 256K DRAMs for the balance of 1990. The sluggish demand for 4Mb devices stems from the lack of design-ins, a package-standard shift from 350 mil to 300 mil, and the resulting mismatch in supply and demand. Competitive pricing also will continue for 256K and 1Mb, as well as 16K, fast SRAMs. Stability is emerging in the 64K fast SRAM market as a result of Japanese-based suppliers de-emphasizing this device and the departure of key SRAM manufacturers from this market. Pricing for 256K SRAMs will be competitive.

For 1991, Dataquest expects to see a definite shift to the 4Mb DRAM from the 1Mb DRAM. The market crossover to the 4Mb DRAM is expected to occur when a four to one (4:1) ratio is achieved between the 4Mb and 1Mb devices. This move could occur in the first quarter; however, it is entirely dependent on the rate of price decline for the 1Mb. There is a chance of a shortage of slow SRAMs in 1991, specifically the 64K (8Kx8). Users have concerns regarding the capacity of 256K slow SRAMs; however, we do not project a lack of this product.

The analog, discrete, and optoelectronics device market experienced weaker than historical performance in 1989. This downward trend has been due to a slowdown in consumer markets, with such items as camcorders and CD players reaching a level of saturation and softness. Dataquest believes that this soft booking and soft average selling price (ASP) environment will continue through the end of 1990. In 1991, Dataquest anticipates that pricing will stabilize and put an end to the slide experienced in 1990. Furthermore, bookings should return to 1987 levels.

SEMICONDUCTOR CONSUMPTION

In the midterm, Dataquest anticipates that semiconductor consumers will take a more conservative attitude toward buying. These customers should not experience difficulties in purchasing semiconductor devices. Memory is no longer in short supply. We expect to see relatively stable lead times and good availability of semiconductor devices throughout the first half of 1991 and, most likely, the remainder of that year. According to Dataquest's September procurement survey, systems sales outlook for the next six months is expected to remain positive at approximately 4.1 percent. (August's growth rate was 5.0 percent.)

The order rate for semiconductors is expected to grow in September by 14.0 percent over August levels. The six-month availability outlook for semiconductors remains very good, and this is expected to continue throughout the first half of 1991.

THE BUSINESS AND TECHNICAL COMPUTER SYSTEMS MARKETS

The business and technical computer systems markets will continue to see growth throughout 1990 and 1991, though at a lower rate than originally forecast because of the current tight economic situation. We have revised our worldwide factory revenue forecast, excluding personal computers, for 1990 downward from a growth rate of 14.2 percent to 7.9 percent. For 1991, we are forecasting a growth rate of 10.7 percent.

Mainframes offer the biggest profit margins in the industry, and this segment is very mature. IBM's recent announcement of the System/390 will effectively stall the market while users assess purchasing plans. The mainframe market may see some movement late in 1991 and in 1992, when the true Summit systems will be available.

Midrange computer systems (which include minicomputers, superminicomputers, and microcomputers) represent about 44 percent of the total market. This segment is experiencing the most difficulty; many midrange vendors reported flat sales through the middle of this year. Many new technologies that compete with older, existing, shared-logic minicomputer technology are being introduced in the midrange segment and especially in the workstation segment. Vendors of traditional minicomputers selling proprietary systems will be facing exceedingly tough competition. The workstation segment will continue to be the fastest-growing segment over the next several years, reflecting the strong movement toward distributed computing. With growth rates for 1990 and 1991 projected at approximately 40 percent each year, workstations account for most of the growth in the computer systems markets.

THE COMPUTER STORAGE MARKET

This last spring, Dataquest estimated a 10 percent growth in worldwide factory revenue for the computer storage market during 1990. Unit shipments were forecast to grow by 18 percent, and ASPs were projected to decline by 8 percent. Preliminary results of our midyear surveys indicate that unit shipments during the first half of 1990 were close to Dataquest's expectations. Unit shipments for the year still are anticipated to grow by 16 to 18 percent.

The revenue outlook is in jeopardy. Dataquest believes that there is excess production capacity in the 3.5-inch hard drive segment of the storage industry (representing 30 percent of factory revenue). This segment appears to be heading for the same problems that 5.25-inch drive producers experienced two years ago (the same manufacturers, in a few cases). At midyear, a price war began in the 3.5-inch, 40MB drive market in retail distribution. At the same time, OEM prices for 3.5-inch drives over 100MB were falling.

The rest of the computer storage market is progressing along the forecast. In both the rigid and flexible disk drive segments, 5.25-inch drives are being replaced rapidly by 3.5-inch products. Demand in the tape drive market is stable. New applications for optical disk drives are creating growth in this segment of the market.

Demand for more and better storage capabilities continues to expand, technological advances in magnetic storage seem to be inexhaustible, and the cost per megabyte of storage is declining rapidly in newly announced storage devices. The need for additional storage capacity is endless, as are the dynamics of the industry.

THE ELECTRONIC PRINTER MARKET

At the Electronic Printer Industry Service spring conference, Dataquest projected the 1990 US electronic printer market growth to be 12 percent in units and 17 percent in factory revenue. Shipments for the first half of 1990 were essentially on track. However, the jury is still out on consumer and business spending during the fourth quarter. A soft fourth quarter (typically 30 percent of annual sales) could reduce the 1990 growth rates by at least 2 or 3 percentage points. Dataquest believes that vendors should take a cautious stance on the market outlook for the next three quarters.

Revenue growth in the electronic printer industry is greater than unit growth because of the continuing printer market trend—from lower-cost dot-matrix impact printers to state-of-the-art nonimpact page printers, which have higher unit prices. During the past few months, demand for 1- to 6-page-per-minute (ppm) printers has been less than expected. At the same time, 7- to 10-ppm printers are shipping much better than expected.

Dataquest believes that this shift in demand is primarily attributable to pent-up demand from PC users. New products in the 7- to 10-ppm segment offer new features, such as scalable fonts, which the PC world has been wanting for a long time.

As market demand changes, so does the structure of the supplier side of the industry. So far this year, to mention a few, the following changes occurred:

- IBM is in the process of selling its Lexington, Kentucky, plant (which includes its personal printers production).
- Hitachi Koki bought DataProducts (which is an expansion by acquisition, rather than by building plants in the United States as other companies have done).
- Siemens divested part of its printer business (below 20 ppm).

Look for many more new and exciting product announcements this fall and next year. User demands for better printing capabilities are increasing, which is continuing to change the structure of the electronic printer industry.

THE DISPLAY TERMINAL MARKET

Dataquest has completed its midyear 1990 census. North American display terminal unit shipments decreased 3.7 percent from the like period in 1989 and were 3.1 percent below forecast. This market continues to grow in Western Europe, especially in preparation for Europe 1992. Higher sales are expected in Europe in 1991 and 1992.

IBM midrange terminals are on schedule, while the 3270 market has slowed in anticipation of IBM's Summit announcement. Processing terminals are the single largest growth segment, with first-half 1990 sales up 45.9 percent over first-half 1989 and 12.7 percent over forecast. Dataquest believes that shipments of processing terminals will increase 77.4 percent worldwide in 1991.

Overall, alphanumeric terminals suffer from a lack of standards—especially for windowing, application program interfaces, and user interfaces. Agreement on standards in these areas would foster further growth among independent alphanumeric terminal vendors.

THE CAD/CAM/CAE MARKET

The CAD/CAM/CAE market produced $12 billion in factory revenue in 1989 and is forecast to grow approximately $2 billion a year for the next few years. Some of the forecast growth for 1990 has not materialized yet, due primarily to product transitions in the electronic design market (EDA). The EDA market is predicted to have a strong fourth quarter as a result of updated products entering the market. If these products do not materialize, some of the projected revenue for 1990 for the CAD/CAM/CAE market will shift into 1991.

The Mideast crisis also is expected to cause slower capital spending for CAD/CAM/CAE equipment, as well as to have a slight dampening effect on the market. Design automation is dependent to some extent on US defense funding. The US federal government may curtail design of new defense execution requirements—which would result in fewer CAD-system buys by both the federal government and the aerospace industry.

The major issues facing vendors in 1991 will be distribution channels, open systems, and standards. Developing a successful distribution strategy is the most challenging of these issues, in that today's CAD dealer channel is inadequate for a robust distribution channel. Typical profit margins for CAD dealers are too low or uncertain to attract top-quality business people for sales, or even management, positions. There are far more good products than there are high-caliber people to sell and support them.

THE PERSONAL COMPUTER SOFTWARE MARKET

Dataquest estimates that personal computer software shipments reached $4.4 billion in worldwide factory revenue in 1989; these are projected to grow by an estimated 11 percent in 1990 and 13.5 percent in 1991. Growth in the 1990 to 1991 time frame will be driven largely by users buying software for new systems and upgrading older versions of their current software. These upgrades will increase as new technologies become more commercially viable. Dataquest expects Windows 3.0 to help drive PC software sales over the next few years because users want to move from character-based to graphical-based interfaces.

Sales of Macintosh software may exceed our previous 1991 projections. (Dataquest projected that Macintosh software would remain at about 12 percent of the total PC software market, based on factory revenue.) The lack of low-cost Macintosh products has restricted the growth of Macintosh systems. If the price of the new low-cost

Macintosh (to be introduced later this year) is in line with what has been reported in the trade press, Dataquest expects the new Macintosh products to compete successfully with low-end PCs.

Word processing, spreadsheet, accounting, and database management systems software will continue to be the major segments of the PC software market, based on factory revenue. Dataquest estimates that these four segments will account for over 50 percent of the total market in 1990 and 1991 and will continue to dominate the market through the mid-1990s.

THE TELECOMMUNICATIONS MARKET

In general, the worldwide telecommunications market is expected to increase by 6.7 percent in 1991 in terms of end-user revenue, with a 7.7 percent compound annual growth rate (CAGR) through 1994. This growth rate is driven primarily by the dominating influence of telecommunications services: local and long distance telephone calls. Excluding this revenue derived from network services, the growth in equipment-related revenue is expected to increase to a 10.1 percent CAGR through 1994. This equipment-related growth is expected to be fueled primarily by growth in the Asia/Pacific (including Japan), Eastern Europe, and rest of world (ROW) regions. Neither the US nor Western European forecasts match the robust growth rates of the other regions.

Overall, the US telecommunications market is expected to increase 4.9 percent in 1991, with a CAGR of 5.2 percent through 1994. Viewing the US telecommunications markets in aggregate, the fastest-growing markets are expected to be cellular mobile radio services, DSUs/CSUs, local area networks (LANs), and satellite earth stations. Network services, the dominating revenue producer, is expected to continue growing at a rather consistent 4.9 percent CAGR. On the downside, modems, statistical multiplexers, and data PBX systems continue to experience declining revenue in the United States, largely because of the advent of replacement technologies, market "commoditization," and market saturation.

The Western European telecommunications market still is expected to perform better than the US market—with a 5 percent increase expected in 1991 and a strong 8.4 percent CAGR forecast through 1994. Viewing all Western European markets across-the-board, the fastest-growing markets are expected to be voice messaging, video teleconferencing, LAN, private packet data switching, cellular telephone, and network management systems. As in the United States, statistical multiplexers and data PBXs are in the declining stages of their product life cycles.

Issues and trends in telecommunications for the 1990s include the following:

- Potential for further deregulation of RBOCs, such as easing of restrictions on manufacturing and information processing activities
- Telecommunications industry migration from being engineering-driven to being market-driven
- Increases in wireless portable communications equipment, such as cellular telephones
- Emerging social acceptance of the "home office" and the need for communications capabilities to make it possible
- Increasing connectivity between computers and telecommunications equipment.

Nancy Stewart
Gene Norrett

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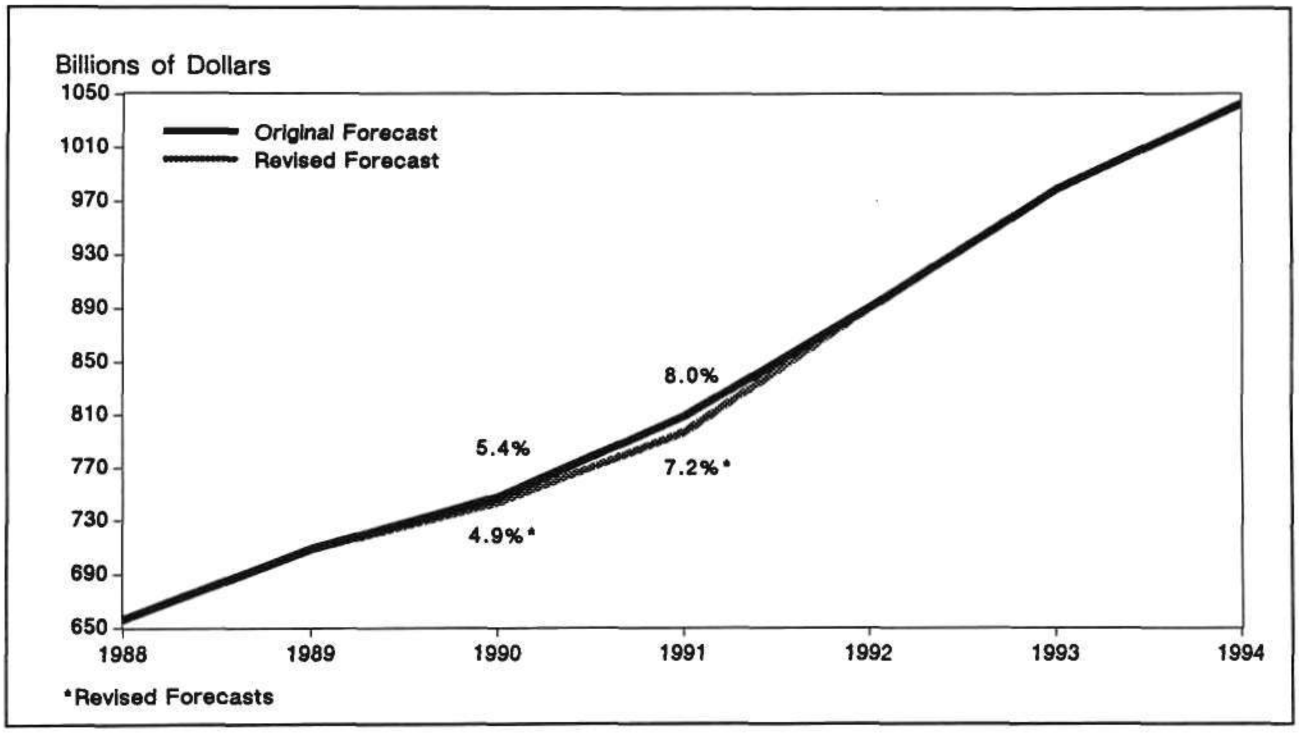
Research Newsletter

THE MIDEAST CRISIS' EFFECT ON THE ELECTRONICS INDUSTRY

The current crisis in the Middle East and its effect on oil prices have sent a shock through world economies and tremors through various industries. In the United States, most analysts have lowered their forecasts for GNP, but few are currently predicting an actual recession. We believe that growth in the global electronics industry, in which the price of oil is a significant factor, will slow in the third and possibly fourth quarters of this calendar year.

Figure 1 shows the current forecast for the world electronics market, as well as the projected decline in growth given the current Mideast situation and overall weakened industry demand. Dataquest believes that growth in the worldwide electronics industry in 1990 most likely will slow just slightly from the original forecast of 5.4 percent to the revised forecast of 4.9 percent. This newsletter will discuss some possible outcomes of the current crisis that should contribute

FIGURE 1
Worldwide Electronics Market Forecast



Source: Dataquest (August 1990)

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in varying degrees over the next few months to the slower growth rate.

POSSIBLE OUTCOMES

Expansion Plans May Be Postponed

In light of the current crisis and business' expectations about its outcome, companies will tend to put off expansion plans and various types of investment purchases. Leveraged companies, worried about paying back what they have already borrowed, may halt expansion plans. Furthermore, many companies may not believe that there will be sufficient business in the future to support current expansion plans. Also, modernization may take place more slowly, particularly in third-world countries. For example, installation of computer systems and phone systems may be postponed.

Adoption of New Technologies May Be Postponed

Adoption of new technologies also may be postponed because of uncertainty in the economy. For example, within the telecom industry the implementation of Integrated Services Digital Networks (ISDNs) may be delayed. ISDNs are high-speed networks used primarily for voice data and video. Although ISDNs currently are being tested, actual implementation will involve major expenditures for companies and may therefore be postponed until economic conditions improve.

Sensitive Purchases May Be Postponed

Slower business conditions may make it more difficult for companies to justify purchases, particularly smaller, incremental-type purchases. PCs, software, services, and upgrades are some examples of the types of purchases typically affected by slower business conditions. Businesses will tend to postpone purchases that may be only marginally necessary. DP/MIS expenditures most likely will be affected. Although prices will rise immediately, purchase decisions will be affected down the road. Most companies have a minimum three-month planning horizon. Thus, the effects of any changes in purchasing behavior will not be seen until the fourth quarter of this year or the first quarter of 1991. In general, companies will be trying to reduce overall expenditures.

No Net Gain in the Leasing Market

The leasing market for electronic products such as computers often benefits when businesses cut back on purchases. However, the market probably will see little if any positive net effect from the current crisis. Although leasing generally helps businesses preserve cash flows and attain some financial benefits, leasing rates also will go up if interest rates go up. Furthermore, the decision to lease still costs money. So if a business postpones the decision to purchase, the decision to lease also may be postponed or not even considered.

Volatile Industries More Affected

The crisis will affect different industries in different ways. The chip industry, which tends to be highly cyclical, now seems to be most directly affected by the crisis. Companies such as Intel have seen their stock prices drop sharply, then fluctuate drastically as well as trade heavily since the beginning of the crisis. Most technology stock indexes have shown a net drop of at least 10 percent over the past few weeks. The wide variety of application areas in which semiconductors are used also make the semiconductor market especially vulnerable to changes in economic conditions. One example is the automobile industry, a large application area for semiconductors, which has been on the brink of a recovery. It may now head into a deep recession. If the automobile industry becomes depressed, the semiconductor industry also will decline because semiconductors are used extensively in autos. The same scenario will occur if the data processing industry declines, as 40 percent of all semiconductors are used in data processing equipment (computers and associated peripherals).

Decreases in Defense Spending May Be Postponed

Given the current Mideast situation, the proposed US defense build-down is likely to be substantially slowed or temporarily postponed. In the post-cold war era, many had expected the United States' defense needs to decline in proportion to the decline of the Soviet threat. The current Mideast crisis has renewed discussion on the issue of what the appropriate defense budget level should be. If US government income declines, there will be more and more pressure to raise taxes. However, businesses can expect to see some tax increases in the future anyway, although maybe not immediately in this election year.

Cost Increases May Be Absorbed

Over the past decade many electronics companies have become constrained. For example, in the 1970s limited competition as well as the strong economy allowed companies to pass along higher costs to consumers at will. But now, as competition has increased and demand has fallen, these electronics companies will be forced to absorb, at least initially, any increases in costs because of increases in oil prices. Many companies will be under margin pressures. If product prices were to increase now, sales would be hurt. And with fixed costs increasing, companies would need to maintain their sales volume to maintain their profitability. The DRAM market, which has been relatively soft for the last four quarters, would be particularly susceptible to these market conditions. Overall, companies may try to offset higher costs and avoid higher prices by implementing strong cost-cutting measures or simply by absorbing increased costs until prices have stabilized.

Less Discretionary Income

Because of increased expenses, consumers will have less discretionary income to spend, and money that could have been spent on other purchases will be pulled out of the economy. Higher oil prices will drain purchasing power away from the rest of the economy. Bush Administration economists estimate that a 50 percent rise in the price of oil would promote a two-step increase in prices: Higher gasoline and heating oil prices would add a percentage point to the consumer price index; and indirect effects, as the oil price increases filter through the economy to computer boxes and medical electronic equipment, would add another percentage point. Dun and Bradstreet recently revised its forecast for the 1990 US inflation rate upward to 4.9 percent and to 4.6 percent for 1991.

GLOBAL PERSPECTIVE

The economic outlook for the US economy has become less optimistic. The US Department of Commerce's final revision of real GNP growth in 1989 has been revised down from 3.0 percent to 2.5 percent. Further, in light of the events unraveling in the Middle East, Dun and Bradstreet has lowered its forecast of growth from 2.5 percent to 1.3 percent in 1990; and from 3.4 percent to 2.8 percent in 1991. Real growth of equipment investment spending by business has been lowered from 4.9 percent to 1.6 percent in 1990, and from 9.0 percent to 6.8 percent in 1991. Real growth of purchases of durable goods by households has been lowered from 2.8 percent to 0.6 percent in 1990, and from 3.4 percent to 1.1 percent in 1991.

Around the world other major economies are in somewhat better shape than the United States. Major oil exporters such as the Soviet Union and to some extent Mexico and Venezuela should be relatively unaffected by the current crisis and may even see their economies improve because of increases in oil exports. Japan must still import most of its oil, but oil provides less than half of the country's total energy. Furthermore, because Japan's economy currently is growing at a faster rate than that of the United States, the impact of the oil shock should have less effect on its GNP.

A significant difference exists in the way Japan perceives the oil crisis, as compared with the United States. Dataquest believes that Japanese companies look at the current crisis as an opportunity and will take advantage of the situation if possible. There should be little, if any, change in capital spending in Japan. On the other hand, we believe that US companies may sit back and wait for events to take their course. Capital spending may decline over the next few quarters in the United States. However, in both countries the net benefit of the current situation worldwide will be that businesses will be forced to become more efficient.

Western Europe is in pretty much the same situation as the United States, consuming relatively more oil than it produces. However, Europe, which has been anticipating 3 percent economic growth, is not on the borderline of a recession, as is the United States. Higher oil bills easily could be paid from high trade surpluses. Eastern Europe, though, has a very strong dependence on imported oil. The oil shock has occurred just as many Eastern European countries are gearing up for economic reform. More costly energy surely will stunt Eastern Europe's predicted growth, as well as opportunities for Western nations to enter Eastern European markets.

Third-world countries fear that the surge in oil prices will lead to renewed political turmoil, higher inflation, and less income. A large number of debtor countries are also oil importers. The current oil shock may push these countries over the edge financially. Many of these countries also will see growth prospects reduced as higher prices for oil absorb money that would have been used for investment and more consumption.

DATAQUEST ANALYSIS

Dataquest believes that the worldwide electronics market overall growth rate most likely will slow to 4.9 percent in 1990. More specifically, we believe that growth will be lower than anticipated in electronic equipment industries such as computers and communication that currently are experiencing weak demand. Previously, Dataquest had forecast upturns in many electronic equipment industries; these upturns have now been postponed. As the growth for electronic equipment slows, the demand for semiconductors will then decline. Growth in the semiconductor market is predicted to be relatively flat in the third quarter; fourth quarter growth is questionable.

Higher oil prices and the oil crisis in the Middle East surely will dampen business activity at least in the near future. But economic conditions have changed since the 1970s and the last oil crisis. The effects of a major disruption to the economy are more distributed and less noticeable than they were in the 1970s recessions. Businesses are less dependent on oil and use it more efficiently than ever before. Inventories of oil are at the highest levels in nine years. Businesses generally seem to be taking a wait-and-see attitude toward the current situation. Much depends on the course of events in the Middle East over the next weeks and months. If the Mideast crisis turns into a long-term situation, the forecast slower growth in the electronics industry could continue well into 1991.

Melanie A. Meyer
Gene Norrett

Dataquest
a company of
The Dun & Bradstreet Corporation

Research Newsletter

DATAQUEST'S 1990 ELECTRONICS INDUSTRY FORECAST

INTRODUCTION

Every year, Dataquest surveys both vendors and users in most major high-technology industries to collect market share and market-sizing data. This newsletter presents a summary of our industry forecasts and is designed to provide an overview of the sizing, trends, and events shaping each industry. Unless otherwise noted, all data are given in terms of factory revenue. Japan is included in the Asia/Pacific region, and totals may not add correctly because of rounding.

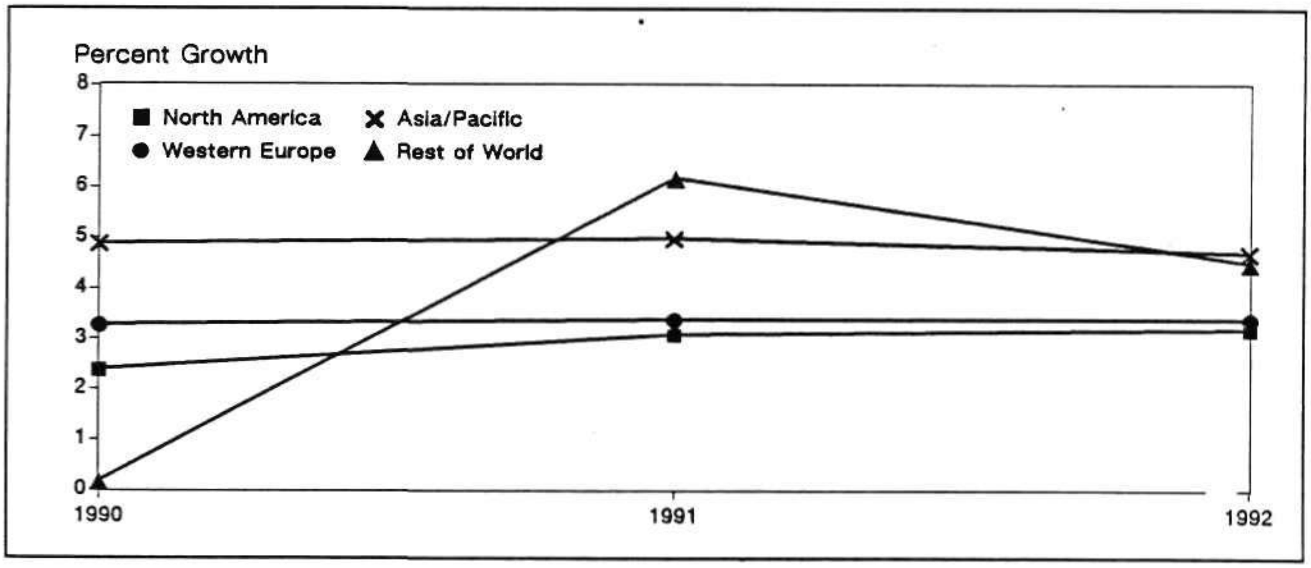
ECONOMIC OVERVIEW

During the late 1980s and throughout the first quarter of 1990, many structural changes took place in the international economy that guarantees that this decade will be as difficult to forecast as the last one. Nevertheless, we believe that the global economy, as compared with that of any one domestic sector, will be the economic catalyst for growth of high-technology markets in the 1990s. Figure 1 shows our economic projections for the four major regions of the world.

Highlights that will fuel future growth include the following:

- North America—The US-Canadian Free Trade agreement will reduce tariffs on most goods, while the Brady plan will assist the development of Latin American countries, thereby creating demand for products and services.
- Asia/Pacific—In the 1980s, Japan's growth propelled its economy to third place worldwide (behind the United States and the Soviet Union). We expect the "Four Tigers" (Taiwan, South Korea, Singapore, and Hong Kong) to enjoy similar rapid growth in the 1990s.

FIGURE 1
Real Gross Domestic Product



Source: The Dun & Bradstreet Corporation, Dataquest (July 1990)

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- Europe—The majority of the 1992 initiatives will become reality, thereby creating a unified market. Furthermore, the most significant of recent events is the raising of the Iron Curtain in Eastern Europe, which in itself opens up a potential market of more than 400 million people.

TELECOMMUNICATIONS

Table 1 shows our current five-year forecast. As is typical in this industry, the vast majority (over 80 percent) of revenue is attributed to network services such as local, long-distance, and international telephone calls. For this analysis, we also have included revenue related to the cable television industry (CATV), which is increasingly becoming a competitive factor in this industry.

Factors influencing our forecast include the following:

- The continuing globalization of the industry, including consistent standards
- Europe—Increasing demand for data/data networking equipment, unification effects of 1992, and the opening of Eastern Europe
- Asia/Pacific—For Japan, we see increasing demand for equipment (both voice and data) due to the opening of trade, along with increasing demand for private networks and competitive network service offerings. The Four Tigers of Asia/Pacific also are expected to consume an increasing amount of telecommunications equipment and services.

Communications—Whether it be voice, the written word, or data, communication is key to business as we know it; therefore, by association, so is the telecommunications industry. Irrespective of international boundaries, the companies positioned to fulfill both the continuing and newly emerging demand for telecommunications will prosper.

TABLE 1
Telecommunications Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$196.6	$207.1	$266.0	6.5%
Western Europe	100.2	102.1	142.1	8.6%
Asia/Pacific	66.8	72.0	102.5	9.2%
Rest of World	40.2	43.0	60.2	8.8%
Worldwide	$403.7	$424.3	$570.9	7.7%

Source: Dataquest (July 1990)

BUSINESS AND TECHNICAL COMPUTER SYSTEMS

Table 2 shows our current worldwide five-year forecast for business and technical computers, excluding personal computers. Dataquest expects the current trend of flat growth in North America to continue. Europe and Asia/Pacific will exhibit increasing revenue as vendors expand their international sales activity. New market opportunities are expected as European unification and the opening of the Eastern Bloc moves forward.

Additional factors influencing our forecast include the following:

- Mainframes—"Downsizing" will become more prevalent; not necessarily all the way down to networked PCs but more often to less expensive platforms that perform the same functions.
- Midrange systems—Lower margins and the importance of indirect channels are forcing vendors to rethink their distribution strategies.
- Workstations—Product life cycles will continue to be very short, and vendors will continue to challenge each other in the price/performance arena. Workstations will be the fastest-growing segment for both the technical and commercial sides of the market.
- All systems—The demand for open systems and standards will continue as proprietary systems decline. Emerging new technologies such as multimedia and the use of strategic processing styles (OLTP, distributed processing/applications, etc.) will stimulate growth. Increasingly, vendors will derive revenue from the "S factor": services, support, software, and systems integration.

TABLE 2
Business and Technical Computer Systems Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
Worldwide	$67.2	$76.8	$107.8	9.9%

Source: Dataquest (July 1990)

PERSONAL COMPUTER SYSTEMS

Hardware

Table 3 shows Dataquest's actual and short-term projections for PCs. The variance in the forecast is caused by an unexpected rise in the number of 386- and 386SX-based PCs sold. Also, more portable and hand-held PCs were introduced and sold in 1989 and 1990 than expected. These PCs typically are priced higher than desktop PC systems sold in 1988. In addition, there was more of an increase than previously expected in sales of PCs with higher-capacity disk drives and greater memory; these factors also increased the average selling price (ASP) per unit. Each of these factors contributed to the higher 1989 revenue sales and 1990 sales projections.

Table 4 shows our current five-year forecast for PCs. Dataquest anticipates that rapid growth of notebook and hand-held PCs will be one of the primary factors driving this forecast. The trend is for smaller, portable, and faster systems to displace larger, bulky desktop systems. Dataquest also expects the emergence of fast, portable notebook and hand-held PCs to create a secondary PC market—PCs that are primarily used for travel.

TABLE 3
Personal Computer Forecast Comparison
(Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$32.8	$38.6	17.7%
Current Forecast	$34.6	$42.4	22.5%
Percent Difference	5.5%	9.8%	

Source: Dataquest (July 1990)

TABLE 4
Personal Computer Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$18.9	$23.0	$34.2	12.6%
Western Europe	11.1	13.7	17.5	9.5%
Japan	2.5	3.3	6.2	19.9%
Rest of World	2.1	2.4	4.8	18.0%
Worldwide	$34.6	$42.4	$62.7	12.6%

Source: Dataquest (July 1990)

Notebook PCs are expected to experience a very rapid compound annual growth rate (CAGR) of 76.5 percent based on unit shipments through 1994. The hand-held category is expected to experience explosive growth of 126.4 percent CAGR, based on unit shipments through 1994, while the price per unit should decline to about $600. Dataquest also expects a proliferation of PCs into Eastern Europe, the Far East, Middle East, and parts of Southeast Asia.

Software

Table 5 shows our current five-year forecast for PC software. Factors driving this forecast include our expectations that international sales of software will grow rapidly. Dataquest expects an increase in the export of PCs to Eastern Europe, the Far East, and parts of Southeast Asia to provide a commensurate increase in PC software sales. Dataquest also expects an increase in sales of PC software to Japan as Japan continues to open up its market to exports. Operating environments and telecommunications software will be key growth areas in the PC software market through 1994.

Growing sales of new PCs will continue to drive sales of PC software. PC software sales will grow at a slightly higher rate than PC hardware sales over the next five years because PC software is sold to the installed base as well as with new systems. The replacement rate of PC software is also higher than for PC hardware because the cost per unit of PC software is significantly lower than the cost per hardware unit. Overall, the growth rates of both PC software and hardware have slowed as these markets mature.

TABLE 5
Personal Computer Software Forecast
(Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$2.7	$2.8	$4.8	12.2%
Western Europe	1.3	1.5	2.4	13.0%
Asia/Pacific	0.3	0.3	0.9	24.6%
Rest of World	0.1	0.2	0.6	43.1%
Worldwide	$4.4	$4.8	$8.7	14.6%

Source: Dataquest (July 1990)

SEMICONDUCTORS

Table 6 shows our actual and short-term projections for worldwide semiconductor revenue, comparing this year's forecast with last year's forecast and actuals. In the second half of 1989, DRAM prices fell much more dramatically than we had anticipated—although we had predicted a decline—thus causing two negative quarters. In addition, commodity analog IC prices also suffered severe price attrition in the last half of 1989. These factors, combined with a general softening of the PC market, are the major causes of our variance with 1989 actuals. We have not changed our basic outlook for 1990; and we believe that the market will be down very slightly from 1989.

Table 7 shows our current five-year forecast by region. After three quarters of negative growth, the worldwide semiconductor industry resumed positive growth in the second quarter of 1990. PC business, in the dumps during the second half of 1989, has begun to turn around dramatically, particularly in Europe. Semiconductor industry sources indicate that their orders began to rebound in the first quarter of this year.

Dataquest expects semiconductor demand to continue to strengthen over the coming months. We believe that growth will continue through 1993, which will be the peak year of this cycle, and begin to taper off during 1994. Although we expect semiconductor penetration in electronic equipment to continue to increase, the overall electronic equipment market is maturing and experiencing slower growth, and relationships between semiconductor suppliers and semiconductor users are smoothing out the traditional volatility in the semiconductor demand curve.

From 1989 through 1994, we believe that Asia/Pacific and Europe will represent the fastest-growing regional markets for semiconductors. In the case of Asia/Pacific, this anticipated growth is due to the low initial revenue attributed to the region (including Japan) and fast-growing economies which still can absorb considerable electronic equipment production growth through domestic demand. In Europe, this fact is due mainly to the 1992 Effect, which is driving trends to produce semiconductors locally in Europe for consumption there and also driving trends toward standardization across Europe for such applications as cellular phone technology.

TABLE 6
Semiconductor Forecast Comparison
(Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$58.2	$57.9	(0.5%)
Current Forecast	$56.4	$56.0	(0.7%)
Percent Difference	(3.1%)	(3.3%)	

Source: Dataquest (July 1990)

TABLE 7
Semiconductor Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$17.7	$17.2	$33.5	13.6%
Western Europe	9.5	9.7	19.2	15.1%
Asia/Pacific	28.8	28.7	58.2	15.1%
Rest of World	0.4	0.4	0.7	11.8%
Worldwide	$56.4	$56.0	$111.6	14.6%

Source: Dataquest (April 1990)

SEMICONDUCTOR APPLICATION MARKETS

Major application segment trends that provide an impetus for semiconductor consumption growth include data processing and communications. Data processing's movement toward decentralized computing and concurrent processing will play a prominent role in consumption shifts. This movement toward desktop computing coupled with the use of smart peripherals will drive higher consumption of MOS function as well as analog devices. Such devices require dedicated controller or logic functions coupled with additional memory. Dataquest expects the consumption of MOS digital devices in data processing to show significant growth from 1989 through 1994. Dataquest forecasts data processing semiconductor consumption revenue to grow at a CAGR of 16.5 percent from 1989 through 1994.

In addition, Dataquest forecasts a 14.1 percent CAGR from 1989 through 1994 for semiconductor consumption revenue in the communications application segment. Brisk growth will be experienced due to expansion in premise telecom applications and a marked improvement in performance within the Japanese and Western European communications industries. Western Europe will experience benefits from standardization and the movement toward a pan-European market. Strong growth in the areas of cellular, networking, and facsimiles constitute key factors in the positive aggregate consumption trends.

Dataquest forecasts particularly high performance from Asia/Pacific-ROW for consumer electronics semiconductor consumption. As in the past, audio and video equipment will provide the base for the majority of consumer electronics semiconductor consumption. The expected high levels of consumption in this region can be attributed primarily to the substantial quantity of goods being manufactured for export.

Display Terminals

Table 8 shows Dataquest's actual and short-term projections for display terminals. The variance in the forecast is caused by our segment 1 (IBM System 3X and compatibles) experiencing a greater demand than previously anticipated.

IBM also is selling more AS/400 multiuser systems in the international market, which creates a strong international demand for twin-ax terminals.

Table 9 shows our current five-year forecast. The primary factors driving this forecast are the general-purpose text and processing terminal (PT) segments. Dataquest's recent report on the 3270 market shows that the PTs will be used increasingly to displace display terminals attached to IBM mainframes, thereby increasing computational power for multiuser systems.

We also expect the Western Europe and Rest of World (ROW) regions to outperform the world market due to the expansion of proprietary and UNIX-based multiuser systems to support the computing needs of a unified Europe.

Table 8
Display Terminal Forecast Comparison (Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$5.2	$5.1	(2.8%)
Current Forecast	$5.4	$5.3	(2.1%)
Percent Difference	3.6%	4.4%	

Source: Dataquest (July 1990)

Table 9
Display Terminal Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$2.3	$2.1	$2.3	(0.2%)
Western Europe	2.3	2.3	2.9	4.2%
Asia/Pacific	0.6	0.5	0.5	(4.0%)
Rest of World	0.2	0.3	0.9	32.6%
Worldwide	$5.4	$5.3	$6.5	3.8%

Source: Dataquest (July 1990)

The demand for IBM 3270-compatible display terminal products also is stronger in international markets, thereby fueling growth in this area.

Graphics and Image Processing

Imaging Subsystems

Table 10 shows our actual and short-term projections for image processing subsystems. The variance in the forecast is caused by the unexpected strong growth in medical ultrasound devices.

Table 11 shows our current five-year forecast. The primary factors driving this forecast are medical and machine-vision applications. Within these applications, the dominant factor in adoption of embedded subsystems for machine vision is the cost-effectiveness of the digital approach.

While the North American region continues to dominate the market, we expect the most growth to occur in Europe. Immediate opportunities can be expected from the raising of the Iron Curtain, but the greatest growth will be fueled by a unified Europe after 1992.

Table 10
Imaging Subsystems Forecast Comparison (Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$1.1	$1.0	(3.1%)
Current Forecast	$1.3	$1.4	0.2%
Percent Difference	25.8%	30.1%	

Source: Dataquest (July 1990)

TABLE 11
Imaging Subsystems Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$1.0	$0.9	$1.2	5.0%
Western Europe	0.2	0.2	0.4	12.4%
Asia/Pacific	0.1	0.1	0.1	0
Rest of World	0.1	0.1	0.1	(14.5%)
Worldwide	$1.3	$1.3	$1.8	5.5%

Source: Dataquest (July 1990)

TABLE 13
Graphic Terminal Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$0.6	$0.5	$0.6	1.7%
Europe	0.2	0.2	0.4	24.6%
Asia/Pacific	0.1	0.1	0.1	29.9%
Rest of World	0.1	0.1	0.1	13.6%
Worldwide	$0.8	$0.8	$1.3	9.7%

Source: Dataquest (July 1990)

Graphics Terminals

Table 12 shows 1989 revenue actuals and short-term projections for graphics terminals. We have updated our forecast based on increasing competition from PCs and workstations for a share of the desktop market.

Table 13 shows our current five-year forecast. The primary factors driving our forecast are the continuing demand for workstations, PCs, and X terminals.

A shift is taking place in the graphics terminal market away from the long-standing domination by the United States. The North American market will continue to grow, but at a slower rate compared with other geographical segments due in part to the large installed base. This occurrence will allow European markets to benefit from the heavy investments made by Western companies and the newly emerging Eastern European markets. The Asia/Pacific region is expected to grow the fastest in terms of percentage increases, but from a small base.

The influence of X Window System graphics terminals will have the strongest positive effect on total graphics terminal performance in the 1990 to 1994 timeframe.

TABLE 12
Graphic Terminal Forecast Comparison (Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$1.0	$0.9	(4.8%)
Current Forecast	$0.8	$0.8	0.4%
Percent Difference	(18.3%)	(13.8%)	

Source: Dataquest (July 1990)

ELECTRONIC PRINTERS

North American 1989 electronic printer market revenue grew less than Dataquest had anticipated a year ago. We believe that this slowed growth was because many users were integrating more of the capabilities of their existing systems rather than spending money on new equipment. This severely impacted the serial printer market, which accounted for nearly all of the forecast shortfall (see Table 14).

The electronic printer market has had major changes during the past two years, which will continue through the rest of the 1990s. The serial printer market is leveling off—demand for dot matrix printers is on the decline (they are being partially replaced by ink jet printers). Serial printers—which have dominated the market for years—are also being replaced by page printers. During 1990, Dataquest believes that worldwide page printer revenue will exceed that of serial printers for the first time.

For the next few years, the key growth areas are expected to be in the page printer (1 to 6 ppm) and in the ink jet segments, with CAGR in the 30 to 40 percent range. Also, many new and exciting advances in printer/printing technologies are anticipated for the 1990s, leading the user to higher

TABLE 14
North American Electronic Printer Forecast Comparison (Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$6.6	$7.2	9.4%
Current Forecast	$6.2	$7.2	15.7%
Percent Difference	(6.4%)	0	

Source: Dataquest (July 1990)

Table 15
Electronic Printer Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$6.2	$7.2	$8.7	7.0%
Western Europe	6.5	7.3	9.3	7.4%
Asia/Pacific	1.4	1.7	2.2	8.8%
Rest of World	0.7	0.8	1.2	10.4%
Worldwide	$14.8	$16.9	$21.3	7.5%

Source: Dataquest (July 1990)

expectations of printing quality and creating new markets for electronic printers. Dataquest's worldwide outlook through 1994 is shown in Table 15.

Document Image Management Systems

Table 16 shows our actual and short-term projections for document image management systems (DIMS). The variance in the forecast was due to the following two factors:

- In last year's database, we counted business and technical DIMS together, whereas 1989 actuals reflect only business DIMS units shipped.
- Low-volume DIMS shipments were lower than expected.

Table 17 shows our current five-year forecast for this market. The primary factors driving this forecast are as follows:

- Major computer vendors—The entry of all of the major computer systems vendors into this market means that they take it seriously as a way to sell hardware and preserve the customer base.

Table 16
Document Image Management Systems Forecast Comparison (Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$1.3	$1.6	24.0%
Current Forecast	$1.4	$1.8	26.0%
Percent Difference	10.0%	12.0%	

Source: Dataquest (July 1990)

Table 17
Document Image Management Systems Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$0.8	$1.0	$2.8	28.7%
Western Europe	0.3	0.4	0.9	22.9%
Asia/Pacific	0.2	0.3	0.4	18.3%
Rest of World	0.2	0.2	0.3	16.0%
Worldwide	$1.4	$1.8	$4.4	25.1%

Source: Dataquest (July 1990)

- Distributed computing—Networked computing is the newest computing wave; and distributed document imaging systems already are coming on strong.
- Cost-per-seat decline—The average DIMS cost per seat, although still high, is expected to decline.

Integrated Office Systems

Table 18 shows our current five-year forecast for integrated office systems (IOS). In 1989, the IOS market grew at its lowest rate, 10.7 percent, since its beginning in the early 1980s. Europe continued to bolster the overall market. IOS revenue is forecast to grow at a CAGR of 13.4 percent from 1990 through 1994. The manufacturer segment remains by far the largest IOS segment. Several factors indicate that this growth trend will continue over the next five years. These factors include the following:

- Within the manufacturer segment, the third-generation office systems form vendors will inject new vitality into shipments.

Table 18
Integrated Office Systems Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$0.8	$0.9	$1.3	10.3%
Western Europe	0.5	0.6	1.1	18.5%
Rest of World	0.1	0.1	0.1	4.8%
Worldwide	$1.4	$1.5	$2.5	13.4%

Source: Dataquest (July 1990)

- UNIX-based IOS should benefit from the continuing popularity of technical workstations, whose vendors are increasingly attempting to penetrate the commercial sectors of their markets.
- Currently the dark horse of the group, PC LAN-based IOS, which has the potential to benefit many more users than either of the other two segments at a price that is much more affordable, is poised to grow explosively.

ELECTRONIC PUBLISHING

Table 19 shows our actual and short-term projections for the electronic publishing market. The variance in the forecast is caused by the unexpected flattening of desktop publishing software unit shipments and a significant decrease in page printer prices.

Table 20 shows our current five-year forecast for PC- and workstation-based publishing. Many growth areas that help drive this forecast exist in the electronic publishing market. Some of these areas are as follows:

- Illustration and image editing software—Graphics software for creating illustrations from scratch and providing ready-to-use illustrative material have great sales potential, not only to new desktop publishers, but also to the installed base of DTP users. Image editing software for scanned images also is a growth area due to the increase in the use of desktop scanners.

TABLE 19
North American Electronic Publishing Forecast Comparison (Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$3.9	$5.1	31.0%
Current Forecast	$3.6	$4.8	34.0%
Percent Difference	(6.9%)	(4.8%)	

Source: Dataquest (July 1990)

TABLE 20
Workstation-Based Publishing Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$4.6	$5.9	$9.8	16.36%

Source: Dataquest (July 1990)

- Hardware opportunities—Laser printer prices are dropping rapidly, thus increasing the ratio of laser printers to CPUs. Scanners are becoming a more common desktop appliance. The high-resolution full-page monitor market also shows very significant growth.

CAD/CAM/CAE

Table 21 shows our actual and short-term projections for the CAD/CAM/CAE industry. The variance in the forecast is caused by stronger growth than expected in some application areas, as well as higher growth in key international markets.

Table 22 shows our current five-year forecast. The primary factors driving this forecast are as follows:

- A strong demand exists for all applications in established international markets. The year 1992 is having an impact on investments made in computer-aided design and manufacturing technology.
- Opportunities are emerging slowly in Eastern Europe and China.
- A reduction of CAD buys in traditional applications is occurring due to the shrinking US defense budget.

TABLE 21
CAD/CAM/CAE Forecast Comparison (Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$11.8	$13.2	10.6%
Current Forecast	$12.4	$14.3	13.3%
Percent Difference	5.0%	8.0%	

Source: Dataquest (July 1990)

TABLE 22
CAD/CAM/CAE Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$4.7	$5.1	$8.2	11.8%
Western Europe	4.3	5.1	8.0	13.2%
Asia/Pacific	3.1	3.7	5.9	13.8%
Rest of World	0.3	0.3	0.7	21.0%
Worldwide	$12.3	$14.3	$22.9	13.0%

Source: Dataquest (July 1990)

- The price/performance ratio of computers continues to improve, giving incentive to buy new hardware and improving the performance of major application software.
- Both vendors and end users are shifting from host-based systems to technical workstations.

PLAIN PAPER COPIERS

Revenue in the plain paper copier market comes from three main sources: sales to the end user, service revenue, and rental income, which represent about 35, 40, and 25 percent of the market, respectively. During 1989, unit sales to end users were unexpectedly flat, causing a 2 percent reduction in our revenue projections from a year ago (see Table 23 for total revenue comparisons). Service revenue in 1989 was 2 percent below our previous forecast, and rental income projections were right on target.

Dataquest anticipates continued growth in most segments of the US plain paper copier market; however, growth rates are expected to be less than in previous years. Many new opportunities exist, particularly in the midvolume segments. Dataquest anticipates that the midvolume segments of the copier market (which account for about one-half of total revenue) will experience healthy growth rates through the forecast period. Table 24 shows our 1990 to 1994 forecast.

We expect two major changes to take place in the copier market. The first is increased productivity. We expect copier manufacturers to continue their improvements in paper handling. We also anticipate that other new features will be added, which will allow the user to prepare a completed report or booklet in one step, thus minimizing the amount of time required at the copier.

The second area of change is more product differentiation. One approach will be improved product guarantees or warranties. Another method will be augmenting these warranties with more sophisticated diagnostic equipment. The diagnostic tools that we expect will be most useful are the ones that are transparent to the user, which will give the user the perception of improved service and reliability. The successful vendors will increase the productivity of their copiers and also will provide prompt, complete service of their products.

Table 23
United States Copier Forecast Comparison (Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$14.1	$14.6	3.9%
Current Forecast	$13.6	$14.2	4.1%
Percent Difference	(3.2%)	(3.0%)	

Source: Dataquest (July 1990)

Table 24
Plain Paper Copier Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
United States	$13.6	$14.2	$14.9	1.8%

Source: Dataquest (July 1990)

COMPUTER STORAGE DEVICES

During 1989, the market performed better than expected primarily because of increased demand for 3.5-inch rigid disk drives. Table 25 compares the final computer storage market results.

Dataquest's forecast for worldwide computer storage factory revenue calls for 9.7 percent growth during 1990. Table 26 shows our forecast through 1994.

Table 25
Computer Storage Forecast Comparison (Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$17.4	$18.7	8.1%
Current Forecast	$17.6	$19.3	9.7%
Percent Difference	1.3%	3.2%	

Source: Dataquest (July 1990)

Table 26
Computer Storage Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$9.8	$10.6	$11.4	3.1%
Western Europe	4.3	4.6	5.4	4.8%
Asia/Pacific	2.2	2.5	2.8	5.4%
Rest of World	1.3	1.7	2.6	15.1%
Worldwide	$17.6	$19.3	$22.3	5.0%

Source: Dataquest (July 1990)

The 3.5-inch rigid disk drive is now king. It will be the largest contributor to computer storage revenue this year with 20 percent of the worldwide market. By 1994, Dataquest expects the 3.5-inch drive market to make up nearly 50 percent of the total computer storage market's revenue. But watch out for the sub-3.5-inch rigid drives. The 1.8- and 2.5-inch drives are bursting onto the scene much more quickly than we anticipated a year ago. The current market they are addressing, notebook computers, are just starting up the demand curve. If that market—and others that demand smaller-diameter disk drives—take off by more than 50 percent per year, our current 3.5-inch rigid drive forecast could be too high.

Storage densities are increasing, as are the cost/performance ratios of products that incorporate new/advanced storage devices. The demand for more and better storage capabilities/capacities will continue to increase, which sets the stage for a dynamic computer storage market in the 1990s.

Note: This newsletter was compiled from material supplied by the following Dataquest groups: Applications Information Group, Central Research Group, Components Group, Information Systems Group, and the Peripherals Group.

Ken Newbury

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Research Newsletter

THE BUSINESS CYCLE: A THING OF THE PAST?

SUMMARY

Dataquest expects the US economy to grow at a compound average growth rate (CAGR) of 3 percent per year from 1990 through 1992. No recession is expected. This newsletter identifies and discusses some of the structural changes to the economy and other variables that contribute to this "no recession" outlook. Although the business cycle has not been eliminated, there is good reason to believe that, at least in the short term, the likelihood of recession—and its accompanying severity—has lessened. The economy's smooth expansion path minimizes the level of macroeconomic "background noise" or uncertainty and thus provides high-technology companies with a relatively hospitable environment to sharpen their company-specific competitive skills.

INTRODUCTION

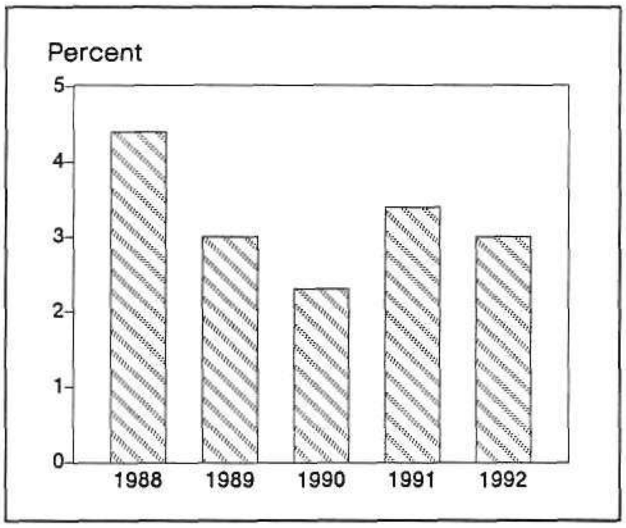
The US economy has been expanding for over seven years. Although it is still shy of the 106-month expansion of 1961 to 1969 during the Vietnam war, it is nonetheless *the longest peacetime expansion on record.* Indeed, excluding the Vietnam-war period, the average duration of the past six US economic expansions has been only 35 months before the economy began to contract. Pessimists fear that the next recession also will be longer and deeper; optimists argue that the business cycle is a thing of the past.

If the latest economic forecast by The Dun & Bradstreet Corporation (Dataquest's corporate parent) turns out to be correct, then the current US expansion has some way to go: D&B forecasts real US GNP growth to average 3.0 percent per year through 1992. As shown in Figure 1, real growth is expected to decelerate to 2.3 percent in 1990, down from 3.0 percent in 1989; to accelerate to 3.4 percent in 1991; and to stabilize at 3.0 percent in 1992. (Except for 0.2 percentage point reduction in 1990 growth, and the addition of the 1992 data point, this forecast is the same as published in last quarter's newsletter entitled *Economic Outlook: In Like a Lamb, Out Like a Lion.* Nothing about the outlook has changed sufficiently to justify further revision at this time.)

But just because the economy avoids outright recession (defined as two or more quarters of negative real growth), it does not mean that the concept of the business cycle is dead. These days, however, a downturn does not have to be a full-blown recession with a contraction in the *level of output;* it might instead take the form of a period of deceleration in the rate of output *growth.*

It turns out that the post-World War II period exhibits milder business fluctuations than the pre-World War II period. Figures 2, 3, and 4 show the

FIGURE 1
US Real GNP Growth
Annual Percent Change



Source: US Department of Commerce, The Dun & Bradstreet Corporation

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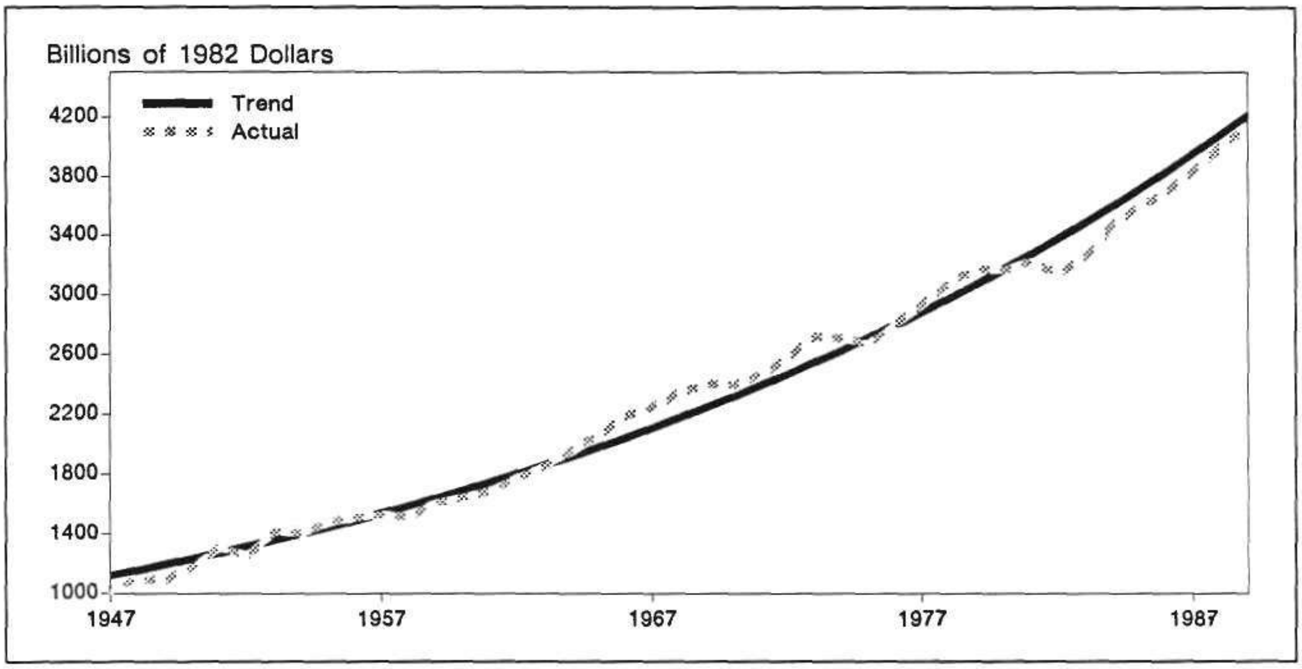
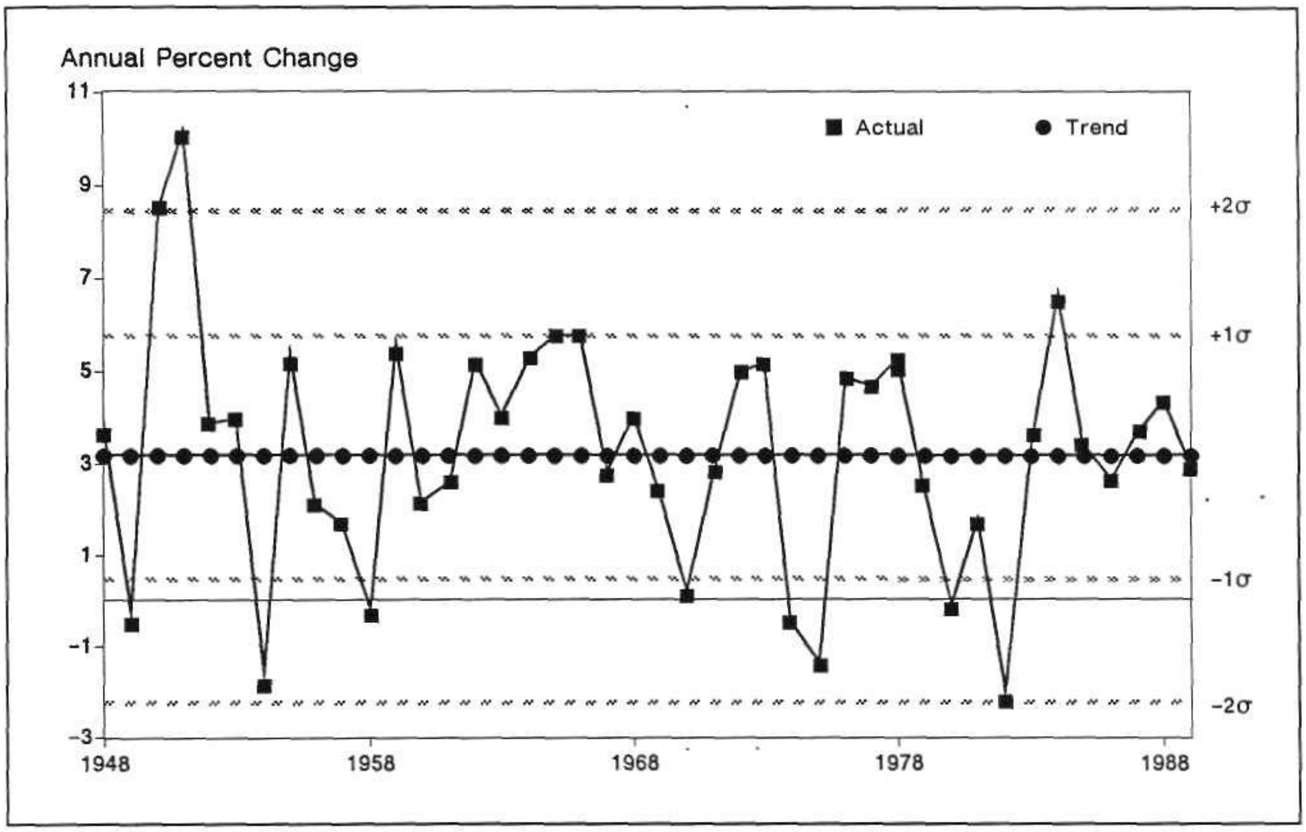
FIGURE 2
US Real Gross National Product



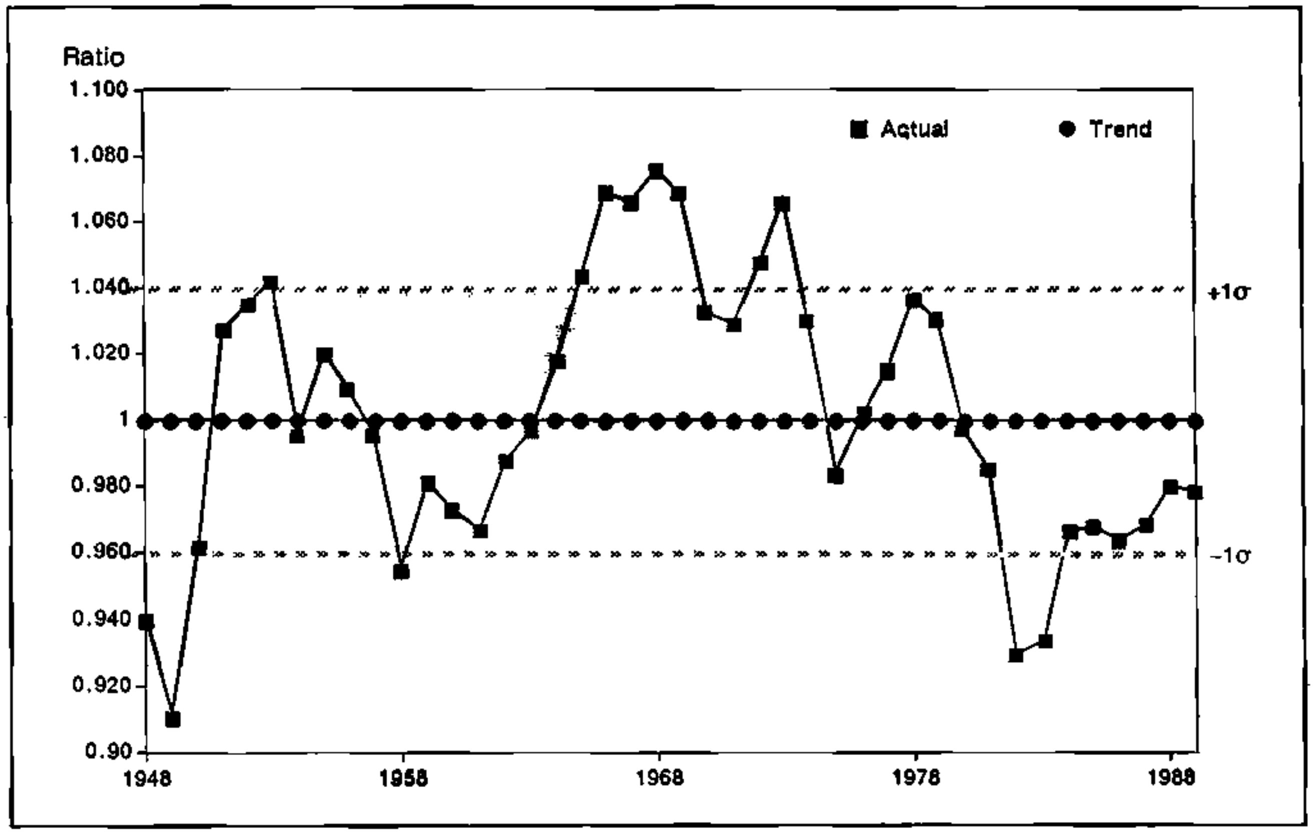
Source: US Department of Commerce, Dataquest (July 1990)

FIGURE 3
US Real Gross National Product—Annual Percent Change



Source: US Department of Commerce, Dataquest (July 1990)

FIGURE 4
US Real Gross National Product—Ratio of Actual to Trend



Source: US Department of Commerce, Dataquest (July 1990)

actual and trend growth paths of US real GNP; the actual and trend *growth rates*, including the ±1, ±2 standard-deviation bands; and the ratio of the actual level of real GNP to its trend level, including the ±1 standard-deviation bands, respectively, through 1989. Current research suggests that the *length* or period of the business cycle has not changed, but that expansions have become longer, contractions shorter, and the amplitude dampened.

THE ECONOMY'S EVOLUTION TOWARD INCREASED STABILITY

Economists and others have come up with numerous and sometimes humorous theories to explain business fluctuations. They range from the mundane (e.g., the interaction of consumption and investment) to the insane (e.g., the sunspot cycle) to the prevailing (i.e., incomplete information regarding money-supply growth, and supply- and demand-side shocks to the economy). Does the dampening of business fluctuations have something to do with the depletion of the ozone layer, harmonic convergence, and the clear-cutting of old-growth stands of redwood trees? Perhaps, but Dataquest looks at some of the more likely reasons that economic activity is now less volatile.

The Shift in Output to Services

The demand for most services is significantly less sensitive to changes in output than the demand for consumer durables and investment goods. The reason is partly because services, unlike goods, cannot be stored as easily. Also, most services are less capital-intensive, and business' capital spending on marginal investment projects tend to be the first item cut when the outlook changes for the worse. As shown in Figure 5, US services' (broadly defined as wholesale and retail trade; fire, insurance, and real estate; and other services) share of output has jumped from 36.1 percent in 1947 to 47.9 percent in 1987. Services' share of total employment has similarly increased. Interestingly, and contrary to popular belief, manufacturing's share of output actually has increased 0.8 percentage points during the past 40 years, from 21.2 percent in 1947 to 22.0 percent in 1987. During the same interval, the primary (i.e., agriculture, forestry, and fisheries; mining; and construction) sector's share of output has declined 8.5 percentage points, from 18.7 percent in 1947 to 10.2 percent in 1987.

Increased Government Spending

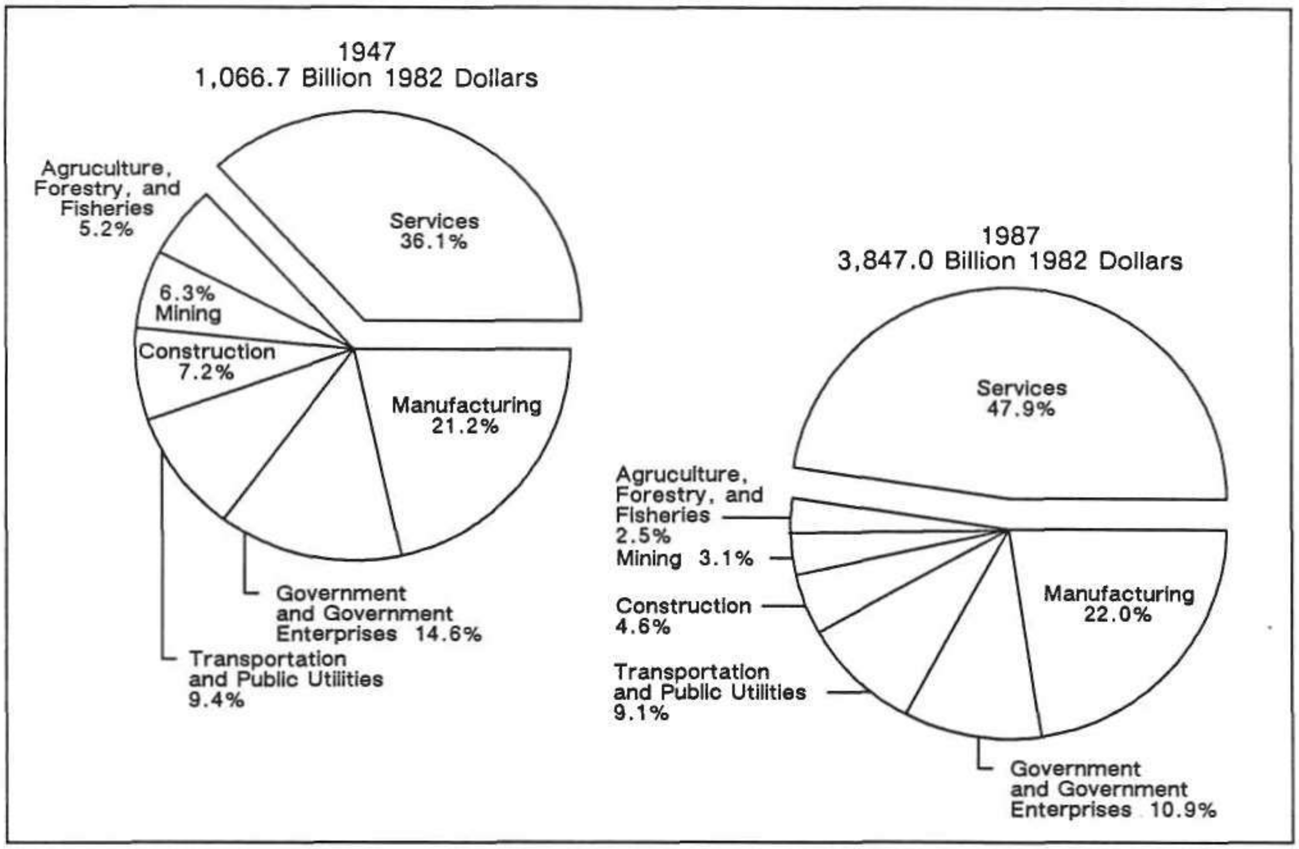
Figure 6 shows that federal, state, and local government spending on goods and services as a share of total domestic expenditure on goods and services has increased from 13.4 percent in 1929 to 17.6 percent in 1947 and to 19.2 percent in 1989. The surge in government spending has had a dampening effect because the public sector does not shrink during contractions. (In fact, the ratio of government expenditure to total expenditure tends to be countercyclical with respect to the business cycle.) "Automatic stabilizers" also have played a bigger role. Taxes automatically shrink and unemployment benefits rise as the economy goes into recession, which helps buoy household income.

Incidentally, if we compare the increasing trend in government spending with the decreasing trend in government's share of total output (see Figure 5), does this confirm our suspicions that *the US taxpayer is paying more and getting less?*

Improved Inventory Control

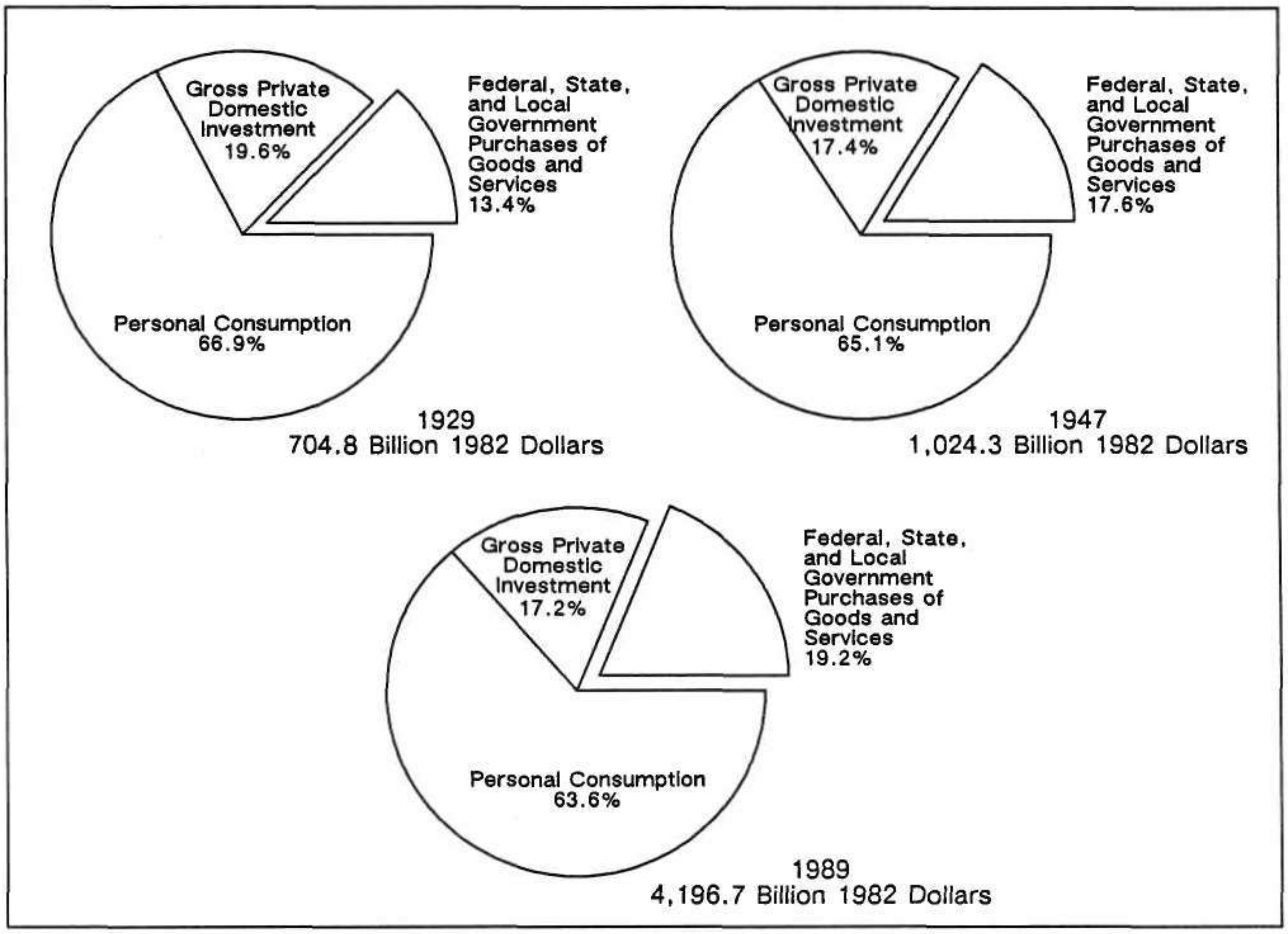
Computers and point-of-sale terminals now give manufacturers and retailers real-time information, allowing them to match production more closely to orders and therefore avoid an undesired accumulation of inventory. In the past, undesired inventory would accumulate rapidly as demand slowed unexpectedly, forcing companies to close factories and lay off employees, thus working actual inventories down to desired levels. Such inventory management often turned a relatively innocuous soft landing into a dramatic recession. For example, the decline in business inventories in

Figure 5
US Real GNP by Industry



Source: US Department of Commerce

FIGURE 6
US Expenditure, Goods and Services



Source: US Department of Commerce

1982 accounted for 41.0 percent of the decrease in total US domestic purchases, while personal consumption expenditure continued to expand at a 1.3 percent rate.

Financial Reform and Innovation

Some of the worst prewar recessions were exacerbated by financial collapses and consequent shrinkages in the money supply. Today, prompt intervention and cooperation by central banks can (sometimes) avert such panics. For example, the collapse of the New York Stock Exchange in October 1987 barely sent a discernible ripple through the real economy.

MORE FACTORS PROLONGING THE EXPANSION

These four changes in the economy's structure are likely to continue to dampen the business cycle in the future, warding off a "coming crash" that some members of the financial press are prognosticating. But other variables, which could yet be reversed, also have contributed to the prolongation of the current expansion.

Lower Inflation

Previous expansions typically were extinguished by accelerating inflation, which forced the Federal Reserve Bank (Fed) to cut money-supply growth. The unexpected change in monetary policy caught producers, consumers, lenders, and borrowers by surprise, with the result that the economy slipped into recession. That is why eternal vigilance on inflation is the best way to prolong expansion.

In Washington, D.C., for instance, the White House is leaning on the Fed to ease up on its fight against inflation by relaxing money-supply growth. Moreover, the Fed is concerned about the extent of corporate debt, the savings and loan collapse, and the (supposed) fragility of the domestic financial system. The result is a reluctance to restrain money growth and raise short-term interest rates. Gradual acceleration in the inflation rate, with the customary crunch to follow, is not wholly implausible, although it is improbable at this time.

Soft Oil Prices

The collapse in world oil prices in 1986 could not have been better timed: It helped give a much-needed boost to growth just as the US and Japanese economies had begun to slow. Doomsayers still fret about a renewed surge in oil and other commodity prices. Indeed, with the recent escalation of Middle East tensions, such a scenario, while perhaps improbable, is, again, by no means implausible.

Asynchronous Economies

Perhaps the most important reason why a worldwide recession can be avoided in the near term is that the United States', Japan's, and West Germany's economies currently are less synchronized with one another than during the past 20 years. In the 1970s, these countries' business cycles were closely aligned; they expanded and contracted in unison. Today, the lack of synchronization is reflected in the relatively large external imbalances between these big three economies. During the expansion of the 1980s, the United States was the world economy's engine, driving Japan's and West Germany's export-led growth. Today, domestic demand is sluggish in the United States and the United Kingdom, but it remains buoyant in Japan and West Germany. Indeed, West Germany's—and the rest of the developed world's—expected investment in East Germany could enhance the current worldwide expansion beyond the bounds that otherwise would be realized in the absence of Germany's reunification.

The rising trend in foreign demand for American exports should help forestall a recession in the United States. At the same time, the shrinking trade surpluses of Japan and West Germany as they meet more of the rise in domestic demand with imports should help keep US inflation at bay.

It's Not Party Time Yet

It's not time to roll out the barrel just yet; clear heads are still needed. Although some important characteristics of the business cycle appear to have changed for the better recently, it would be erroneous to conclude that the business cycle is a thing of the past. However, based on the evidence presented, it is fair to conclude that the world has entered a period in which the *probability* of a recession in the near term, and its attendant severity, has diminished.

Perhaps the biggest risk to the expansion (and the most difficult to quantify) is an unexpected external shock—a sudden trade war, an unexpected and growth-diminishing change in fiscal policy, oil price rise, debt default, some far-reaching political event, a natural disaster in a major international trade center, etc. Prior to the trebling and doubling of world oil prices in 1973 and 1979, respectively, most forecasters looked forward to continued uninterrupted growth. However, what really happened was that the US economy proceeded to slide into two of its severest and protracted recessions of the postwar period.

Implications for High-Technology

In view of the fact that the macroeconomic forecast remains unchanged from the previous quarter—and furthermore, does not call for a recession through 1992—the implications of the outlook for high-technology business also remain unchanged. In fact, the implications, listed as follows, bear repeating from last quarter's *Economic Outlook*:

- In the current and expected near-term future economic environment, Dataquest maintains that company- and/or industry-specific variables such as technology and factor-input prices will play a more important role in influencing high-technology company performance than economic aggregates such as national income, employment, inflation, and interest rates.
- This should not be interpreted to mean that company and industry performance is completely invariant with respect to overall economic activity. High-tech business is a capital-intensive business in the business of selling capital goods. Obviously, there is a direct relationship between aggregate investment spending and high-tech business conditions. The short-run relationship between the aggregate economy and high-tech company and industry performance is, however, relatively "loose" and more variable when compared with other industries. In the long run, these aggregate variables—and others such as the quality of the labor force, fiscal policy, regulatory environment, and tax incentives (or disincentives)—contribute greatly to a high-tech company's or industry's international competitiveness.

- The economy's relatively smooth near-term expansion path should minimize the background noise or uncertainty usually associated with doing business.

Dataquest is the last to deny that competing in the electronics business these days is easy. We admit that the going is tough, either because of a heightened level of *honest* international competition, or a (sometimes correctly) perceived presence of unfair trade practices. But it is a new era and this is the way the world *is*. In this context, subjective value judgments about how the world *ought to be*, are irrelevant.

Executives and managers face a myriad of variables that influence their company's performance, ranging from those that management controls directly to those that must be taken as given. Trying to change things that are beyond a company's control is misguided management and wastes effort and resources.

Dataquest advises its clients to take this opportunity during the lull between the inevitable macroeconomic storms to be diligent in sharpening their competitive edge. Companies need (sic, must) focus on the specific variables *they control*, which will contribute most to future competitiveness, profitability, and growth. As tough as it is to compete these days, it is easier to run a business in an expanding economy than in one that is declining.

Terrance A. Birkholz

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Research Newsletter

DATAQUEST'S 1989 ELECTRONICS INDUSTRY MARKET SHARES

INTRODUCTION

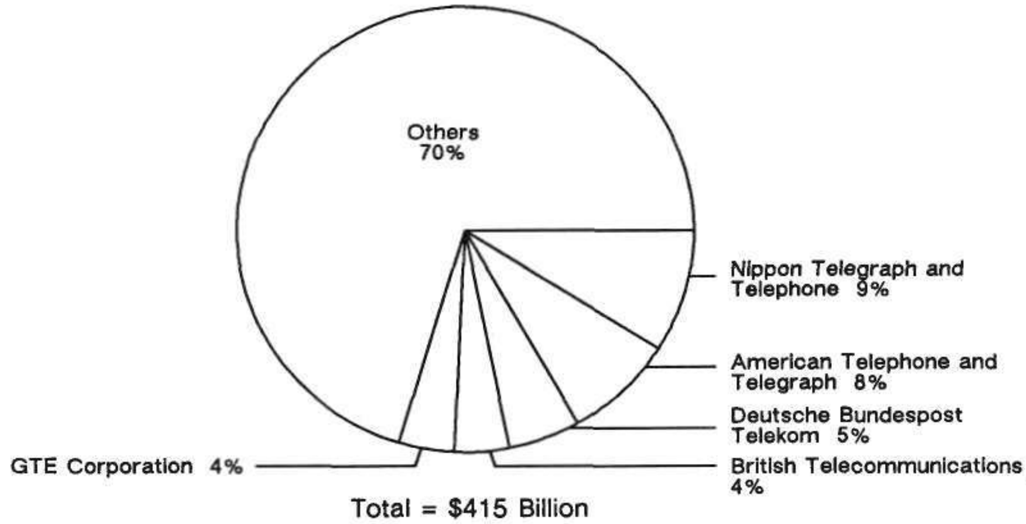
Every year, Dataquest surveys both vendors and users in most major high-technology industries to collect market share and market-sizing data. This newsletter presents a summary of the 1989 market share results and is designed to provide an overview of the major players and major events of 1989 in the high-technology markets of telecommunications, business and technical computer systems, personal computer systems, semiconductors, display terminals, graphics and imaging systems, electronic printers, document image management systems, integrated office systems, electronic publishing, CAD/CAM/CAE, plain paper copiers, and computer storage devices.

Unless otherwise noted, all data are given in terms of factory revenue.

TELECOMMUNICATIONS

The revenue market shares shown in Figure 1 reflect the total telecommunications market, including network services and equipment sales. As is typical in this industry, the vast majority (over 85 percent) of revenue is attributed to network services such as local, long distance, and international telephone calls. Because of this revenue imbalance, the market share leaders shown below are representative of network providers—postal, telegraph, and telephone organizations (PTTs) and regional Bell operating companies (RBOCs)—and not equipment manufacturers. As a point of comparison, the top five equipment providers, in alphabetical order, (Alcatel, AT&T, NEC, Northern Telecom, and Siemens) have a combined

FIGURE 1
Telecommunications
Estimated 1989 Worldwide Revenue Market Shares
(Billions of Dollars)



Source: Dataquest (June 1990)

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equipment-related revenue of slightly over $36 billion—which is almost exactly the total telecommunications-related revenue of NTT, the number-one telecommunications supplier.

The staggering size of the telecommunications market, combined with the necessity of communications standards and network compatibility, highlights the international character of this industry, which, therefore, demands a global perspective. (Of the 5 companies shown in Figure 1, 4 countries are represented as worldwide market share leaders.) Expanding the list to the top 10, the RBOCs start appearing along with Alcatel and Bell Canada Enterprises (includes Northern Telecom). Then, 6 different countries are represented in the top 10 market leaders.

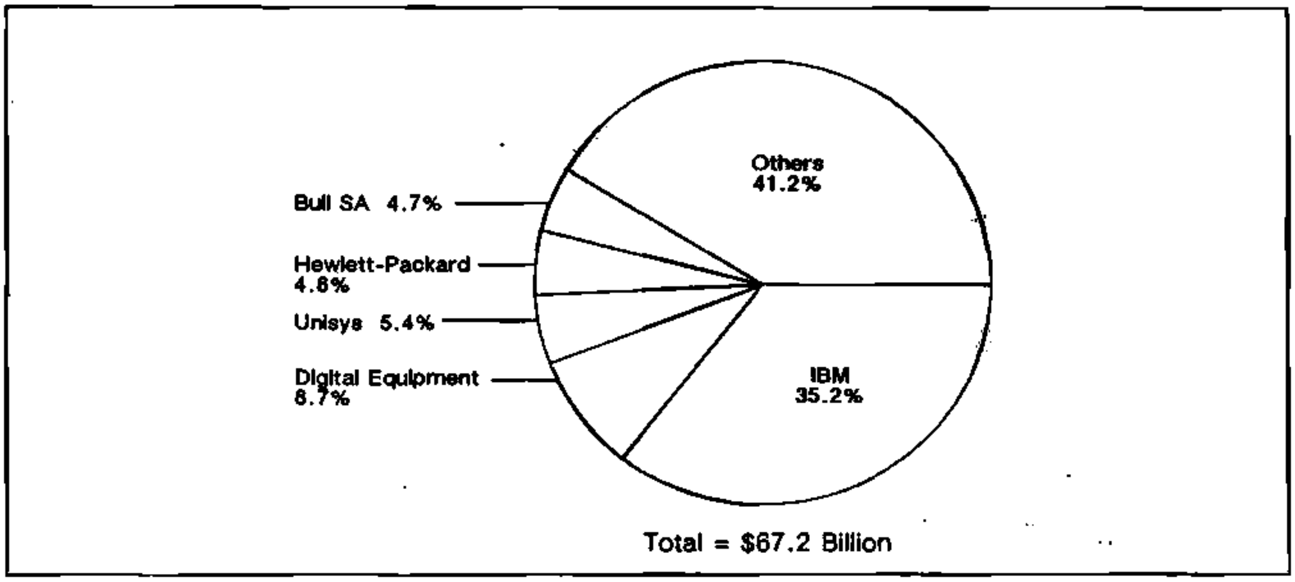
The 1990s portend to be an exciting time for the telecommunications industry. The continuing globalization of the industry, utilization of communications standards such as ISDN, ongoing mergers and acquisitions, and the opening of the Eastern bloc nations set the stage for a tumultuous business environment for the next several years.

BUSINESS AND TECHNICAL COMPUTER SYSTEMS

The business and technical computer systems industry showed only moderate growth in 1989. Totalling $67.2 billion (excluding personal computers) in worldwide factory revenue, the market grew only 9 percent over 1988. The only segment of the market showing any real spark was the workstation segment. There was significant growth in this segment, not only on the technical side, but also on the commercial side of the market where workstations made a strong debut. The mainframe and midrange (superminicomputers, minicomputers, and microcomputers) segments of the market have stagnated. The supercomputer segment showed a small amount of growth but remains a relatively small niche.

Figure 2 shows the total market and the market shares of the top vendors in 1989. Remaining in the lead with a market share of 35.2 percent, IBM continues to grow at a very moderate rate. IBM's saving grace in 1989 was the AS/400. In 1989, this product line completed its first full calendar year of general availability. Even though shipments of these superminicomputers systems fell short of many independent predictions, the AS/400 accounted for the bulk of revenue growth in the commercial side of the market last year. Digital Equipment holds on to second place in the market, with 8.7 percent share of the market. As a major vendor of minicomputers, Digital has seen its fortunes fall with the declining popularity of the traditional minicomputer. Digital has been able to recoup some lost ground through its workstation line.

FIGURE 2
Business And Technical Computer Systems
Estimated 1989 Worldwide Revenue Market Shares
(Billions of Dollars)



Source: Dataquest (June 1990)

Unisys placed third in the market in 1989, with 5.4 percent of the market. Though not a particularly good year overall for Unisys, the company did make gains in the mainframe segment with the 2200 line. Hewlett-Packard ranks at number four in 1989, with a market share of 4.8 percent. Hewlett-Packard was able to augment its market share slightly this year with the purchase of workstation vendor Apollo.

Coming in at fifth place is France's Bull S.A. With a market share of 4.7 percent, Bull (including Bull HN) came in right on the heels of Hewlett-Packard. Bull struggled in the first half of 1989, but was able to regain momentum in the second half, even against increased non-Europe-based competition.

Other vendors that are likely to make headway into the top vendors' domain over the next several years are Fujitsu, Hitachi, NEC, Siemens (with Nixdorf), and Sun Microsystems, all with market shares in the 4.3 to 2.5 percent range in 1989.

PERSONAL COMPUTER SYSTEMS

Hardware

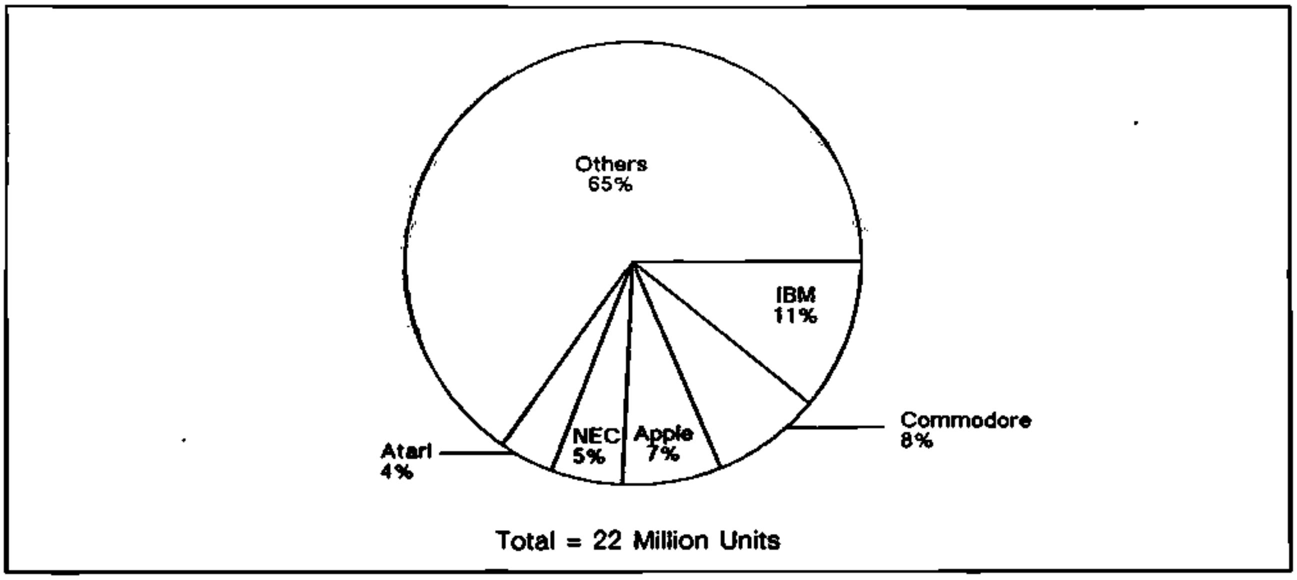
The year 1989 was a year of little relative change in the personal computer industry; previous industry leaders held their positions, and second-tier vendors continued to compete ferociously in all distribution channels. This state of affairs was maintained through the implementation of advanced technologies.

Computers that use Extended Industry Standard Architecture (EISA) finally appeared in 1989. So far, EISA has been implemented only on high-end 80386 and 80486 systems.

Despite facing an onslaught from PC-compatible makers, IBM is still at the top of the heap in terms of units shipped and revenue. IBM's share of compatible shipments is double that of its nearest competitors, NEC and Compaq.

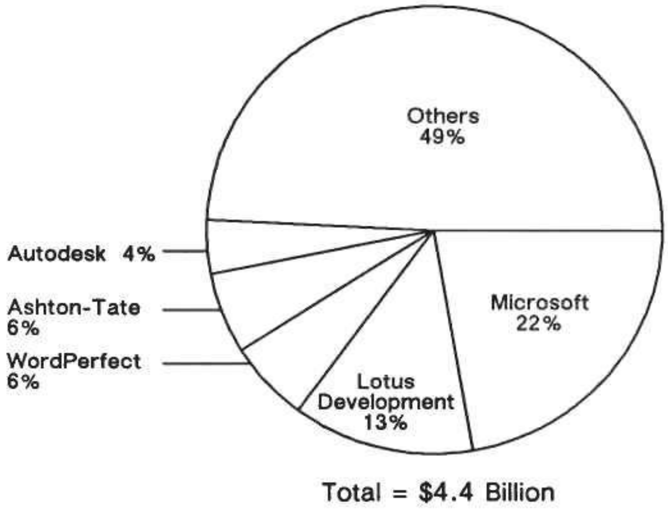
Commodore and Apple remain in second and third place, respectively, and the top five personal computer vendors hold 35 percent of the overall unit marketplace (see Figure 3). While NEC's aggressive marketing, strong channel push, and fleshed-out product line helped to give it 5 percent of the total market, the fact that the company sells a special Japanese-language machine only to Japanese customers dramatically skews its market share. Other major competitors in the top 10 unit PC suppliers are Compaq, Epson, Olivetti, Tandy, and Toshiba.

Figure 3
Personal Computers
Estimated 1989 Worldwide Unit Market Shares
(Millions of Units)



Source: Dataquest (June 1990)

FIGURE 4
Personal Computer Software
Estimated 1989 Worldwide Revenue Market Shares
(Billions of Dollars)



Source: Dataquest (June 1990)

Software

The year 1989 was a mixed year for PC software vendors. The top five vendors continue to control the lion's share of the market, with 51 percent of the personal computer software market. The leading personal computer software markets—spreadsheets, word processing, and database management systems—continue to be dominated by single vendors: Lotus, WordPerfect, and Ashton-Tate. Competition is heating up in each of these markets, as competitors introduce successful products such as Borland's Quattro Pro and Paradox and Microsoft's Word for Windows.

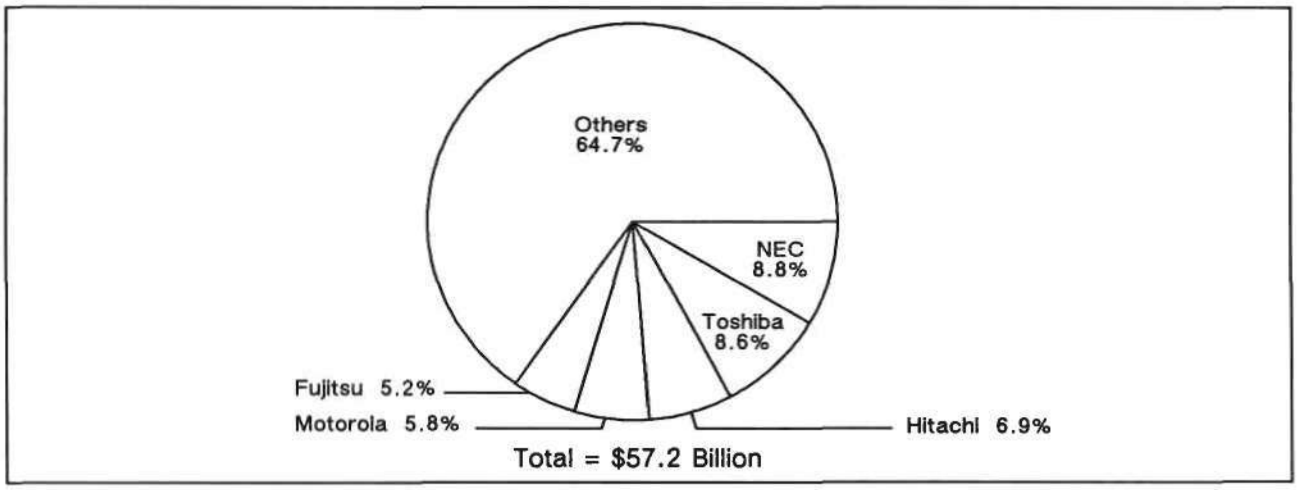
The top five vendors remain the same as in 1988. Ashton-Tate dropped from number three in 1988 to number four in 1989 (see Figure 4). Ashton-Tate's decline in revenue was largely due to its unsuccessful introduction of dBase IV. These dBase products accounted for an estimated 74 percent of Ashton-Tate's revenue in 1989. Microsoft continues to dominate the market with 22 percent market share. As in the past, Microsoft will maintain its lead position with its broad range of successful products. WordPerfect, with its flagship product, WordPerfect, stayed firmly on top. The company continued to hold a substantial lead in the word processing market.

SEMICONDUCTORS

The worldwide semiconductor market revenue grew 12 percent in 1989, slowing from a 33 percent growth rate the previous year. Significant events of 1989 in the industry include the following:

- Japanese companies continued to gain share of the worldwide semiconductor market and now hold 52 percent of it, up from 51 percent in 1988.
- Asia/Pacific (excluding Japan) companies' market share grew to 3.5 percent.
- Japanese companies' share of the North American chip market grew to 26 percent, while North American companies' share of the Japanese chip market remained constant at 9 percent.
- NEC remains the number-one semiconductor supplier in the world, followed by Toshiba, Hitachi, Motorola, and Fujitsu.
- MOS memory was clearly the market leader, growing 40 percent.
- Companies that are strong in MOS memory continued to dominate the market because of their heavy reliance on MOS memory sales.

FIGURE 5
Semiconductors
Estimated 1989 Worldwide Revenue Market Shares
(Billions of Dollars)



Source: Dataquest (June 1990)

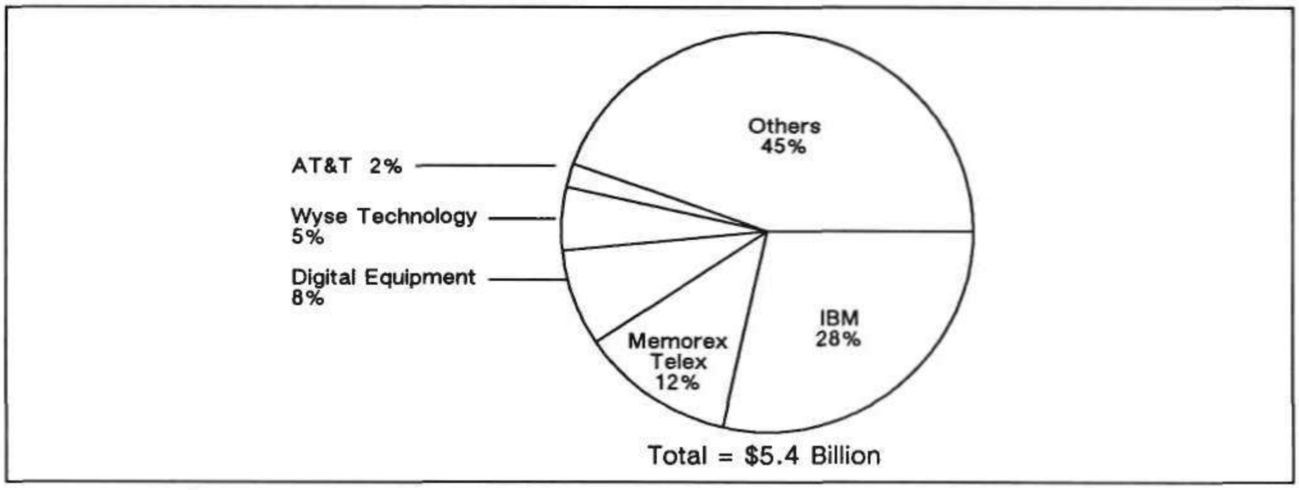
Figure 5 shows the top five semiconductor vendors' shares of the worldwide semiconductor market. Companies that participate in the volatile DRAM market continue to gain market share over the long term, although severe market downturns and questionable profitability of this market in the past caused many US firms to leave it.

Our data also clearly show that the US semiconductor industry's goal of achieving 20 percent market share in Japan is far from realization. However, in light of the plans that many Japanese purchasers have announced to increase their purchases of foreign semiconductors, this 1991 goal might conceivably be reached.

DISPLAY TERMINALS

The display terminal market decreased slightly during 1989, by 0.6 percent, compared with 1988 revenue. Figure 6 shows worldwide

FIGURE 6
Display Terminals
Estimated 1989 Worldwide Revenue Market Shares
North America-Based Vendors
(Billions of Dollars)



Source: Dataquest (June 1990)

display terminal market shares for the top North America-based vendors. IBM led with 28 percent of the market. Memorex Telex, Digital Equipment, Wyse Technology, and AT&T also turned in good performances.

During 1989, there were declines in the minicomputer, protocol-specific, and IBM 3270 segments of the display terminal market. The IBM 5250 market remained strong because of the continued addition of terminals to AS/400 installations.

The ASCII terminal market grew about 9 percent over 1988. Wyse is the market leader in this segment. Ampex exited the market and C. Itoh repositioned itself as an OEM manufacturer.

In the processing terminal market, revenue grew by 38 percent during 1989. Dataquest believes that the primary growth areas remain in the ASCII and processing terminal segments of the display terminal market.

GRAPHICS AND IMAGING SYSTEMS

Graphics Terminals

Figure 7 shows the 1989 worldwide revenue of $795 million and the top five vendors in the graphics terminal market.

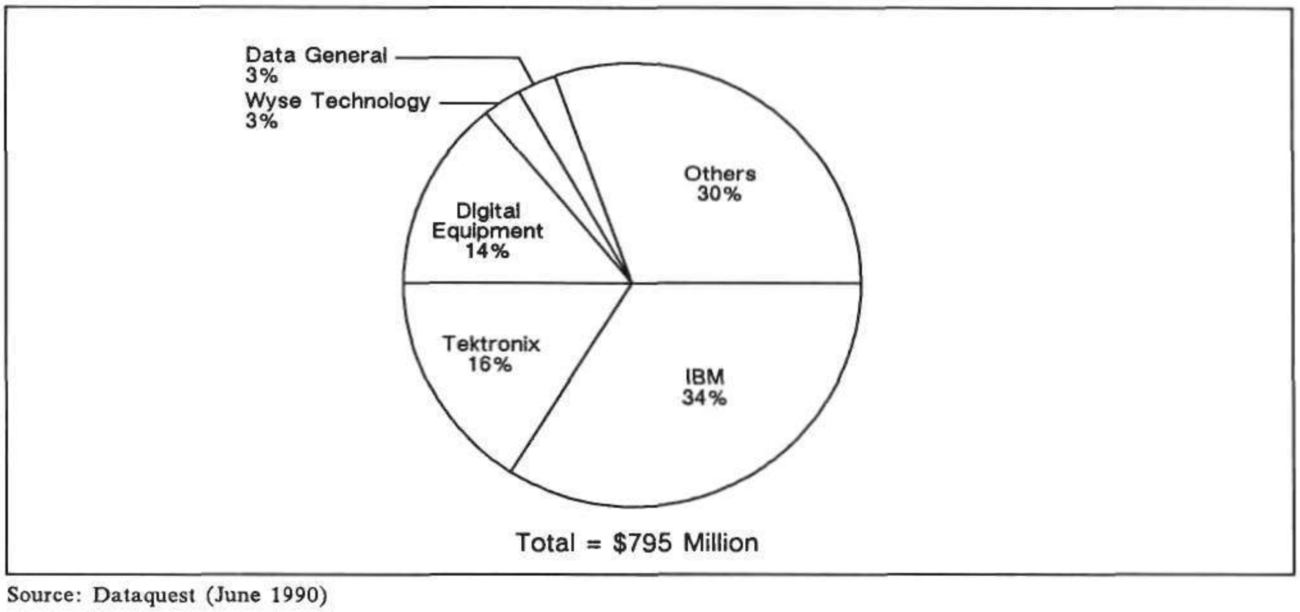
IBM's introduction of the 6090, a 5080 replacement, during 1989 helped it to maintain market share. Most other companies had lower revenue because of increased competition from personal computers and workstations. Dataquest expects the real growth opportunities for graphics terminals to be in the X Window protocol segment.

Imaging Subsystems

The 1989 worldwide revenue for the image-processing subsystems was $1.34 billion, a revenue increase of 26 percent compared with 1988. Figure 8 shows the top five vendors in the image-processing subsystems market.

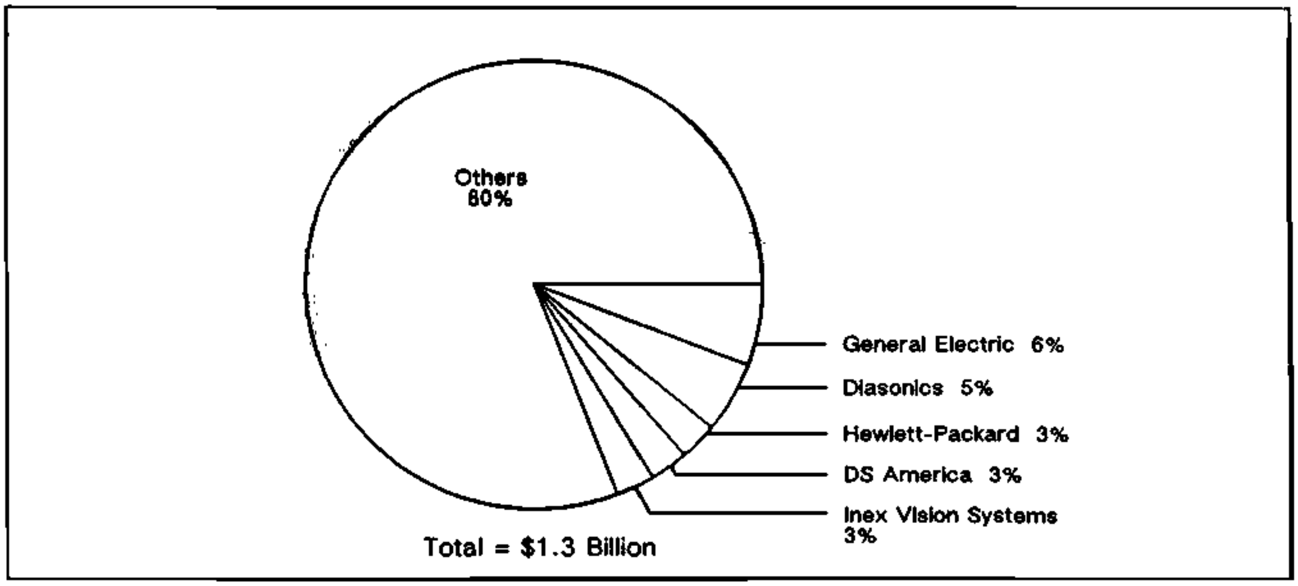
The top three vendors are all in the medical-imaging application segment, which grew by 50 percent during 1989. Revenue in the machine vision application increased 24 percent compared with 1988—Inex Vision Systems is the leading vendor in this segment. Electronic prepress application revenue grew by 16 percent last year—DS America is the market leader in this segment of the imaging subsystems market.

FIGURE 7
Graphics Terminals
Estimated 1989 Worldwide Revenue Market Shares
(Millions of Dollars)



Source: Dataquest (June 1990)

FIGURE 8
Imaging Subsystems
Estimated 1989 Worldwide Revenue Market Shares
North American-Based Vendors
(Billions of Dollars)



Source: Dataquest (June 1990)

ELECTRONIC PRINTERS

Worldwide electronic printer factory revenue grew to $14.8 billion in 1989, up 13 percent over 1988. The year 1989 was a good year, but a year of many changes. Worldwide serial and line printer revenues were essentially flat, while the page printer market grew by nearly 38 percent. The soft market for personal computers in North America during the last half of 1989 resulted in only 3 percent growth in the North American printer market. The Western European electronic printer market grew by an estimated 25 percent—continuing its 20 to 30 percent growth pattern.

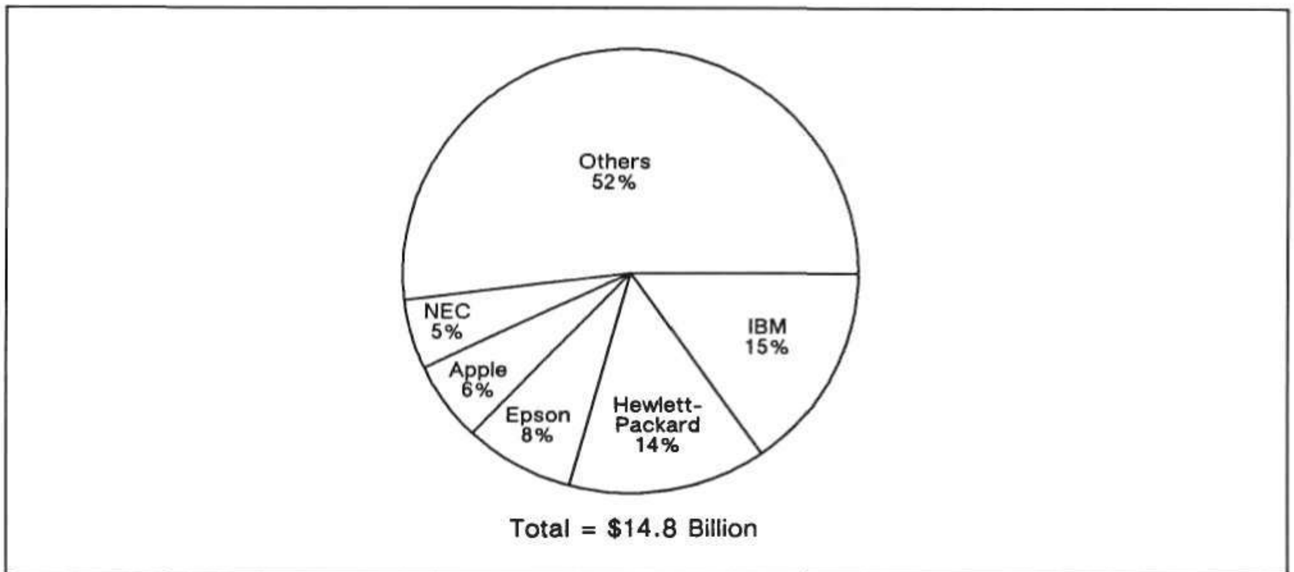
The introduction and acceptance of many 4-ppm to 6-ppm printers during 1989 added to the many changes taking place in the printer market. The availability of faster processors, more on-board memory, and improved software have all contributed to the advances in the printer/printing technology. Printing quality is improving and printing speeds are increasing. It is now easy to reprint pages that were too time-consuming and/or too costly to reprint with previous technologies.

The user is moving to a higher level of quality expectations. Dataquest expects these trends to continue and many new and exciting advances in printing technology and user acceptance to occur during the 1990s.

Figure 9 shows the major vendors of electronic printers. North American companies have about 50 percent of the worldwide market; Japanese and Western European companies have approximately 40 percent and 10 percent market shares, respectively.

The top five vendors have about 50 percent of the worldwide market. Individual company market shares drop off rapidly below the 5 percent range. There are 10 companies with a 2 to 4 percent market share and over 40 companies in the 1 percent and under range.

FIGURE 9
Electronic Printers
Estimated 1989 Worldwide Revenue Market Shares
(Billions of Dollars)



Source: Dataquest (June 1990)

DOCUMENT IMAGE MANAGEMENT SYSTEMS

The document image management systems (DIMS) market experienced very steady and healthy growth in 1989. Traditionally a market dominated by systems integrators and turnkey image systems vendors, the balance of power shifted as the major computer systems vendors entered the market. Figure 10 depicts the major vendors selling DIMS.

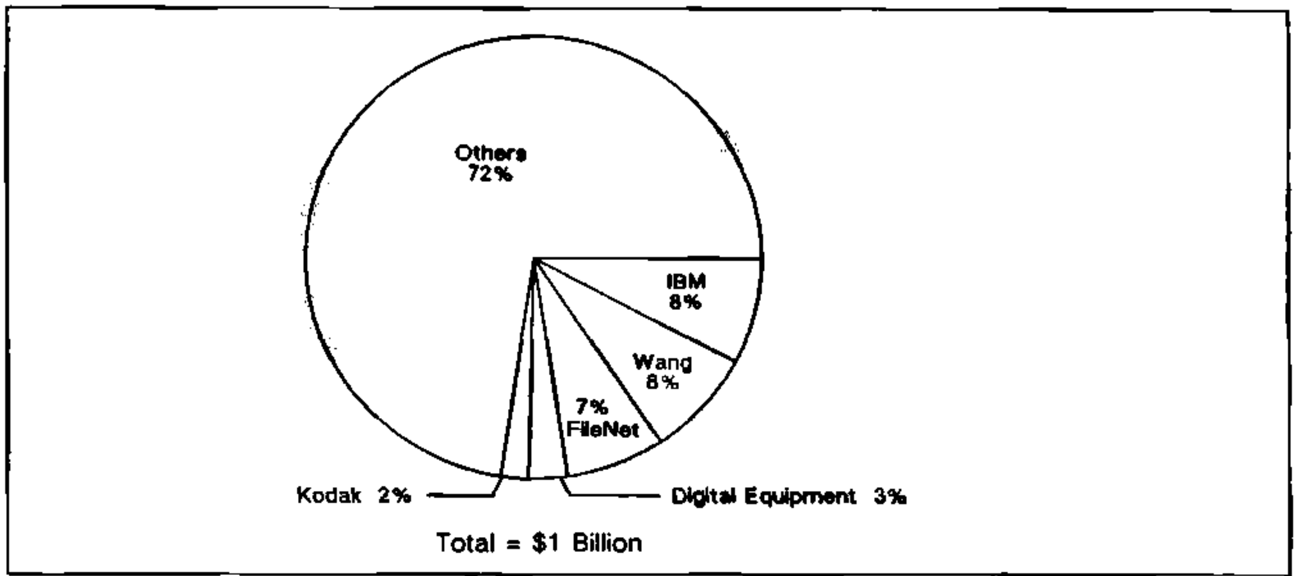
The DIMS market consists of low-, mid- and high-volume systems. While the low-volume segment continued to grow in 1989, this segment began to grow at a slower rate. This slowdown indicates a trend where users are moving document imaging into a more dynamic, networked, work-group environment rather than using it for standalone filing and retrieval.

The midrange segment grew at the fastest rate by far. This growth reflects a maturing of document image system's use. Following are some reasons for this strong growth:

- Current users are upgrading single-user systems to multiuser versions.
- The introduction of lower-priced, work-group systems by high-end vendors.
- More attractive "starter" prices make it easier for the next wave of image systems users to cost-justify installing a first system.

High-volume systems also showed strong growth, but at a slower rate than the other two segments. Key factors that have influenced this segment are the high degree of customization required for a system—in many cases over $1 million per system—and the entry of several major computer systems vendors into the document imaging market. The high degree of customization may limit the total available market. The entry of computer systems vendors into the market will provide more market coverage; this is expected to drive high-volume systems up over the next five years.

FIGURE 10
Document Image Management Systems
Estimated 1989 Worldwide Revenue Market Shares
North America-Based Vendors
(Billions of Dollars)



Source: Dataquest (June 1990)

INTEGRATED OFFICE SYSTEMS

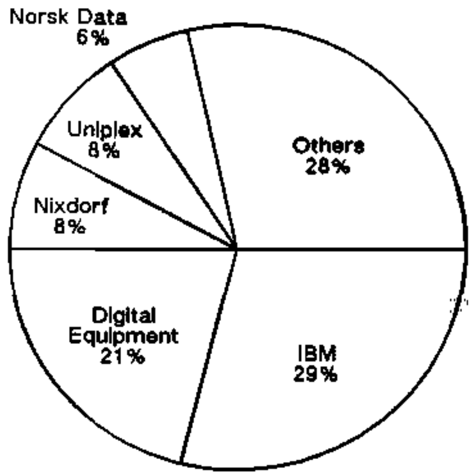
Increasingly being positioned as a strategic platform rather than a mere set of productivity tools, integrated office systems (IOS) have the potential to become the primary mechanism whereby vendors maintain control of their accounts, in a world where they are increasingly less able to differentiate themselves on the basis of their hardware offerings alone. IOS are becoming very sophisticated and challenging for those vendors with the determination to capture that potential.

There are three main segments in the IOS market: manufacturer-based systems, UNIX-based systems, and PC LAN-based systems. Manufacturer-based systems account for over 80 percent of the revenue. Figure 11 depicts the major vendors in the IOS market.

Several factors are currently influencing or will influence the IOS market in the future:

- The impact of third-generation systems
- The move toward the client/server model of computing, to which office systems are so well suited
- The emergence of new and exciting technologies—including multimedia, user agents, and document management systems
- The potential integrating capabilities of office systems, through both software and connecting disparate hardware systems
- The attraction of more users by unbundled IOS and unbundled pricing

Figure 11
Integrated Office Systems
Estimated 1989 Worldwide Revenue Market Shares
(Billions of Dollars)



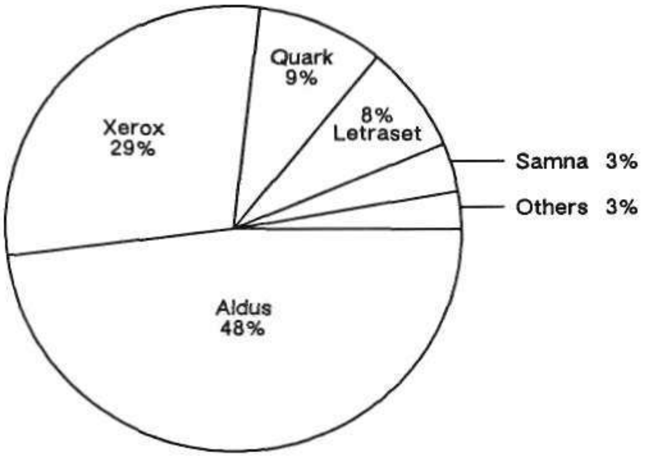
Source: Dataquest (June 1990)

Electronic Publishing

The PC and PC-compatible publishing market exhibited strong growth from 1988 to 1989 despite lackluster performance from the traditional market contenders. Figure 12 depicts the leading vendors in the PC-based publishing market for page composition software used by Apple and IBM personal computers. The enormous installed base of PCs and PC-compatibles continues to provide a largely untapped market for electronic publishing, especially for inexpensive products tuned to operate within the limitations of 640K memory and 80286 processors. This untapped market potential should contribute to promote strong market growth in the future.

The year 1989 marked the first decline in previously breakneck US growth rates for the traditional suppliers of page composition software, the product category that spawned the desktop publishing (DTP) phenomenon. Dataquest does not believe that this Macintosh (Apple Computer) publishing market deceleration is indicative of a gloomy decade ahead for DTP. Significant, relatively untapped Macintosh publishing product opportunities still exist in the United States and Europe including technical publishing, illustration and intelligent character recognition (ICR) software, fonts, clip art, personal laser printing, and desktop scanning.

FIGURE 12
Page Composition Software, PC-Based Publishing*
Estimated 1989 Worldwide Market Shares
North America-Based Vendors



* Page composition software $400+ per unit.

Total = 226,000 Units

Source: Dataquest (June 1990)

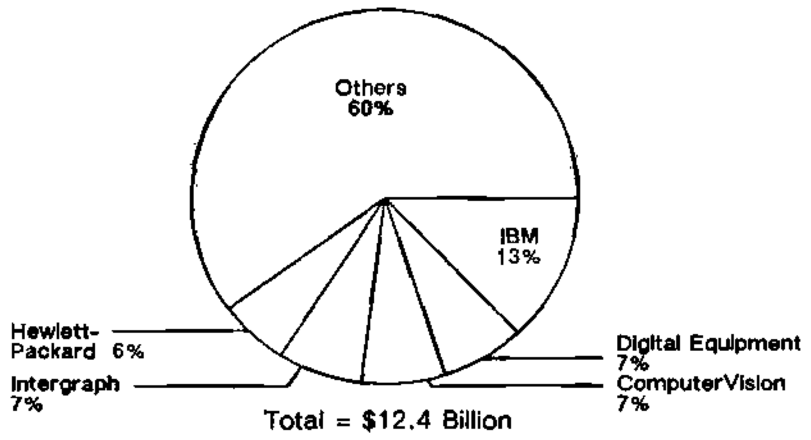
CAD/CAM/CAE INDUSTRY

The CAD/CAM/CAE market experienced robust growth, expanding 14 percent in 1989. Such strong growth in the face of industry instability is clear evidence of this market's vitality as well as its insatiable demand for leading-edge CAD/CAM/CAE products. Advances in core technologies added fuel to the growth by creating new applications and adding value to proven applications. Figure 13 depicts the leading vendors in the CAD/CAM/CAE market.

During 1989, a number of important underlying trends affected the performance of the worldwide CAD/CAM/CAE industry including the following:

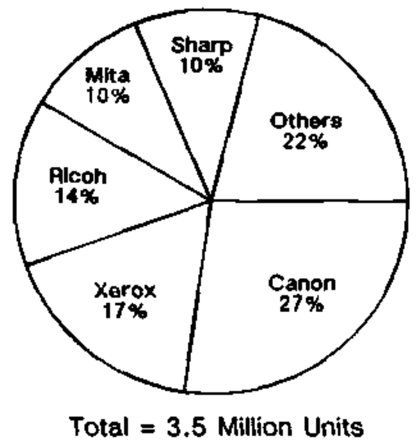
- Intense competition in end-user markets—Strong demand for CAD/CAM/CAE products reflects the fierce competition in the markets that rely on this technology.
- Market globalization—Japan continues to be a hotbed of activity for CAD/CAM/CAE vendors; the European market surpassed all forecasts in gaining even more ground as the largest regional consumer of CAD/CAM/CAE tools.
- Pushing the price/performance envelope—Increasing workstation performance and fierce price competition among computer vendors continued to be a driving force behind the CAD/CAM/CAE market's strong growth.
- Growing overlap between PCs and workstations—In 1989, the overlap in price/performance between PCs and workstations grew even larger.

Figure 13
CAD/CAM/CAE
Estimated 1989 Worldwide Revenue Market Shares
(Billions of Dollars)



Source: Dataquest (June 1990)

Figure 14
Plain Paper Copiers
Estimated 1989 Worldwide Market Shares



Source: Dataquest (June 1990)

Plain Paper Copiers

Plain paper copier unit shipments grew by 4 percent during 1989. Although the copier market is leveling out, opportunities remain in particular segments of the market—specifically in the midvolume segments. Dataquest anticipates that the midvolume copier segments will continue to grow at healthy rates through 1994.

Demand for products in the midvolume segments will be met primarily through the dealer distribution channel, with the units manufactured in Japan. We expect growth in Asia/Pacific and Eastern Europe to be higher than that of the more mature US, Western European, and Japanese markets for the next few years.

Figure 14 shows the top five vendors' unit shares of the worldwide plain paper copier market. The market is dominated by Canon, Xerox, and Ricoh, with a combined market share of nearly 60 percent. Sharp and Mita have a combined share of 20 percent; Konica, Minolta, and Toshiba each participate with 4 to 6 percent of the market.

COMPUTER STORAGE

The worldwide computer storage revenue grew by 8 percent during 1989 to $17.6 billion. Figure 15 shows the market leaders in computer storage devices. Mergers and consolidations continued, with many companies being bought out by larger companies or filing for bankruptcy under Chapter 11.

The computer storage market is dominated by North American and Japanese companies. European and Rest of World companies have less than 5 percent of the worldwide market. At the segment level, the geographic breakdowns are as follows:

- The 3.5- and 5.25-inch rigid drive market is dominated by North American companies, with over 90 percent of the respective markets.
- The flexible drive market is served almost entirely by Japanese companies (over 95 percent).
- The tape drive market is served mostly by North American companies (over 70 percent).

The computer storage market is undergoing many changes. The following are just a few highlights of the 1989 computer storage market:

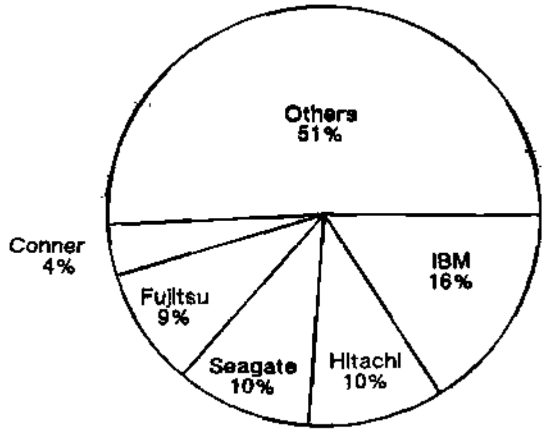
- Seagate's acquisition of Imprimis made Seagate a 70 percent market share leader in unit shipments in the rigid 5.25-inch segment.
- Conner Peripherals became the fastest-growing company in disk drive history, selling principally to OEM buyers.
- Hewlett-Packard began a quality war by announcing 5-year warranties and 150,000-hour mean time between failure (MTBF) rates on its 5.25-inch hard disk products.
- The worldwide tape drive market crossed the $2.5 billion mark during 1989, an increase of 17 percent from 1988.

More people are using more storage devices, which is expanding the market potential. Magnetic-recording densities are increasing, along with the cost/performance of the products that incorporate these new higher-density storage devices.

Paul Wittrock
Patricia S. Cox

Note: This newsletter was compiled from material supplied by the following Dataquest groups: Applications Information Group, Central Research Group, Components Group, Information Systems

FIGURE 15
Computer Storage Devices
Estimated 1989 Worldwide Revenue Market Shares
(Billions of Dollars)



Source: Dataquest (June 1990)

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Research Newsletter

CAPITAL EQUIPMENT SPENDING: SOME 1990 RECESSION PROTECTION

The capital-equipment sector is one of the most important of any industrialized economy. Since many areas of capital spending are highly interest-rate sensitive, this sector is often a leading indicator of economic growth.

In recent years, more and more capital-equipment spending has been for information-industry products such as computers or sophisticated measuring devices. This adds to the robustness of this sector for two reasons: First, the usefulness of these items is dependent upon harnessing new technologies, lessening the sector's reliance on the economy's business cycle. And second, information-industry products generally are replaced more rapidly than other types of equipment, increasing the demand for replacement capital.

Higher levels of capital spending are also frequently seen as a panacea to the trade deficit in the U.S. With more efficient equipment in use, productivity is enhanced. Higher productivity means more goods can be manufactured from a given set of resources, and therefore can serve as a sort of "magic bullet" to alleviate the trade deficit in the U.S., without sacrificing domestic consumption or stimulating inflation. A recent Dun's 5000 survey on firms' capital spending plans shows that, despite higher interest rates and weakness in many areas of manufacturing, there are still some magic bullets remaining in the economy's weapons arsenal.

This small sector comprised only about 9.6 percent of real GNP in 1989, but has contributed more than its share of business-cycle oscillations in recent years. From Figure 1, it is obvious that the growth rate of capital-equipment spending is usually higher than real GNP growth when the economy is expanding, and lower when the economy is in recession. Looking at the previous recession in 1982 and the first part of the subsequent recovery through 1984, annual growth of capital-equipment spending rose from -9.3 percent during the 1982 recession to over 20 percent in 1984. At the same time, real GNP growth increased from -2.6 percent to 6.8 percent. Between 1984 and 1988, capital-equipment spending grew at least 8 percent in every year, except 1986 when depressed oil prices drove down the demand for energy-related equipment. In 1989, equipment spending grew 5.0 percent while the entire economy expanded 3.0 percent.

COMPONENTS OF CAPITAL SPENDING

From Table 1, it is apparent that almost half—48.4 percent to be exact—of all equipment investment is information industry-related, using as a rough definition the four components listed in this table. This share has exploded in recent years as information has become a more integral part of the economy. Most of this meteoric growth has occurred in the past 10 years: in 1960, this share was only 10.9 percent and grew to 20.3 percent by 1979.

The information-industry segment of capital spending is much less dependent on interest rates than other segments. Because of the rapid pace of technological change, the useful life of a computer or sensitive measuring device is much shorter than that of a turbine, tractor or desk. The emergence or application of a new technology is the key factor businesses use to decide whether a high-tech good will be worthwhile investment. Once this initial investment is made, the demand for replacement capital will be determined by obsolescence. In this manner, the explosion of information industry expenditures is a self-perpetuating process.

Corporate Research Newsletters 1990

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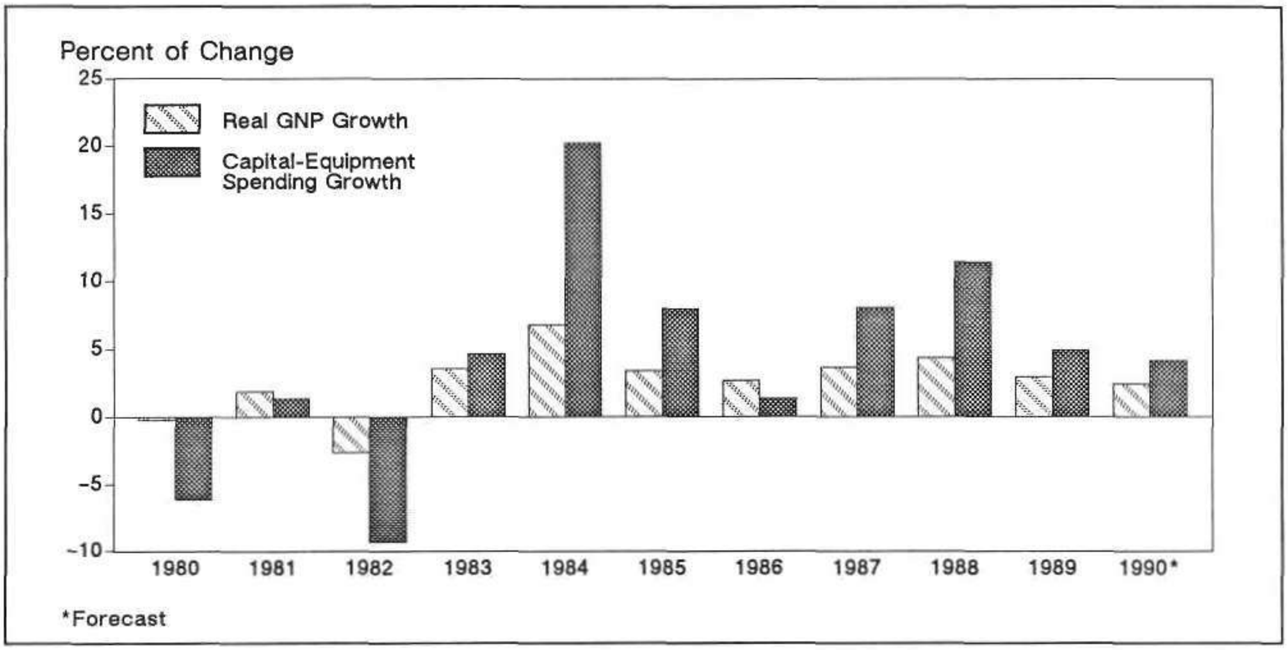
FIGURE 1
Real GNP and Capital Equipment Spending



Source: The Dun & Bradstreet Corporation

TABLE 1
Share of Equipment Investment by Type—1989 (Percent)

Information Processing Equipment	48.4	-
Computers and Office Equipment	-	32.2
Electrical and Communications	-	9.6
Scientific and Engineering Equipment	-	3.6
Photographic Equipment	-	3.0
Transportation Equipment	15.9	-
Motor Vehicles and Parts	-	11.8
Aircraft	-	3.0
Other Transportation Equipment	-	1.1
General and Special Industrial Equipment	9.5	-
Metalworking Machinery	4.0	-
Furniture and Fixtures	3.7	-
Agricultural Machinery and Tractors	3.3	-
Electrical Transmission and Distribution	3.0	-
Other Equipment	12.2	-

Source: The Dun & Bradstreet Corporation

Another implication of this technologically based capital spending is reduced inflation. The GNP implicit price deflator (a national-income-account price index) for information equipment has fallen every year since 1983 by an average of 6.5 percent. Implicit price deflators are adjusted for quality improvements, so the decreases say that information equipment users are getting much more for their money. Even though these quality adjustments are difficult to calculate (by what criteria can one compare today's computers with what was available five or ten years ago?), their contribution to reducing overall inflation cannot be ignored. In 1989, this deflator fell only 2.2 percent, but this was still sufficient to subtract 0.3 percentage points from the economy-wide GNP implicit price deflator.

The second major component of equipment investment is in the transportation sector. About two-thirds of this investment is for new passenger automobiles. But this share is not representative of total passenger car investment because it excludes disinvestment (i.e., resales) of used cars, which are subtracted from total investment. Thus, the net investment in passenger vehicles comprises less than 30 percent of all transportation investment. The aircraft industry fills much of the remainder of this component, as do trucks, buses, ships and boats, and railroad equipment.

One distortion in these areas of spending centers on the leasing of equipment. Today, because of tax incentives and cashflow requirements, many companies lease cars, trucks and aircraft as a substitute for ownership. When a company purchases a car for its own use, it is treated as an investment. When it leases the same car, it is considered a service provided by the lessor. Hence, some equipment purchases may be found in the transportation or business-service sectors. The purchase of the car by the lessor is not counted in the GNP statistics because GNP is defined as the sum of all final goods and services produced in the economy. The purchase of the leased car is the action of an intermediary.

THE DUN'S 5000 CAPITAL SPENDING SURVEY

In December and January, the Dun's 5000 Capital Spending survey was conducted to try to ascertain this volatile sector's contribution to economic growth in 1990. This annual survey polled 5,000 firms selected to be representative of the U.S. population as a whole.

Of all firms that undertake capital spending projects (and about two-thirds do, according to the survey), 40.9 percent of respondents forecast an increase in their capital spending in 1990 from 1989 levels, and 34.5 percent expected a decrease. This is down slightly from 1989's 46 percent of firms who planned to increase their capital spending and about equal to 1988's 41 percent.

Construction and service sector firms had the most ambitious plans, with about 45 percent of these businesses saying they would increase their spending. Manufacturing firms were not far behind at 43 percent. Mining, wholesale and retail firms had the most pessimistic capital-spending plans for 1990.

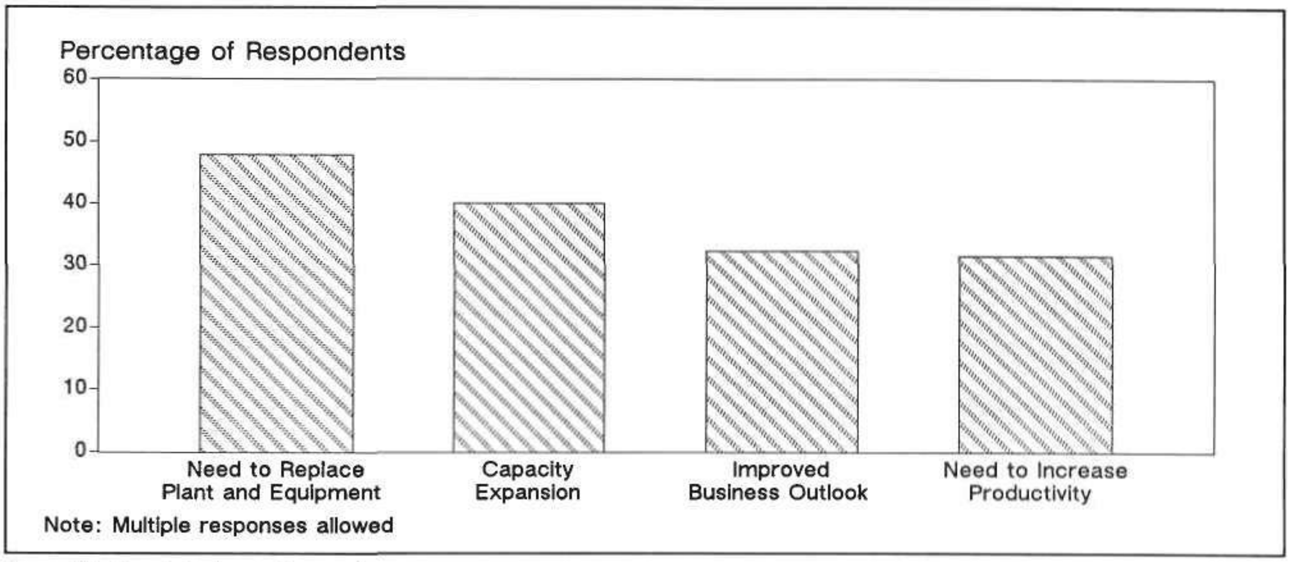
By firm size, the larger the firm, the more likely it is to have plans to increase capital spending in 1990. Only 31.7 percent of firms with fewer than 20 employees are planning to increase spending this year, while 46.7 percent of firms with 1,000 or more employees, and 51.5 percent of firms with 10,000 or more employees, anticipate more spending.

For the firms that intend to increase spending in 1990, Figure 2 outlines the reasons behind these more ambitious plans. These data show that, while the business cycle is an important consideration, the demand for replacement capital is the principal decision-making consideration.

The Dun's 5000 survey asked the firms that are involved with capital-spending projects about the factors that will affect their spending plans in 1990. The results, shown in Figure 3, indicate that the single most important factor affecting this year's spending is last year's spending. Like Figure 2, this reflects the fact that a great deal of capital-equipment spending is done on an ongoing basis. Further, many projects simply take more than one year to complete or are put in place over the course of at least two calendar years.

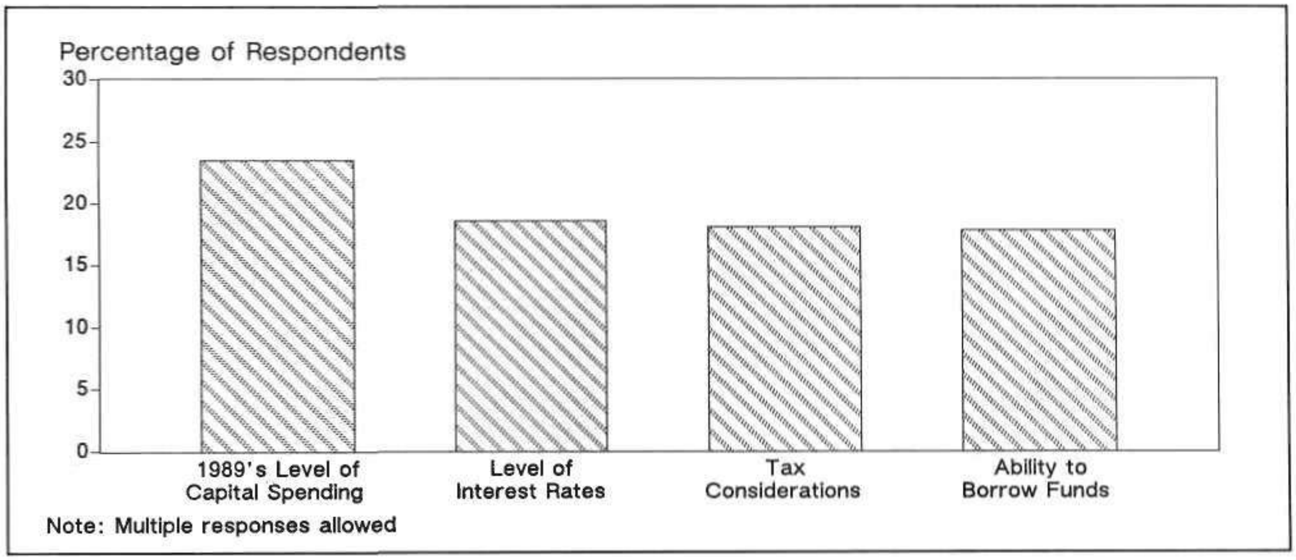
Figure 3 also shows that interest rates, while still an important consideration, are not the sole determinant of capital-equipment spending plans, at least in today's relatively stable interest-rate environment. In addition, the importance of structural considerations, such as tax laws or the availability of funds, cannot be ignored as key determinants of capital spending.

FIGURE 2
Reasons for Increased Capital Spending in 1990



Source: The Dun & Bradstreet Corporation

FIGURE 3
Factors Affecting Capital Spending Plans in 1990



Source: The Dun & Bradstreet Corporation

Overall the outlook for capital equipment spending is good, but not quite as healthy as last year. The recent edging up of interest rates and the restricted availability of funds will hurt the plans of many smaller businesses, but will have much less of an impact on the spending plans of larger firms. Capital spending measured in constant dollars grew 5.0 percent in 1989 and 11.5 percent in 1988. Taking into account these considerations, capital-equipment spending growth in 1990 should be around 4.0 percent.

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Bernadette Cesena

Dataquest

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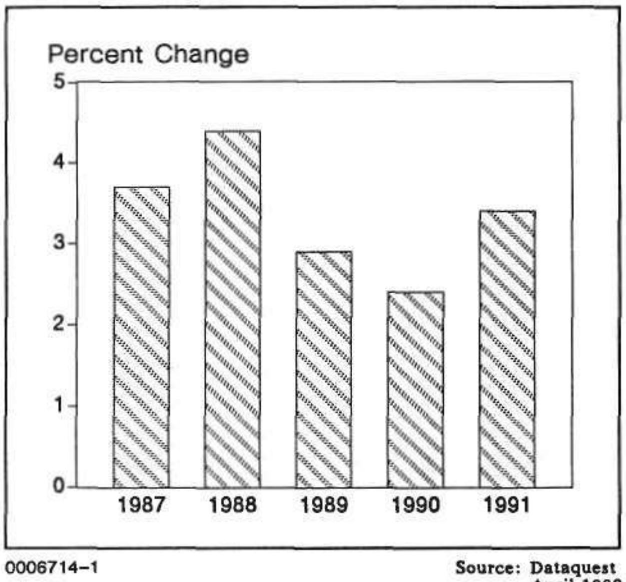
Research *Newsletter*

ECONOMIC OUTLOOK: IN LIKE A LAMB, OUT LIKE A LION

SUMMARY

The U.S. economy in the 1990s will start with a period of slow growth that is largely the result of economic events in the latter part of 1989. Although we should see real GNP growth of approximately 2.5 percent in 1990 (see Figure 1), the weakest year of the current seven-year-old expansion, the second half of the year will be decidedly better than the first half. Thereafter, the economy should return to the trend growth rates seen during the past three years. The economy's relatively smooth near-term expansion path should minimize the level of "background noise" or uncertainty and thus provide a relatively hospitable *macroeconomic* environment in which to do business.

FIGURE 1
Real U.S. GNP Growth



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Source: Dataquest
April 1990

LOOKING BACK TO THE FUTURE

A review of the economy's performance in 1989 will help frame the forecast for 1990 and 1991. Economic growth slowed significantly to 2.9 percent in 1989 from 4.4 percent in 1988. The following several changes in the business climate contributed to this slowdown:

- Large increases in food, energy, and apparel prices reduced consumer expenditure on these items and on many other goods.
- Many households' income taxes for the 1988 tax year were much larger than expected. Much of this resulted from incentives built into 1986's tax reform package that led households to defer 1986 and 1987 income to 1988.
- Automobile manufacturers overproduced in the first half of 1989 and subsequently scaled back production in the second half. Consumers responded enthusiastically initially to incentives, but sales dropped dramatically once these discounts ended.
- Interest rates rose sharply during 1988, and the dollar's three-year descent came to an end. This fact was important for the economy in 1989 because interest rate and exchange rate changes affect investment spending and exports with a lag of approximately 6 to 18 months. Thus, once these changes ran their course in 1988, their contribution to economic growth in 1989 was subdued.
- Hurricane Hugo and the Loma Prieta earthquake sharply reduced output in South Carolina and California, respectively.

Despite these changes, consumer and business optimism remained relatively high throughout 1989. Because of this optimism and because each

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of these changes either is temporary or will finish running its course in the near term, the likelihood of a recession is low.

Growth in the first half of 1990 will probably start out slowly but positively as some of 1989's problems linger. But by the second half of 1990, the economy should resume the unimpeded growth that was seen throughout much of the current expansion.

THE NEXT TWO YEARS: IN LIKE A LAMB, OUT LIKE A LION

A sector-by-sector analysis of the economy for the 1990 through 1991 period follows. This analysis is based on the economic trends of 1989 and the qualitative information contained in The Dun & Bradstreet Corporation's data and surveys.

Real GNP grew a moderate 2.9 percent in 1989. Although this figure was higher than the 2.7 percent average growth for the 1980s, it still was approximately 40.0 percent less than 1988's 4.4 percent growth. In 1990, growth should continue to slow to about 2.4 percent and then rebound in 1991 to approximately 3.4 percent. Slower growth should lead to a deceleration in inflation, from 4.8 percent in 1989 to 4.4 percent in 1990 (as measured by the Consumer Price Index); slower growth also should contribute to the unemployment rate rising slightly from 5.3 percent in 1989 to 5.4 percent in 1990. Quicker growth in 1991 will likely be accompanied by a slight acceleration in the inflation rate to the 4.5 to 5.0 percent range and a commensurate drop in the unemployment rate to 5.0 percent. (Additional indicators of U.S. macroeconomic activity are given in Table 1.)

Consumer Spending—Slow but Not Dead

Consumer spending is a major contributor to economic growth; consumption expenditures represent approximately two-thirds of GNP.

More than 80 percent of all consumer spending involves frequently recurring purchases on relatively price-insensitive nondiscretionary items such as food, clothing, housing, and health care. Growth rates for these items should remain at their present moderate levels. For the other 20 percent of expenditures, which are relatively more price sensitive and discretionary (e.g., cars, home appliances, home electronics) sales forecasts are closely tied to interest rates of these items, consumers' income, and demographics.

If the inflation rate remains relatively stable, consumer expenditure should remain at or above 1989 levels, particularly for discretionary goods. In addition, already tight labor markets in many regions and weakening demand for labor in many others will offset each other, placing wage and income growth in 1990 on a par with 1989. Finally, demographic variables such as a rapid increase in the number of two-income households, substitution of work for leisure, and a growing population of elderly yet affluent consumers should also help keep consumer spending buoyant in upcoming years.

Investment Spending—Generally Healthy, but Subject to Risk

Equipment investment will likely be one of the strongest areas of the economy in 1990. In general, investment is interest-rate sensitive, although probably less so than in the past. With interest rates declining in 1989, the stage is set for firms to commit to new projects in 1990.

In 1989, almost one-half—48.3 percent—of all equipment investment was related to the information industry. (Computers and office equipment accounted for 32.1 percent; electrical and communications equipment, 9.5 percent; scientific and engineering equipment, 3.6 percent; and photographic equipment, 3.0 percent.) This figure compares with 20.3 percent in 1979 and 10.9 percent in 1960.

It turns out that equipment related to the information industry is much less sensitive to interest rates than the remainder of the equipment segment. Because of the rapid pace of technological change, the useful life of a computer or sensitive measuring device is much shorter than, for example, a machine tool or tractor. The expectation of the future emergence or application of a new, more productive technology is the key factor in deciding whether or not a high-technology product will be a worthwhile investment. Thereafter, the demand for replacement capital will be determined by the obsolescence of this piece of equipment. In this manner, the explosion of information-industry expenditure is a self-perpetuating process. Also, high-tech equipment's increasing share of total equipment investment spending probably has made overall equipment investment spending less sensitive to changes in interest rates, thus dampening the investment cycle.

TABLE 1
Major Macroeconomic Indicators

	1987	1988	1989	1990	1991
			Billions of Current Dollars		
Nominal GNP	4,524.3	4,880.6	5,232.5	5,578.5	6,040.0
Rate of Change (%)	6.9	7.9	7.2	6.6	8.3
			Billions of 1982 Dollars		
Real GNP	3,853.7	4,024.4	4,142.5	4,240.2	4,383.0
Rate of Change (%)	3.7	4.4	2.9	2.4	3.4
			Index, 1982 = 100		
GNP Deflator	117.4	121.3	126.3	131.6	137.8
Rate of Change (%)	3.2	3.3	4.1	4.2	4.7
			Index, 1977 = 100		
Industrial Production	129.8	137.2	141.5	145.0	150.7
Rate of Change (%)	3.7	5.7	3.1	2.5	3.9
			Percent		
Capacity Utilization	81.0	83.5	83.9	83.1	84.0
Civil Unemployment Rate	6.2	5.5	5.3	5.4	5.0
			Millions Employed		
Employment, Establishment Basis	102.2	105.6	108.6	110.7	114.2
Rate of Change (%)	2.7	3.3	2.8	1.9	3.2
			Billions of 1982 Dollars		
Real Final Sales	3,830.0	3,996.5	4,118.0	4,226.0	4,362.9
Rate of Change (%)	2.1	4.3	3.0	2.6	3.2
			Billions of 1982 Dollars		
Private Domestic Demand	3,164.0	3,286.3	3,368.5	3,471.3	3,601.9
Rate of Change (%)	2.7	3.9	2.5	3.1	3.8
			Billions of Current Dollars		
After Tax Profits	142.0	168.9	159.4	155.8	178.7
Rate of Change (%)	23.2	18.9	(5.6)	(2.3)	14.7
			Interest Rates (%)		
3-Mo. Treasury Bills	5.77	6.67	8.11	7.70	8.30
30-Yr. Treasury Bonds	8.58	8.96	8.45	8.40	8.85
			Index, March 1973 = 100		
FRB Exchange Rate	96.9	92.8	96.6	89.7	91.1
Rate of Change (%)	(13.7)	(4.2)	6.3	(9.0)	1.6
			Billions of Current Dollars		
Federal Surplus (Unified, Fiscal Year)	(149.0)	(155.1)	(154.1)	(150.0)	(140.0)
Rate of Change (%)	32.6	(4.1)	(0.6)	(2.7)	(6.7)

Source: The Dun & Bradstreet Corporation
U.S. Department of Commerce
Federal Reserve Board

Offsetting the strength in equipment investment is investment in either industrial or residential construction. Given today's surplus of office space, excess factory capacity in many industries, and a backlog of unsold homes, construction is unlikely to contribute to overall economic growth; in fact, it may be a minor drag.

Meanwhile, the outlook for inventory additions is flat. In 1989, many sectors, such as retail and automobiles, made great efforts to reduce their stocks of unsold goods in anticipation of a weaker 1990. Having almost completed this sell-off, business' inventory growth will remain flat until a more hospitable economic climate materializes. Nonetheless, inventory investment is notoriously volatile and difficult to predict. As a result, inventory changes are one of the leading contributors to forecast errors. An earlier-than-expected replacement of goods on empty shelves or a resumption of the drawdown in inventory stocks may add or subtract significantly from real GNP growth.

Net Exports—No Longer Improving

The improvement in the net foreign trade position of the United States was one of the major contributors to the strength of the economy between 1986 and 1989. In 1990, however, net exports (i.e., exports less imports) will cease to be a significant driver of economic growth.

Much of this past growth occurred because of a booming export sector. Many exporters exploited the immediate relative price benefits accorded them as a result of the 1985 to 1988 decline in the dollar. In 1989, the dollar's depreciation against other major currencies came to an end and even reversed itself slightly. Although the export levels remain near all-time highs in many industries, the absence of any improvements prevents export growth rates from being comparable with the levels of two years ago.

On the import side, the demand for many types of imported goods remained intact even after the dollar fell. Several reasons for this demand are as follows:

- Many imported goods now come from countries with currencies that have depreciated very little, if at all, against the dollar. These countries include Canada, Mexico, and Pacific Rim countries such as South Korea and Taiwan.
- Consumer and manufacturer demand for certain commodities now are highly inured toward imported goods. Because many imports have made up a significant portion of sales within the United States for a long time, style and quality perceptions, supplier relationships, and other contractual obligations with importers will take a long time to break.
- Some countries, notably Japan, have reduced their profit margins on many goods, absorbing any exchange-rate-induced price increases.
- With export growth slowing and the demand for many types of imported goods continuing, not much more progress is expected in the net exports position of the United States in 1990 or 1991.

Government Spending—Especially Weak Because of Tight Budgetary Considerations

The cutbacks in federal government purchases have been well documented. In many large areas, spending will be held at or near past levels (such as in agricultural programs), or will likely decline (as in defense spending). The prospect of additional Gramm-Rudman-Hollings mandated spending cuts in late 1990 (fiscal 1991) exacerbate the gloominess of this sector. The combination of a weaker economy and spending cuts should keep the federal deficit to within $10 billion to $15 billion of fiscal 1989's $154 billion deficit through fiscal 1991.

Approximately 60 percent of government spending is done by state and local governments. As in several areas of consumer spending, a great deal of government spending is recurrent, such as for police and fire protection and schools. But revenue shortfalls in many larger states will inhibit growth in this segment of spending.

Interest Rates and the Dollar—Rates Bottom Out Early in 1990; Dollar Resumes Its Decline

The slow growth expected in the first half of 1990 will apply downward pressure on interest rates as the Federal Reserve Board attempts to steer the economy away from a recession. However, some of the downward pressure will be mitigated because the Fed also is aiming to reduce inflation, which can be rekindled by a lower exchange value of the dollar raising the prices of imported goods.

The downward pressures on the dollar are likely to resume, notwithstanding the dollar's recent rise against the yen. Interest rates in countries in which the United States competes for capital (e.g., Japan, West Germany) are expected to rise. This rise would channel international investment funds away from the United States and into other countries, weakening the demand dollars. The United States is highly dependent on this foreign capital to finance its federal budget and trade deficits.

Because the current weakness in the economy is expected to persist through the early part of 1990, interest rates should reach their trough during this period. Thereafter, a stronger economy along with higher inflation rates and mounting downward pressure on the dollar will send interest rates back up. The dollar is expected to fall approximately 5 percent from today's levels by the end of 1990. Higher interest rates and stronger economic growth will create a small rebound for the dollar in 1991.

DATAQUEST CONCLUSIONS

Dataquest maintains that company- and/or industry-specific variables such as technology and factor-input prices play a more important role in influencing high-technology company and/or industry performance than broad economic aggregates such as GNP, employment, inflation, and interest and foreign-exchange rates. Nonetheless, performance in the overall economy and high-technology business is positively correlated. As such, the economy's relatively smooth near-term expansion path should minimize the background noise or uncertainty usually associated with doing business. Electronics and semiconductor manufacturers should take this opportunity to hone their competitive edge by focusing on those specific variables that will contribute most to future profitability and growth.

Terrance A. Birkholz

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Research Newsletter

A NEW DECADE—WHERE DOES OPPORTUNITY LIE?

INTRODUCTION

This newsletter is the first of a quarterly series covering demographic trends affecting the conduct of high-technology business now and in the future. The three newsletters to follow will look, in detail, at specific factors that will have a direct impact on high-technology companies.

SUMMARY

As we look forward to the next 10 years, the key factors influencing changes, slowdowns, or growth in job occupations and industries in the late 1980s will persist into the 1990s. The major factors causing a shift in occupations and industries were social patterns, age, income, and education.

The baby boomers remain the single most influential segment in our society. The progressive aging of this group continues to have a significant impact on the dynamics of the workplace and on companies attempting to meet their demands. Since the 1970s, baby boomers gradually have become absorbed in the workplace; this was continued throughout the 1980s.

The framework of the eighties was influenced by socioeconomic shifts in our society. This movement will continue to create a complex workplace and heighten the demands of organizations to respond throughout the nineties.

LOOKING BACK—RECAP OF THE EIGHTIES

As the 1980s drew to a close, the most obvious trend was that job and industry growth rates were slowing.

Some industries and occupations experienced slow growth, such as manufacturing and clerical workers. This trend is expected to continue.

In contrast, some industries and occupations, such as services and computer programmers, had faster growth rates than average, and this pattern is expected to flourish well into the nineties.

INTRODUCTION TO A NEW DECADE—THE NINETIES

As we begin the 1990s, the overall labor-force growth rate is slowing. But, some occupations and industries will grow rapidly, as illustrated in Figure 1.

This growth will be the catalyst to push companies to shift their emphasis to training and educating employees to meet the demands of the future, such as technological changes, which will require a higher skill level to perform a job function. As the population ages, the number of available new workers will decline, necessitating retaining the existing work force.

Several factors that will contribute to the changes in growth rates, both in employment and industry, are the following:

- Changes in the industrial composition
- Changes in technology
- Changes in business practices

The organizations responding in a strategic and thorough manner will maintain the competitive and profitable edge.

OCCUPATIONS FOR THE 1990s

The pressures on organizations to hire, promote, and keep employees have been intensified in recent years. Some of these pressures are the following:

- The influx of women and minorities into the work force

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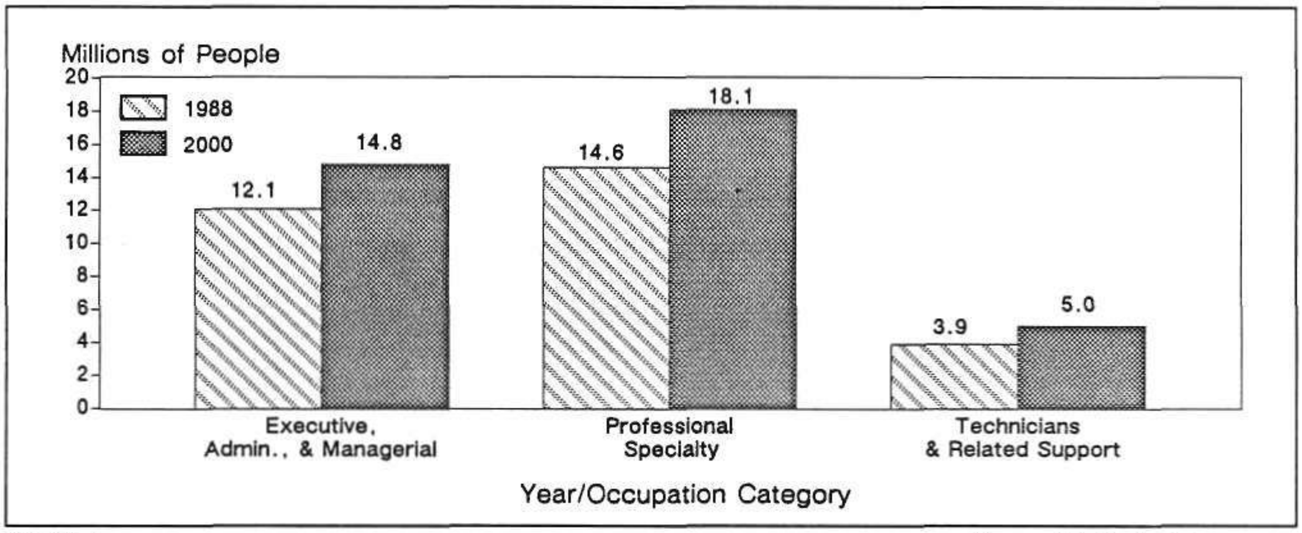
FIGURE 1
Employment by Major Occupational Category 1988 and 2000



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Source: U.S. Dept. of Commerce Bureau of Labor Statistics

- The demand to achieve certain educational levels to fulfill job specifications
- The growth/decline of particular industries
- Technological advances

High Growth

The top three major occupational areas, as defined by the Bureau of Labor Statistics, are projected to grow more rapidly than the average for total employment during the next 10 years. These occupational areas are also those requiring the highest levels of education. The top three, illustrated in Figure 1, are:

- Executive, administrative, and managerial occupations
- Professional specialty occupations
- Technicians and related support occupations

The executive and managerial segment is expected to increase 22 percent or add 2.7 million jobs by the year 2000. A by-product of an increase in the number of managers and administrators is that a layer of complexity is added to the organizational structure. Although the number of new jobs will increase substantially, the growth rate is less than in recent years. Between 1976 and 1988 this segment grew twice as fast as total employment.

The professional specialty occupations are expected to increase 24 percent, or by 3.5 million people, over 10 years. This occupational segment includes computer specialists, engineers, lawyers, and elementary and secondary teachers.

The growth rate of technicians and related support occupations is expected to reach 32 percent, a faster rate than any other major occupational group. One of the fastest growing segments since the mid-1970s, this group includes engineering and science technicians and computer programmers.

The occupations group of services will singlehandedly add more jobs than any other major group. By the year 2000, this segment will increase by 23.0 percent, or 4 million jobs. This sector will represent 16.6 percent of total employment.

Medium Growth

Marketing and sales occupations are expected to have a better than average growth. This growth is attributed to the high concentration of these occupations in two growing industries, wholesale and retail trade.

Decline

Administrative support, which includes clerical, is expected to have a below average growth. In the previous 12 years, administrative support had grown fairly steadily with total employment. Technological advances and the increased utilization of office automation equipment have been two influential factors in the slowing growth of this area. Occupations most affected by the decline are typists, word processors, stenographers, and statistical clerks.

OCCUPATIONS BY INDUSTRY

The same factors impacting occupational trends are simultaneously affecting growth or decline in industries. By the year 2000, 18 million *new* jobs will be added, with the majority emerging in the service-producing sector.

High Growth

Service-producing industries are expected to make up 79.0 percent of all nonfarm wage and salary jobs in the year 2000. Although services will sustain healthy growth, the rate is slower than the 4.8 percent a year experienced during the 1976 through 1988 period. This new growth rate translates into 33.7 million jobs, up from 25.0 million in 1988. Leading service-producing industries adding jobs, as seen in Figure 2, will be retail trade (3.8 million); private health (3.0 million); and business services (2.7 million).

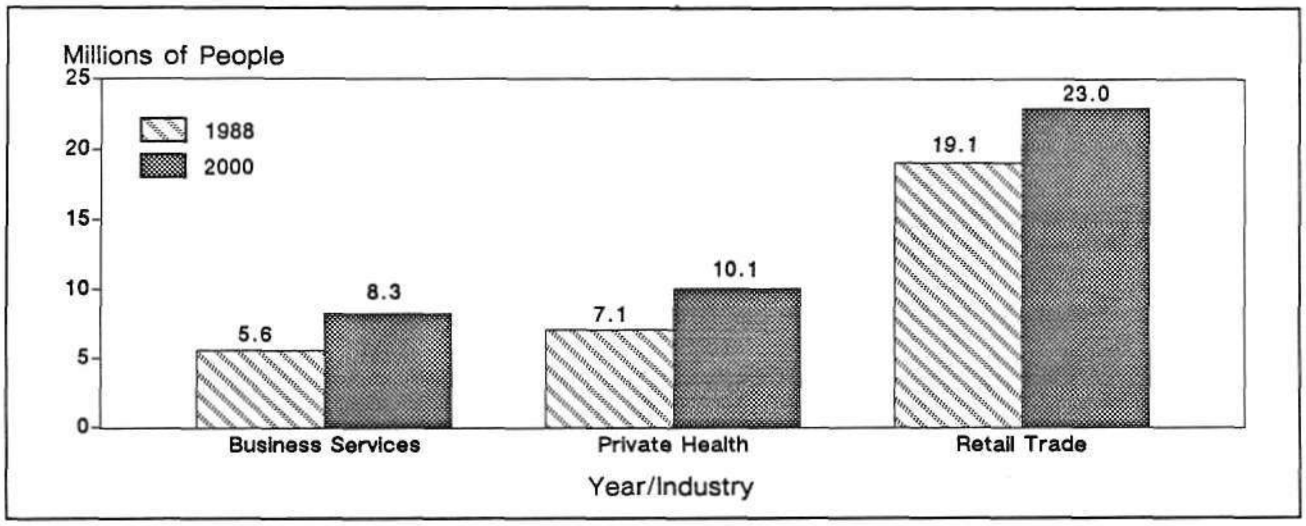
Retail trade will move past manufacturing as the second largest source of employment. Many retail jobs are part-time, and those people likely to fill these vacancies are today's youth. An additional 3.8 million new jobs will be added in this sector by the year 2000. This means one of every five wage-and-salary jobs will be in retail. The number of potential workers in this category is shrinking, causing a problem in finding enough willing individuals to fill the numerous openings.

The health care industry is growing, and this growth is having a significant effect on the economy. It is speculated that total expenditures for health care may reach 15 percent of current-dollar gross national product by 2000, up from 11 percent in 1989.

Even though society as a whole is living longer and in many cases, living more wisely, a greater number of individuals are seeking health services. New technologies are the main force boosting this demand. More people are undergoing tests and diagnostic procedures, taking more drugs, and seeing more specialists than ever before. This trend will continue on because our population is aging and, typically, persons over 75 are higher users of hospital services.

Directly related to the growth of the health care industry is the increase in the number of health-related occupations expected in this decade.

FIGURE 2
Employment in Service-Producing Industries 1988 and 2000



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Source: U.S. Dept. of Commerce
Bureau of Labor Statistics

It is projected that 7 of 10 of the fastest-growing occupations will be health related.

On the heels of growth in the health care industry is the business services sector. Within business services, and in fact, the fastest growing in the whole economy, is *computer services*. This sector is expected to grow by 4.9 percent a year. Occupations that will benefit directly from this surge are operations research analysts, computer systems analysts, programmers, and other related computer specialists.

Medium Growth

Increases in school enrollments are expected to result in almost 1 million new jobs in public education. Baby boomers began having a greater number of children in the 1980s, compared with the low birth rate of the 1970s.

Over the next decade, it is anticipated that the education sector will add 1.2 million jobs, including teachers and administrative staff. The increases will be primarily in public elementary and secondary schools.

Employment in colleges has been rising even though the number of *traditional* college-age (18 through 24) individuals has been declining since 1981. Enrollment has been maintained by the number of older, women, foreign, and part-time students attending college.

The finance, insurance, and real estate sectors are expected to add 1.1 million new jobs. The sectors of wholesale trade and transportation, communications, and public utilities will add 907,000 and 548,000 new jobs, respectively.

Decline

By the year 2000, the number of jobs in manufacturing is anticipated to decline slightly from 19.4 to 19.1 million. The 1988 total for manufacturing jobs of 19.4 million remains far below the peak of 21.0 million reached in 1979. Although plant closings and company restructuring will preclude overall employment levels in manufacturing from rising to previously high levels, production is expected to show healthy growth in this decade.

Real output of U.S. manufacturing is projected to grow at 2.3 percent a year. As trade imbalances improved and the economic problems of the early 1980s waned, both production and the number of jobs in manufacturing began to rise. This trend should continue throughout the coming decade.

RESPONDING TO CHANGE

Dataquest believes that organizations should be taking proactive measures to ensure their ability to respond to the work-force demands of the future. As the types of jobs and growing businesses continue to shift, dated hiring practices must be revamped to accommodate change.

Greater emphasis must be placed on educating our human resources, starting in our schools and continuing with training within organizations. Skill requirements are heightened to function amid an array of new technologies. It is no longer a "learn as you go" work environment. Rather, formal instruction enabling workers to perform effectively and to meet the job requirements is imperative.

New products being developed should be designed with the end user in mind. Product success is contingent on demand. Thus, opportunity lies in designing products that meet the needs of those industries and occupations expected to have healthy growth over the next decade.

DATAQUEST CONCLUSIONS

Many opportunities for high-technology products and services exist in this decade. The framework of society is moving from production to a service orientation. Companies that will succeed and be profitable are ones that equip themselves with the ammunition to address the needs of tomorrow's work force and workplace.

Bernadette Cesena

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Research Newsletter

A PREVIEW OF THE 1990s

INTRODUCTION

Most sectors of the electronics industry will experience slower growth rates during the early 1990s. Reduced growth is anticipated for many reasons, such as the following:

- The proliferation of new products and technological advances during the past few years has grown faster than most users' ability to absorb these products fully.
- The path toward standardization remains crooked, and connectivity of existing and new equipment will become more of an issue—to the user.

The electronics industry will undergo basic structural changes during the 1990s. These changes will result from the globalization of telecommunications networks, the maturation of sectors of the computer industry, the ongoing expansions in the Asia/Pacific area, continued company consolidations and alliances, and the new market potentials in Eastern Europe.

These are only a few highlights of Dataquest's views about the 1990s. This newsletter discusses some of the significant events of 1989, major trends anticipated for the next few years, and how these trends will influence the outlook for the mid-1990s and beyond.

The following is a brief summary of Dataquest's first quarter Forecast Forum. It is a preview of the in-depth analyses and forecasts that will be provided by each of our Industry Service Groups in their upcoming publications and conferences.

U.S. ECONOMY: SLOWER GROWTH IN 1990

The 1990s will commence in a slow growth mode, with no recession anticipated in the near future. The first half of 1990 will be affected directly by the lingering impact of 1989 events. Two key 1989 events that contributed to the slow start in 1990 are the large consumer price increases in food, energy, and apparel, and the two natural disasters, Hurricane Hugo and the San Francisco Bay Area earthquake.

Consumer spending (i.e., personal consumption) constitutes two-thirds of the gross national product (GNP). The GNP has been affected strongly by rising prices, and this increase in prices is fostering cautious spending by consumers. The natural disasters have caused a reduction in output from South Carolina and California, respectively.

According to The Dun & Bradstreet Corporation, real GNP is expected to grow at 2.4 percent in 1990, down from 4.4 percent and 2.9 percent in 1988 and 1989, respectively. Slower growth in 1990 should lead to reduced inflation rates and to a slight rise in the unemployment rate. In 1991, the economy is predicted to bounce back, with real GNP expected to be 3.4 percent.

TELECOMMUNICATIONS MARKET: MIXED GROWTH

Forecast growth for the telecommunications industry as a whole remains mixed. Overall, we expect the U.S. telecommunications market to grow a little more than 5 percent in revenue between 1989 and 1990. The greatest influence on this market is its growth rate in the revenue traditionally attributed to local and long distance calling services. This sector will account for 88 percent of the total market, or $148 billion in 1990. The equipment side of the market will grow faster at 9 percent and will account for slightly more than $29 billion in 1990. In Europe, we expect total telecommunications services to grow at almost double the U.S. rate, or 9 percent. Equipment revenue is expected to parallel that of the United States, at approximately 9 percent.

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The major forces driving telecommunications include the following:

- Globalization of worldwide networks, markets, and standards
- Rapid movement to a digital telecommunications network
- Transition from an engineering perspective to a marketing focus
- Continued consolidations and alliances

The telecommunications marketplace truly became international during the late 1980s. The ramifications of the recent events taking place in Europe, alone, are monumental. To meet these rapidly evolving markets requires the globalization of networks and standards. We believe that excellent opportunities exist for expansion in Europe and the Pacific Rim regions. The expansion of all geographic markets will create opportunities for further investments in the 1990s.

The digitalization of the network poses problems and presents potential. As a result of a digital network, bandwidth (data-carrying capability) will no longer be an issue or a constraint. Simultaneous video, data, and voice transmission will become a reality once standards are finalized. One step along this road is the implementation of the Open Network Architecture (ONA) standard. Implementation of this, or other standards, will create a new "information services" market—potentially large markets for gateway products, and, we believe, the eventual unbundling of traditional Telco (i.e., local and long distance charges) services.

The acceptance of the Integrated Services Digital Network (ISDN) has been lower than anticipated; however, usage is expected to increase at a steady pace from the existing 85,000 access lines in service to 1.4 million access lines in service by 1994. Today, ISDN enjoys broad industry support, all critical standards are in place, field trials are under way at selected locations, and initial "islands" of local services are available.

As the telecommunications industry moves from an engineering-driven market, the key factors for success will change. Although technology is important, customer service and support, solution-based applications, personal communications, distribution, and account management will be the focus for successful companies in the 1990s.

We expect mergers, acquisitions, consolidations, and alliances to continue; partially as a result of competition, but also as a result of the globalization of the industry. Companies continue to seek options that create the necessary financial and marketing resources to crack the ever-rising entry barriers in both the domestic and international markets.

The 1990s portends to be an interesting and tumultuous decade for the telecommunications industry.

COMPUTER SYSTEMS MARKET: UNEVEN GROWTH

The computer systems market is likely to see a period of uneven growth over the next several years, in both the business and technical segments. Dataquest believes that the market will be growing at a slower rate than has been experienced in the past several years. Listed below are factors that can influence the market during the 1990s.

Dataquest believes that the following factors work against a continued period of high growth, negatively affecting the market:

- Maturing market—The business segment, representing approximately 80 percent of the total market, is exhibiting slower growth.
- Average selling prices (ASP)—The ASPs of many systems are continuing downward, resulting in narrower profit margins and stalling revenue growth.
- Gap between hardware and software technology—Much advanced hardware technology is underutilized because of the dearth of applications.
- Standards—The standards battle is confusing to users, and many people are waiting to see which standard will prevail before investing in new systems.
- Movement away from large systems—With smaller, yet more powerful, systems gaining wide acceptance, many users are moving away from large mainframes.

The potential for a sustained high rate of growth does exist. Dataquest believes that there are a number of factors that may have a positive effect on the computer systems market, as follows:

- Continued expansion of the base—Several new markets, such as on-line transaction processing (OLTP), distributed processing, and newly opened geographical markets, can cause renewed vigor in the market.

- New software for existing systems—Software to utilize existing systems fully will drive users to the next generation of hardware.
- New applications and technology—New applications and technology are being explored that could drive new growth in the market, such as video E-mail, artificial intelligence embedded in relational databases, and the client/server architecture.
- Technical workstations—Movement of more technical workstations into the business segment of the market can fuel the workstation market.
- Standards—Standards offer users the ability to mix and match systems to provide the best solution.

Even with the introduction of new technologies and the opening of new markets, Dataquest does not believe that these new technologies will be in widespread use until the 1993 to 1995 time frame. We believe that ASPs will continue to drop, squeezing margins even further. The growth of proprietary systems will continue to decline while systems based on open architectures will grow at a much faster rate than proprietary systems.

Standards can be a boon or a bust for the market. Dataquest believes that standards will continue to emerge. Open standard systems offer users investment protection, a secure upgrade path, and interoperability. On the other hand, we believe that standards will never be settled fully, causing confusion among users.

New markets offer some hope that a double digit rate of growth can be maintained. Distributed processing and OLTP offer major opportunities. The potential for a large, new market for technology in Eastern Europe is encouraging.

Examining all of the factors that are likely to impact the computer systems market, Dataquest is forecasting that the market will grow at a reduced rate through the early 1990s to mid-1990s and then see a return to higher growth rates in the latter half of the decade.

UNIX SYSTEMS SOFTWARE: STEADY GROWTH

The outlook for the UNIX system software market is good. Dataquest believes that continued strong growth will occur in this market. A number of factors affecting the UNIX market will allow the market to continue to maintain strong growth, such as the following:

- Workstations—One of the fastest growing markets in computer systems, workstations are in large part fostering the movement of UNIX into the business segment of the market.
- Growth of multiprocessing computers—Multiprocessing computers are moving computer technology from the scientific environment into the mainstream commercial computer market as file servers.
- Decline of proprietary systems—The market is moving to the open standard of UNIX and toward open systems, away from proprietary systems.
- IBM's entry into the UNIX market—Dataquest believes that IBM's newest entry, RISC System/6000, brings more credibility to the commercial marketplace for RISC-based UNIX systems, especially among the Fortune 100 companies.
- Expanding markets—Europe is moving to UNIX in a big way. The Japanese are enthusiastic about UNIX for real-time and industrial applications and for workstations.

Really, UNIX is an enabling technology. It is becoming a check-off item for people buying systems. The use of UNIX protects a company's investment in training and hardware. The UNIX market is in a strong period of growth, and we believe that it will continue for the next several years. Graphical user interfaces that shield the complexity of UNIX's command language, the PC DOS-to-UNIX software applications, and fault-tolerant UNIX systems will help UNIX make major inroads into the commercial market in the coming years.

PERSONAL COMPUTER MARKET: SLOWER GROWTH

Dataquest's preliminary market estimates show that 1989 U.S. PC unit shipments grew by an estimated 8 to 9 percent. Our forecast at the beginning of last year was 10.2 percent growth for the U.S. market. We predicted that worldwide PC unit shipments would increase by 10.3 percent. Preliminary figures show that the worldwide market grew by approximately 10 percent. Most companies did not do as well as we had anticipated at the beginning of 1989; however, almost every company increased its unit shipments over 1988.

The number of PC models available in 1989 almost doubled over the previous year. More than 1,000 PC vendors/models are in the market. This large number is primarily because there are few barriers to entering this industry. It is easy to buy a motherboard and a box to go around it and get into the PC business; however, the success rate is low.

The speed at which technology changes was exemplified when Compaq announced the LTE notebook PC, which is a 7-pound, 40MB hard disk, 286-based product with a floppy disk. At the same time, another company came out with their "new" product. This new product was an 8-pound, no hard disk, 8088-based notebook PC, priced $500 above Compaq's LTE.

On a unit basis, the 286-based machines were still the highest-selling boxes in both the worldwide and U.S. markets during 1989. The 386-based PCs sold extremely well in 1989, to the extent that Intel Corporation is currently pushing its limits of production. Preliminary estimates are that the 386 SX sold 1.2 million units in the United States in 1989.

During 1989, improvements in color LCD technology resulted in the introduction of color laptop PCs. Dataquest expects to see many more color LCD laptops in the 1990s, particularly as color technology improves. These products will be expensive and probably will not gain wide market acceptance for at least another few years.

Some extended industry standard architecture (EISA) and microchannel-compatible products were introduced in 1989. So far, EISA products have been confined to the very high end of the PC market, which is primarily 486-based products. Our forecast for the EISA market is that it will parallel the 486 market. The 486 line probably will have only microchannel-compatible or EISA architecture.

With the U.S.S.R. and the Eastern Bloc opening up, PC vendors are excited about selling into these new markets. The major problem, however, is converting currency. Vendors also are trying to learn how to sell products into these new markets.

APPLICATIONS MARKETS: CONTINUED GROWTH, SLOWER RATE

Many computer companies today are looking to the applications area as a panacea for many of their problems. The applications markets currently are growing faster than the computer market, but slower than they have in previous years. Forecast growth is between 10 and 15 percent through the middle of the 1990s and single-digit for the remainder of the decade.

In general, the applications markets are maturing and experiencing consolidation and partnering similar to that of the computer market. For example, in the CAD/CAM area, approximately two mergers and/or acquisitions per month occurred during the past 18 months. Because of these maturing market conditions, success in the 1990s will not depend solely upon a company's technological prowess, but on its ability to manage distribution problems and instill a favorable market perception.

Clearly, the proliferation of nonstandard products has become an issue that must be resolved as soon as possible. For example, currently there are so many variations of UNIX that each one is almost a proprietary product. The real growth potential of many applications hinges on a convergence of the many different standards. Many companies currently are having difficulty implementing their next-generation systems because of the wide array of development alternatives.

From the applications market perspective, many companies already have purchased most of the technology they can use currently. A huge market is developing for companies/individuals to assist the end users efficiently integrate their current systems.

Key areas of interest for applications during the 1990s include the following:

- Increased decentralization of applications
- The workstation as the "computer market" of the decade

Key markets/software technologies for the 1990s include these:

- Document imaging—Emerging
- Color publishing—Embryonic stage
- Multimedia—Technology that can be embedded in or give a face-lift to many applications

DISPLAY TERMINAL MARKET: CONTINUED CONTRACTION

Preliminary estimates of the U.S. display terminal market show approximately a 3 percent reduction from the 1988 unit level. Dataquest forecast a slight increase in the 1989 market; however, that did not happen, primarily because of the softness in the minicomputer market and events surrounding the 3270.

The 3270 market was nearly 100,000 units less than expected. Had that segment held, the display terminal market would have been essentially flat in 1989. Most major vendors experienced reduced 3270 demand, particularly IBM.

In total, the industry is expected to experience a continued slow contraction, both in unit shipments and in the number of vendors. Mergers and acquisitions will continue, and some companies will just simply drop out of the market.

Although expected in the long run, the dramatic growth in the high-end PC and workstation markets during the past couple of years changed the structure of the display terminal market. Recent advancements in LANs also accelerated the replacement of display terminals by intelligent terminals.

For the most part, terminal prices have stabilized. In fact, a few vendors have increased prices by 5 to 10 percent; however, a continuation of significant price increases is not expected in the long run.

We believe that current technology is sufficient for most display terminal applications. Enhancements will be offered; however, there appears to be no major technological changes on the horizon.

Although slower growth is expected for the total display terminal market, we see new opportunities and growth in the processing, X Window, and ISDN display terminal segments.

ELECTRONIC PRINTER MARKET: MODERATE, SLOWER GROWTH

Preliminary estimates of the 1989 electronic printer market show unit growth rates approximately 10 percent less than we forecast a year ago. Many factors contributed to this softness in the market. Perhaps the most significant factor is that users are trying to integrate more of the features and functions of their existing equipment, rather than spend money on new systems.

Dataquest expects a general softening to appear in several segments of the computer market through late 1990 or mid-1991. Reduced computer demand and the trend toward more integration (interconnection of existing printers and other equipment) will translate into slightly reduced growth rates, particularly for serial and line printers.

The real growth area remains in the page printer market. The 8-page-per-minute (ppm) printer has been the industry standard page printer for nearly five years. During 1989, the introduction and acceptance of many 4-ppm to 6-ppm printers has resulted in a structural change in the market. More than 100 different new models were introduced at COMDEX; the result has been a major change in both improved cost/performance and user acceptance.

The 4- to 6-ppm printer, priced at $1,000, now allows the user to do much more than a few years ago—for about the same cost (with the daisywheel printer costing more than $1,000 four years ago). Printing speeds are faster and the quality is much better. It is now easy to reprint pages that were too time-consuming and/or too costly to reprint with previous technologies.

The recent advances in printer/printing technology resulted from the availability of faster processors, more on-board memory, and improved software (particularly for descriptive languages, such as PostScript). The user is moving to a higher level of quality expectations.

These enabling technologies will continue to lead the user to even higher levels of expectation, which, in turn, will foster the development of improved hardware and software for better-looking type, font styles, graphics, and color. These trends will continue, and we expect many exciting advances in printing technology and user acceptance during the 1990s.

COMPUTER STORAGE MARKET: STEADY GROWTH

Most sectors of the computer storage market saw significant growth during 1989. Although preliminary estimates of the 1989 unit market indicate that most sectors experienced somewhat slower growth than previously anticipated, slower was still double-digit growth in several areas, and many new and exciting things are still happening in the magnetic storage industry.

As expected, the small rigid disk market grew by more than 20 percent in 1989. The 5.25-inch disk market contracted again; however it did not shrink as much as previously forecast. CD ROMs are on track with earlier expectations. Selected tape storage forecasts are being reduced; however, there is still plenty of life in that market. Tape storage is essential to backing up all of the new, higher-density disk drives that are entering the storage market.

Dataquest believes that the trends in computer storage through the mid-1990s will be similar to those of the past few years—with smaller, denser products replacing their larger, less dense counterparts. The new 2.5-inch disk drives (or smaller) and CD ROMs will penetrate many new products during the next couple of years.

The magnetic storage industry is experiencing mergers and consolidations similar to several other sectors of the electronic industry—in this case, the activity is mostly at the top. The larger firms are profitable; the smaller ones are not. During 1989, more than 15 companies, in many cases founders of a specific technology, filed Chapter 11 and/or were bought out by larger firms. We see a continuation of this trend—the big are getting bigger.

Many exciting changes are predicted for the storage market for the 1990s, particularly in the area of continued rapid increase in magnetic recording densities. What amounts to a revolution in the areas of increased densities and improved cost/performance is on the horizon. We expect several progressive moves to occur in the optical disk industry during the next year or two. In other areas, we expect the following:

- Gigabit-per-square-inch recording densities soon will be commonplace
- 500 megabits will be on a single 3.5-inch disk
- 1.5- to 2.5-inch rotating disks and many other new products will drive down the cost of rotation magnetic storage to 20 cents per megabit during the next few years.

SEMICONDUCTOR MARKET: SLOW START, THEN STEADY GROWTH

In October 1988, Dataquest forecast that the worldwide semiconductor market would grow 10 percent in 1989; our preliminary numbers show that the market did indeed grow 10 percent, with negative quarter-to-quarter growths in the first, third, and fourth quarters. We believe that the worldwide semiconductor market will turn the corner in the second quarter of 1990, when positive growth will resume after three consecutive quarters of negative growth.

The areas of North America, Asia-Pacific, and ROW will have the strongest growth rates. Japan and Europe both will experience negative growth. No region is expected to grow more than 3 percent in 1990.

During 1990, the 68040 and 80486 microprocessors will be widely available. These powerful microprocessors, mixed-mode ASICs, and higher-density DRAM devices all will require advances in high-speed interconnect packaging technology.

The competitive pressures in the semiconductor industry are continuing to grow. More and more, microprocessors have become proprietary, with only a single vendor producing today's state-of-the-art devices. Pricing pressures remain high in the DRAM arena. This market is doubly hard to enter because of the extremely high, approaching the half-billion dollar mark, cost of building a fab to produce DRAMs.

Questions exist about the status of the U.S.-Japan semiconductor trade agreement, which is due to expire in September 1991. The goal under the agreement was for non-Japanese companies to hold 20 percent of the Japanese semiconductor market by 1991. Our 1989 figures show that foreign penetration of the Japanese market is less than 11 percent (10 percent for North American companies). Will the agreement be renegotiated and/or extended? That remains to be seen.

The slump in the semiconductor market also is driving down capital investment in new semiconductor plants and equipment; we expect capital spending to show a slight drop in 1990. In 1989, the Asia/Pacific region surpassed Europe in the amount of capital spending for the first time. Japan continues to be the leader in this area. Due to increasing chip complexity, semiconductor-manufacturing equipment continues to grow more expensive—thus, raising the barriers of entry and allowing the rich to get richer and the poor to get poorer.

Clearly, 1990 will be a year of challenges for the global semiconductor industry. However, we believe that the worst is over and that current stabilizing factors—such as inventory control, order improvement, and DRAM production control—are setting the groundwork for an industry recovery. Combined with the favorable economic conditions predicted to persist through 1990 and 1991, we expect the industry to complete its recovery this year and grow at a modest clip in 1991 and beyond.

The topics presented above, as well as many other issues affecting the short-range forecasts and outlook through the mid-1990s, will be discussed at length in Dataquest Conferences (see conference schedules on the next page), including our assessment of technology changes and many of the product and market opportunities of the 1990s.

Dataquest's Industry Services and Central Research Group contributed substantially to the contents of this newsletter.

Paul Wittrock

Dataquest

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1990 Conference Schedule

Semiconductor User and Application Markets	February 12-13	San Francisco, California
Service and Support *(Ledgeway Service Industry Executive Conference)*	April 9-10	Boston, Massachusetts
Japanese Components	April 12-13	Tokyo, Japan
Document Processing	April 23-26	Palm Springs, California
Electronic Publishing	*April 23*	
Electronic Printers	*April 24-25*	
Copying and Duplicating	*April 24-25*	
Color	*April 26*	
Computer Storage	May 2-4	San Jose, California
Dataquest Seminar at SEMICON/West	May 23	San Francisco, California
Opportunity Europe Seminar	TBA (May)	Boston, Tarrytown, San Jose
European Components	June 6-8	Paris, France
Display Terminal and Graphics and Imaging	June 18-19	Monterey, California
European Electronic Printers	June 25-27	Amsterdam, The Netherlands
European Copying and Duplicating	June 27-29	Amsterdam, The Netherlands
Personal Computer	June 27-29	Monterey, California
Distributed/Technical Computing	September 26-28	To Be Announced
Information Systems and Automation	October 1-5	Tokyo, Japan
Semiconductor	October 8-10	Monterey, California
Strategic Industry	October 9-10	Taipei, Taiwan
European Telecommunications	October 10-12	Nice, France
Telecommunications	November 5-7	Monterey, California
European Computers	December 4-7	Barcelona, Spain

For reservations or further information about these conferences, call (800) 624-3282 in the United States, 81-3-546-3191 in Japan, or 33-1-48-97-3100 in France.

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Research Newsletter

THE "NEW" AMD ENTERS ITS THIRD DECADE

SUMMARY

For a decade and a half, Advanced Micro Devices (AMD) was "the company that could." Brash, arrogant, with innovative products, aggressive marketing, lavish parties, and intense employee loyalty, AMD was the premier Silicon Valley company. In the late 1980s, however, the wheels came off the bandwagon. A covey of financial analysts have written the company off as being beyond recovery, destined to the living dead category. Another group of industry experts believes that an acquisition by a much larger company is the only hope. Neither of these situations is inevitable, however, because it is Dataquest's conclusion that AMD, while not ready to challenge NEC or Toshiba for the number one ranking, is in much better shape than most outsiders realize.

BACK TO FUNDAMENTALS—THE ROAD TO RENEWED EXCELLENCE

In the 1970s, the term "lean and mean" was associated more with AMD than with perhaps any other Silicon Valley semiconductor company. Critics of the company's management allege that AMD relaxed its Spartan doctrine in the early 1980s, resulting in its decline. Dataquest is not entirely comfortable with that observation. The management of the company employed a philosophy and strategy that delivered almost 15 years of admirable revenue and profit growth. The fault, if we are forced to find one, is that while the company's management was among the earliest to anticipate the horrendous effect that the Japanese semiconductor industry could have on the fate of the U.S. players, the company nevertheless failed to react quickly enough to the changes that major competition from Japan brought. AMD's management counters that quick reaction was not easy, due to the length of time that it took the U.S. government to reach a consensus on the semiconductor trade issue. In particular, AMD's leaders expressed frustration that the delay cost the company valuable market share in both the United States and Japan.

Almost like the dinosaurs of a million years ago that failed to sense a certain chill in the air, AMD continued on a path that had heretofore produced distinction. By the mid-1980s, however, the company was in trouble. Today, AMD appears to be an entirely different company from either the spunky start-up of the 1970s or the somewhat disarrayed leviathan of the 1980s. Like a middle-aged man who has just survived cardiac arrest and has seen fit to change lifestyles, AMD appears once again to be lean, robust, and considerably wiser. Its management readily gives the perception of having come to grips with the rules of the coming decade. Chairman Jerry Sanders is back to focusing on sales and marketing, his province of personal excellence. Tony Holbrook, president and chief technical officer, is concentrating on the company's future, while Rich Previte, executive vice president and chief operating officer, is directing day-to-day operations and maximizing profits from the company's core businesses that must carry AMD into the early 1990s.

ARCHIMEDES AND AMD

Thousands of years ago, the ancients learned of the strength of three-sided structures. This wisdom has not been lost by AMD. The new AMD frequently describes its plans as being "three-legged" strategies. For example, the *immediate course* for the company is as follows:

- **Cost containment.** "Lean and mean" has been replaced with "lean and essential." Within recall, Dataquest has rarely, if ever, listened to a long-range planning presentation in which the

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future didn't look bright. However, the reality is that AMD must achieve profitability with its *existing* capabilities and cadre of products. The company has pared back costs such that breakeven is believed to be in the $260 million to $265 million-per-quarter range. On this basis, the management believes that it will report profitability throughout 1990 in the context of flat IC demand worldwide.

- **Process technology.** Chairman Sanders states, "If you are not with the state of the art in process technology long term, you are not going to be a major player." Much more on this shortly.
- **Leadership and proprietary products** (the company's core products). AMD must continue to dominate its current position in sole-sourced products and its leadership position in multisourced chips. AMD's performance in 80286 processors during 1990 will be critical to the company. Proprietary products present a different twist. AMD views these as products that have a high barrier to exit (the opposite of entry). These are devices that once designed in, are highly unlikely to be replaced by competitive parts. These include AMD's 29K embedded microprocessor products, the company's formidable position in programmable logic devices, and its network and LAN chips.

SILICON VALLEY'S LARGEST CMOS START-UP COMPANIES

Quickly now, what Silicon Valley company has the highest growth rate in CMOS? LSI Logic? VLSI Technology? Cypress? IDT? Very few would fault you if you failed to mention AMD; however, based on Dataquest's latest figures, AMD's CMOS revenue in the late 1980s appears to have had the highest compound annual growth rate (CAGR) among Silicon Valley companies that have significant CMOS sales. "Fourth quarter 1989 CMOS revenue reached a record 26 percent of total sales," according to Mr. Sanders. In the five years between 1984 and 1989, the company invested more than $1 billion in research and development, most of it focused on CMOS technologies. However, during that same period, the company's management couldn't seem to find the handle on getting consequential market position from that investment. CMOS DRAMs, SRAMs, ASICs, and some microcomponents were started and stopped with dubious frequency. What many observers of the company fail to realize is that while the product positioning during this "dark age" period was less than sterling, CMOS process prowess improved continuously, such that today, AMD has the *positioning* to be one of the few dominant CMOS powerhouses of the 1990s. We believe that by the end of fiscal year 1990, approximately one-third of the company's projected revenue will be derived from products manufactured in advanced CMOS technologies. The company's new more than $100 million development center has been designed around a 0.35-micron capability. By current standards, as we enter the next decade, AMD should be on par with any worldwide semiconductor producer when technology and manufacturing capability are being measured.

A central strategy of the company is to seize CMOS product opportunities. EPROMs, which were a bane to the company in 1987, were a boom in 1989. The differences are not subtle. In 1988, about one-third of the company's EPROM products were in CMOS technology, compared with the fourth quarter of 1989 when essentially 100 percent of AMD's EPROM chips were being fabricated in the company's state-of-the-art CMOS factories. AMD's original business plan mentioned bipolar technology so frequently that one concluded that MOS to the company meant "mostly others' strategy." At the dawn of the last decade of this century, the company's management has declared that "bipolar is dead" and is aggressively converting its programmable, microcontroller, and "targeted market" products to CMOS. Dataquest accepts the company's bipolar obituary in the context of broad future growth opportunities. However, we believe that AMD has an excellent opportunity to dominate certain bipolar technology markets such as high-speed PALs, in which bipolar is the only way to get there.

WHEN YOU END UP WITH LEMONS, MAKE LEMONADE

Process proficiency and manufacturing adroitness are only part of the formula. The industry is legion with entities that made huge capital investments but failed to execute when challenged. Nobody at AMD has attempted to hide the fact that the loss of the Intel 80386 manufacturing and marketing rights was a formidable and mostly unanticipated blow. The company swallowed hard and responded with an ultrahigh-performance *CMOS* version of the industry-standard 80286, the 80C286. Critics argue that the '286 is passé and that AMD is still living in the waning warmth of past glory. This observation is probably true for desktop PCs, but it is clearly not accurate for laptop and notebook computers in which the 80286, especially a low battery drain CMOS version, will be the workhorse.

Dataquest has forecast that the laptop and notebook segment of the PC market will grow at a CAGR of 60 percent over the next four years. At a minimum, this provides AMD with the opportunity to coin good revenue from its super 286 CMOS chips through 1993 or 1994. Intel is not unacquainted with this opportunity, but intends to ride its 32-bit 80386SX horse to battle. Intel has launched a curious, if not unique advertising offensive that politely discredits the supposedly anachronistic 80286 in favor of the totally modern 80386SX. Intel appears to be counting on the concept that only the most radical of the "plastic pocket protector set" buys a computer on the basis of CPU chip specifications, and that the vast majority of PC purchasers will conclude that 32 bits are always better than 16. Conventional wisdom is probably on Intel's side in this issue; hence, AMD is going to have to augment its strategy with a premium.

Dataquest believes that the 80C286-versus-80386SX performance specifications will be largely lost in the dust as far as the users are concerned, and that the real contest will be price. This being the case, AMD has an arguable advantage over Intel. AMD's significantly smaller CMOS 286 chip has less than half the number of transistors as Intel's 386SX. As such, the company's game plan of keeping the 80C286 priced at less than half of the 80386SX appears to be a viable strategy. If the company can employ an attractive price to gain the users' attention, a CMOS 286 that runs Windows and OS/2 as well as DOS, plus 25-MHz performance and a "sleep mode" for battery operation, may find its way to a lot of sockets in the early 1990s.

Before we leave this topic, AMD's management advises us that with regard to the litigation pending with Intel over rights to the 80386, a ruling on liability is expected by mid-1990, with a remedy session to follow.

DATAQUEST ANALYSIS

So, is AMD out of the woods? No, but neither is the company lost without a compass. AMD's manufacturing and technology capabilities are as good as anybody's in the world. The trick now is to focus on product execution. Technological prowess was sufficient to establish leadership in the 1970s, and niche strategies worked in the 1980s. Dataquest believes that the companies that move to the top in the 1990s will be the ones with products that can overwhelmingly dominate their market of choice, à la Intel or Motorola in microprocessors where one almost needs binoculars to see the other competitors. It's not apparent that AMD is in that position at this time; however, there are forces coming together that suggest that the company's product portfolio could start delivering predictable revenue growth and improved profit performance. AMD holds approximately 10 percent of the fast-growing EPROM market and is the number one supplier of 1Mb devices. Its 2Mb device is currently ramping, with the 4Mb product to follow shortly. The company's position in both bipolar and CMOS PLDs is excellent, as is its future in the increasingly important field programmable gate array (FPGA) market. With laptop and notebook PCs expected to grow at a brisk rate in the early 1990s, AMD should do well, especially on a unit basis, with its iAPX86 CMOS, high-performance, 80286 microprocessor. Rounding out this list are the company's FDDI, ISDN, and embedded microdevice products.

This stable of products, while insufficient to give the company a hammerlock grip on any one market, should nevertheless provide the foundation for above-average growth over the next several years. The company management apparently thinks the same way. In the nearer term, Wall Street estimates place AMD's 1990 revenue in the $1.175 billion to $1.200 billion range, with earnings per share of $0.55 to $0.65. This translates to approximately 7 percent revenue growth during a period when Dataquest believes that semiconductor revenue worldwide will increase only about 1 to 2 percent. Can the company leverage this position of renewed health to the next echelon where it begins to dominate key markets? The management thinks so. We'll have to wait and see.

David L. Angel

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Research *Bulletin*

DRAM MARKET UNCERTAINTY FORGES ALLIANCE

SUMMARY

Intel Corporation and NMB Semiconductor (NMBS) (part of the Minebea Group of Japanese companies) announced a joint venture on January 22 whereby Intel will be the sole worldwide distributor for NMBS's DRAM products. This joint venture will combine NMBS's highly automated, low-cost manufacturing capability with Intel's extensive sales and marketing network worldwide. Roger Norby, vice president and general manager of Intel's Contracting and Random Access Memory Division, will head up the new venture, to be called Intel/NMBS DRAM Fabrication Company. Transfer of the total output from Minebea to Intel should be completed by the end of the third quarter of 1990. Intel's DRAM resale arrangements with Micron and Samsung will continue, and Intel will honor any of NMBS's existing agreements. Initially, Intel will make a "nominal" investment in the venture; this investment was characterized as a "goodwill gesture." Dr. Gordon Moore, Intel chairman, speculated that the deal could add as much as $100 million in revenue to Intel this year.

INTEL'S DILEMMA: CAN IT BE A U.S. DRAM SUPPLIER WITHOUT BUILDING A FAB?

In Dataquest's opinion, Intel seems to be attempting to derive a formula whereby it can operate successfully as a U.S. DRAM supplier without having to foot the capital outlay expenses, thus avoiding the worst vagaries of the commodity DRAM market. Intel apparently hopes to achieve this in a number of ways. First, there is considerable synergy between the two companies' product lines. NMBS sells high-speed DRAMs to the high-performance PC and workstation users, and with this broadening of its product line, Intel would hope to garner increased exposure among such accounts where it also targets sales of its high-end microprocessors. Moreover, the high-speed DRAM product offered by NMBS is probably less susceptible to the very wide price variations experienced in the commodity DRAM market. This stability will provide some insulation from drastic price declines. The agreement establishes a mechanism for frequent pricing review, which Intel expects will also minimize its risk. However, Dataquest assumes that because of Intel's status as NMBS's sole distributor, it will be very important to both parties that the logistics of managing NMBS's production capacity be well executed.

CAPITAL SPENDING

NMBS will continue to make the capital-intensive investments necessary to manufacture future generations of product. Currently, NMBS manufactures high-speed DRAMs at two fabs in Tateyama, Chiba, Japan, and expects to complete a new $350 million 4Mbit DRAM facility in the second quarter of 1990. The 200,000-square-foot facility will have an initial processing capacity of 10,000 6-inch wafers per month, increasing to 20,000 wafers per month when fully operational. Initially, NMBS's new fab will produce stacked-trench 4Mbit DRAMs. Subsequent production plans include planar ferroelectric DRAMs using technology accessed though the company's agreement with U.S. start-up, Ramtron. Intel's insistence that it would avoid having to make the capital investment for a DRAM fab would seem to indicate that NMBS will be totally responsible for the funding of a fourth fab in the United States—site and timing undisclosed. This makes sense in light of another comment made by Dr. Moore stating that one of the benefits accruing to Intel from this arrangement would be access to low-cost Japanese capital.

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DRAM DISTRIBUTOR

This joint venture could prove to be very interesting because it means that a U.S. company will be distributing Japanese product worldwide, including in Japan. Strategically, this could be an excellent move for Intel. Intel will have the opportunity to work with a Japanese supplier to gain greater access to the Japanese market with a broader product line. Intel has sold memory devices previously, but primarily through distribution. This deal would seem to imply that Intel will need to strengthen its direct sales channel for memory, which is the channel that users of high-performance devices typically buy through. Because of the synergy between NMBS's DRAMs and Intel's microprocessors, Intel will be able to deploy its own strong OEM distribution channel to good advantage.

TECHNOLOGY ISSUES

NMBS will continue to procure DRAM designs as it has in the past from companies such as Alliance, Inmos, Ramtron, and Vitelic. Intel gains access to NMBS's strong memory-oriented memory process technology. Exactly what kind of access this arrangement will permit Intel to other companies' technology remains to be seen, because it will presumably depend on the terms of their respective contracts with NMBS. Dr. Moore anticipates that as the sole distributor of NMBS's product, Intel will have some influence on what the new products should be. One of NMBS's acknowledged strengths is the highly automated nature of its fabs, which does not lend itself to conversion to multiple products—thereby limiting the venture solely to DRAM production. Lost technical expertise in this area on Intel's part makes it unlikely that Intel would consider direct reentry into the DRAM market.

DATAQUEST ANALYSIS: POTENTIAL MARKET IMPACT

According to Dataquest's most recent worldwide market share survey, NMBS held the number 15 position worldwide in the MOS memory market, with memory revenue estimated at $279 million, up from $199 million the prior year. NMBS is the leading supplier of high-speed DRAM devices. From NMBS's perspective, this relationship will allow it to gain an expanded customer base and not have to maintain a large sales force and support organization for a narrow product line. A longer-term benefit could be the possibility of access to European fab capacity through the Intel connection in order to meet the EC's 1992 policy regarding domestic IC production.

Based on our analysis, this venture would appear to very much stack up in Intel's favor. Although this arrangement seems like an interesting move from Intel's perspective by extending its DRAM product portfolio and complementing its microprocessor line, it remains to be seen whether or not NMBS can remain a low-cost manufacturer with competitive technology, given that it historically has been dependent on external design/technology development.

Patricia Galligan
Fred Jones
Bart Ladd

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Research Newsletter

DATAQUEST CONFERENCE LOOKS TO DECADE OF OPPORTUNITIES

INTRODUCTION

October is one of the loveliest months of the year along the Northern California coast, with warm clear days and crisp cool nights. This was the environment for Dataquest's 16th annual Semiconductor Industry Conference in Monterey, October 8 and 9, 1990. A near-capacity crowd enjoyed the Monterey weather, good food, and challenging discussions as participants and speakers looked ahead through the decade.

Dataquest president Manny Fernandez set the conference theme—"The Next Decade. . .Where Do the Opportunities Lie?"—with a look at future products and the technologies necessary to support them. He envisioned a decade of growing wireless communications, smart home products, higher automation in the office, multiple-use smart cards, real-life imaging, multimedia, and electric cars. To make these products work, Mr. Fernandez said, we need microprocessors that run at 250 mips, ASICs with logic that use more than 100,000 gates, analog devices that operate in the gigahertz ranges, and memories beyond the 64Mb size.

But the industry must deal with some major issues such as the education crisis, which is a major limiting factor for industry, he said. The industry will need to change, because the cost of capital is forcing new intercompany agreements. Common R&D and production facilities may become necessary. Cooperation, a theme repeated by nearly every speaker, emphasized an urgency for closer relationships between suppliers and customers.

Figures 1, 2, and 3 show conference attendees working hard exploring future opportunities and later enjoying a private tour and buffet dinner at the Monterey Bay Aquarium.

FIGURE 1
All Work and No Play. . .

Source: Dataquest (November 1990)

SIS Newsletters Components Group

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Figure 2
Attendees at Buffet Dinner

Source: Dataquest (November 1990)

Figure 3
Visiting the Aquarium

Source: Dataquest (November 1990)

THE ISSUES

The Evolving PC

Roger Johnson, chairman, president, and CEO of Western Digital Corporation, examined the changing PC as a driving force in semiconductor development. The PC will be a companion to the way we think, replacing pencil and paper, operating without a keyboard, and offering new ways to communicate, he said. PCs will be smaller, be lighter, and have more functions, and they will be fully portable like a notebook or vest pocket date book, not just carryable.

These PCs will be able to draw on vast networks and databases because of their high connectivity. Their low cost and ease of use will place them in the hands of average people who today have little direct contact with computers. Mr. Johnson believes that mass storage will change from the disk to solid state. "The days of PCs being technology driven are over," he said. "In the future they will be application driven, based on the user's needs." He sees the small and portable computers as the drivers for expanding the existing market areas.

The New Face of Personal Electronics

Hiroyuki Mizuno, executive vice president and member of the board of Matsushita Electric Industrial Co., Ltd., said the boundaries between science, industry, and home products are fading as personal electronics gain more information-handling and communications abilities. Systems are becoming more user friendly, often being preprogrammed for human needs, Mr. Mizuno said. For instance, there are washing machines that use fuzzy logic to determine the amount of detergent needed and how long to wash, based on the amount of dirt in the clothing. Or air conditioners that self-adjust, depending on the outside temperature, the humidity, and the number of people in the room.

Mr. Mizuno sees an increasing trend toward personalization of electronics in the growth of individually used products. This trend is leading to more interactive multimedia technology for information, education, and business and will grow in home use.

Straining for a National Budget

Congressman Tom Campbell, a representative from the Silicon Valley area, brought the governmental point of view to the conference attendees, but not according to plan. Scheduled to speak at Monday's luncheon, he was kept in Washington, D.C., by the budget conflict. However, Congressman Campbell spoke from his office via an audio link.

He reported on the difficulties of arriving at a budget compromise because of economic assumptions that, at the time, he believed to be flawed. The assumptions included an oil price at $24 per barrel or less, an inflation rate of 5.2 percent in 1990 dropping to 3.0 percent in 1994, and a 90-day T-bill interest rate falling from 7.7 percent in 1990 to 4.2 percent in 1995.

Congressman Campbell sees the Administration position on high technology as one of macroeconomics, preferring to provide the right environment through lower interest rates, lower capital gains tax, a lower budget deficit, R&D tax credits, and a better intellectual property regime rather than direct support. He believes that the White House will oppose direct governmental contributions to commercial technology, similar to that for military technology through DARPA.

Corporate Strategies for Success

The industry has seen three basically different types of semiconductor companies develop and grow in the 1980s—fabless, pure-play semiconductor, and building-block supplier. The issue of which type will be the most successful in the 1990s was examined by a panel of three top executives from three successful companies: Dr. T.J. Rodgers, CEO of Cypress Semiconductor (pure-play); Frank Gill, Intel Corporation senior vice president and president of Intel Systems Group (building-block); and Gordon Campbell, president and CEO of Chips & Technologies (fabless). David Angel, vice president of Dataquest's Semiconductor Components Group, moderated the discussion. Mr. Gill, Dr. Rodgers, and Mr. Campbell are shown in Figure 4.

Representing the pure-play position, Dr. Rodgers led the session by attacking the concept that Japan was an unbeatable juggernaut in the

FIGURE 4
Corporate Strategists

Source: Dataquest (November 1990)

electronics industry. He noted that the United States, not Japan, has the highest productivity level and the world's largest economy, and Germany has the most favorable trade balance. Dr. Rodgers did the following:

- He disputed the estimates of capital needed to design and build a fab. (Cypress has invested only $80 million in two fab locations.)
- He disputed the estimates of $200 million to design a microprocessor. (Cypress invested $7 million in Ross Technologies to produce a RISC microprocessor.)
- He said that a major competitive hindrance for many US semiconductor producers is low production yields, but Cypress is closing this gap with Japan.

Mr. Gill said that the building-block supplier looks at the different functions of a PC and then logically combines those functions, often onto a single chip. This building-block approach has resulted in the number of chips in a PC being reduced from 170 to less than a dozen plus memory.

He said that it is necessary to market at a product level the customer wants. Intel, for example, sells chips, modules, subsystems, or even complete systems but does not consider itself a vertically integrated company. However, it can result in a company relationship as customer, vendor, and competitor simultaneously.

Mr. Campbell said the advantages of the fabless supplier for the producers include higher profitability, more consistent costs, lower financial risks, faster product ramp-ups, and the ability to migrate technologies quickly.

The customer's advantage of using a fabless supplier is as follows:

- The value added by design
- Time to market
- Stable product costs, because equipment utilization does not impact costs as it does in companies with fabs
- The ability to move quickly into new technologies, because a fabless company uses multiple foundries and can offer a variety of technologies

Mr. Campbell believes that chips of the future will be more complex, containing more software and performing more functions. He also foresees more use of outside foundries, even by companies that have fabrication facilities.

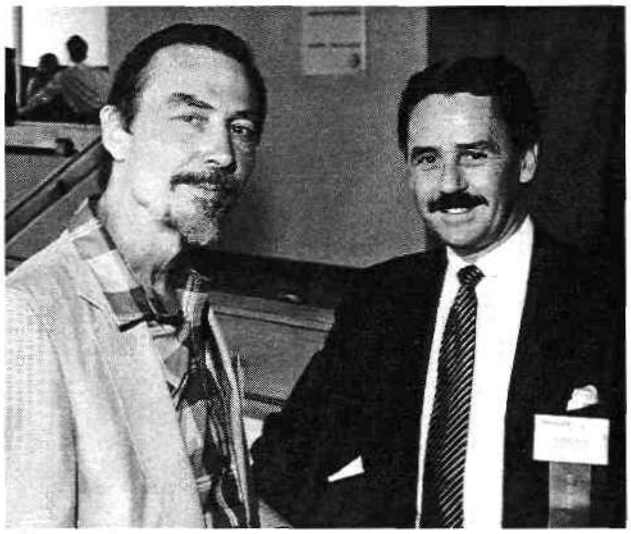
The panelists said that the increasing cost of capital is a key issue and could slow the rate of technology development. They all said that the business climate for semiconductor producers in the United States is becoming more difficult, so company executives should be better educated about the marketplace and should change their companies to fit market shifts.

The Semiconductor Wake-Up Call

Conference attendees heard Professor Carver Mead of the California Institute of Technology comment on the perpetuation of change in the semiconductor industry. Dr. Mead shared his "Mead's Laws of the Economics of Innovation," which include Return on Innovation, the Headroom Principle, and the Repeated Major Innovation Law. Figure 5 shows Dr. Mead meeting with Dataquest's David Angel before speaking to a capacity audience.

Dr. Mead foresees no slowdown in innovations during the 1990s. He defines a "major" innovation as ". . .you weren't looking for it there. Most of these innovations I was standing right there looking, and I was looking the wrong way. Major innovations are always the ones in a different direction than everybody is going and therefore cannot be planned."

FIGURE 5
Decade of Innovation Discussed



Source: Dataquest (November 1990)

FIGURE 6
Trying to Get Smaller

Source: Dataquest (November 1990)

Getting to Smaller Geometries

Lithography represents a critical enabling technology for producing semiconductors of submicron geometries, a principal requirement for developing the high-performance products of the 1990s. Lithography equipment constitutes the largest segment within the worldwide wafer fabrication equipment market, essentially 25 cents of every dollar spent on front-end equipment. But very little of the equipment purchased in the 1980s will be usable for making the masks needed in semiconductor production.

Dataquest gathered a panel of four experts from the equipment and user communities to discuss these issues. The panelists were Dr. Gene Fuller, manager, Stepper Programs, SEMATECH (optical lithography); Robert Hill, functional manager, Advanced Lithography Systems, IBM (X-ray lithography); Dr. Neil Berglund, assistant to the president and executive director of marketing, ETEC Systems (e-beam lithography); and Dr. John Skinner, director of advanced photomask technology at DuPont Photomask (maskmaking). Dr. Fuller, Dr. Berglund, and Mr. Hill are shown in Figure 6. Dr. Peggy Wood, senior industry analyst of the Dataquest Semiconductor Equipment, Manufacturing, and Materials Service (SEMMS), moderated the panel discussion.

The panelists concluded that optical lithography will continue to be the dominant technology for several years because of the significant installed equipment base and know-how. Also, a considerable time lag is associated with developing new technologies. If optical lithography is going to be replaced in the next ten years by another lithography technology, a full development effort must be started today. Lithography equipment costs will go up in every equipment category as mask specifications get tighter and the design rules continue to shrink.

The Memory Impact

Most of Tuesday morning was devoted to memories, specifically DRAMs. Dr. Tsugio Makimoto, general manager, Semiconductor Design and Development Center, Hitachi Ltd., said that the current $14 billion DRAM market will grow to $100 billion by the year 2000. The gigabit era will replace the megabit era. Memory consumption today at 160Kb for every man, woman, and child in the world will become 8Mb by the end of the decade.

The most crucial issues affecting the ability to meet user needs are lithography, packaging, and costs, said Dr. Makimoto. Product diversification will increase, and many memory products will include ASIC-type logic functions. But progress will have a price, he said. The cost to produce a million parts a month will go up, yield will become more critical, and the investment costs will become much heavier.

A panel discussion, led by Mr. Angel, focused on operating conditions, costs, and constraints of the 1990s. The panelists included David Sear, vice president of Fujitsu America; Robert Brown, vice president and group executive of Toshiba America Electronic Components; William Gsand, vice president and general manager of Hitachi America Ltd.; Joseph Parkinson, chairman and CEO of Micron Technology; and Frank Jelenko, vice president of NEC Corporation. Figure 7 shows Mr. Brown, Mr. Sear, Mr. Gsand, and Mr. Jelenko enjoying the balmy weather during the morning break.

The panel believed that the price-per-bit would be influenced by the following:

- Die size—Die size is becoming increasingly difficult to shrink.
- Wafer size—Increasing wafer size increases the number of die processed at the same time, reducing unit die cost.
- Wafer fab cost—Increasing equipment cost will drive up cost per bit.
- Cost of capital—Higher capital costs reduce return on investment.
- Process cost—Complex architectures may need up to 30 mask steps. Mr. Parkinson disagreed that so many mask steps are needed.
- Diversification—As the number of formats and packages increases, smaller process lots are run, thus increasing costs. The number of distinctive parts estimated by Mr. Brown and Mr. Gsand reach into the hundreds for the four standard DRAM sizes.

All agreed that multichip modules (MCMs), particularly with embedded logic functions, were in the future. Mr. Brown thought DRAMs would be shifting to 3.3V by 1994, and Mr. Sear said he thought epitaxial wafers would be needed for the 64Mb parts.

Packaging for High Performance

As chip performance increases, packaging issues become more critical. Dataquest's industry analyst for packaging, Mary Olsson, forecast some dramatic changes that could alter the semiconductor and printed circuit board industries. The demand for high-density interconnect capabilities will drive the industry toward MCM (see Table 1).

Ms. Olsson said that although the dual in-line package (DIP) still is the leader, it is experiencing

FIGURE 7
Enjoying a Break

Source: Dataquest (November 1990)

TABLE 1
Multichip Module Drivers

	Current	Near Term 1993-1995	Long Term 1997-2000
MPU Speed	20 MHz	100 MHz	300 MHz
ECL			Photonic logic
Logic/ASIC	150-400ps	50-150ps	1.5-2.0ps
Memory	CMOS	BiCMOS	BiCMOS/FERRAM
PC	1MB	16MB	128MB
Workstation	8MB	128MB	512MB
Speed	20-80ns	9-60ns	<25ns
GaAs			
Logic/ASIC	50-80ps	20-60ps	<5-10ps
Memory	16K/3ns	>60K/3ns	>100K/3ns

Source: Dataquest (November 1990)

the end-of-life decline, from 79 percent of all packages in 1989 to 68 percent in 1990. Surface-mount technology will dominate by the year 2000, with the quad flat pack showing the greatest growth rate because of the increasing number of leads.

The Change in User/Supplier Relations

Irv Abzug, General Technology Division vice president and director of corporate procurement at IBM, used the IBM example to tell the audience how semiconductor supplier/customer relationships must change. IBM buys 1.5 billion devices a year and has gone from an "arm's length" relationship to one of shared information using electronic data interchange and a partnership in technology.

The challenges of the 1990s are to provide solutions, not just products, said Mr. Abzug. "Clearly, we are entering a period when companies will either satisfy their customers or simply pass into history." Mr. Abzug noted that quality is a key element in the 1990s because if 99.9 percent of the products shipped were defect-free, then with 1.5 billion devices shipped to IBM each year, 1.5 million would be defective. Mr. Abzug said that suppliers need to be included in product cycles earlier than ever before and that system makers need to share more information with key suppliers.

Redrawing Borders

Europe's semiconductor market is being rejuvenated as Europe goes to a single market in 1992, reported Dr. Jonathan Drazin, Senior Industry Analyst at Dataquest's Denham, England, office. The most difficult challenge for the European Community (EC) is to break down the provincial barriers on technical issues, such as telecommunications standards.

Pan-European markets are beginning to form through R&D projects and the EC's standards committees. Dr. Drazin said he already sees an impact through the restructuring of companies, such as GEC and Siemens buying the telecommunications and defense company Plessey, to take advantage of a more unified market.

Dr. Drazin said the initial opportunities for business with Eastern Europe are in telecommunications. Eastern Europe and the USSR cannot wait to build a telecom infrastructure from the inside. "Without a telecom infrastructure that works, no industry in Eastern Europe can compete effectively. Without an industry, there will be no private income for individuals to sustain the consumer electronics market," he concluded.

Conference attendee Tom Egan (AT&T) chats with Dataquest president Manny Fernandez in Figure 8.

Figure 8
A Moment to Socialize

Source: Dataquest (November 1990)

The Price of the Future

Accomplishments do not come free, and the cost to compete is growing faster than the semiconductor market, Dataquest's Fred Zieber, vice president, told conference participants. The magnitude of current and future costs points to a change in the structure and nature of the semiconductor industry, and he envisions a significant attrition in the future.

Mr. Zieber concluded:

- The next five years will be difficult for semiconductor companies, and the survivors will be the ones pursuing long-term strategic roles.
- In some product areas, success will have as much to do with finance as with technology.
- The cost and complexity of building a fab, requiring outside project management, will have a leveling effect on technology.
- The expected decline in the number of chips per wafer will increase wafer capital and processing costs and slow the rate of price/performance improvement.
- Midsize semiconductor companies will feel extreme pressure, being too small to be major and too large to be niche players. So small players will have to take a quantum step to become major players.
- Many companies will need to make a choice between competing with dollars and competing with creativity. Some companies will forego fabs, design, or marketing.
- The full-service company is disappearing, and companies must seek new ways to cut costs outside the corporate walls, such as cooperative efforts with suppliers, customers, or other industry members.
- The real price of the future is meeting the need for a quantum increase in efforts outside the corporate walls.

Marc Elliot
Michael Boss
Peggy Marie Wood

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Research Newsletter

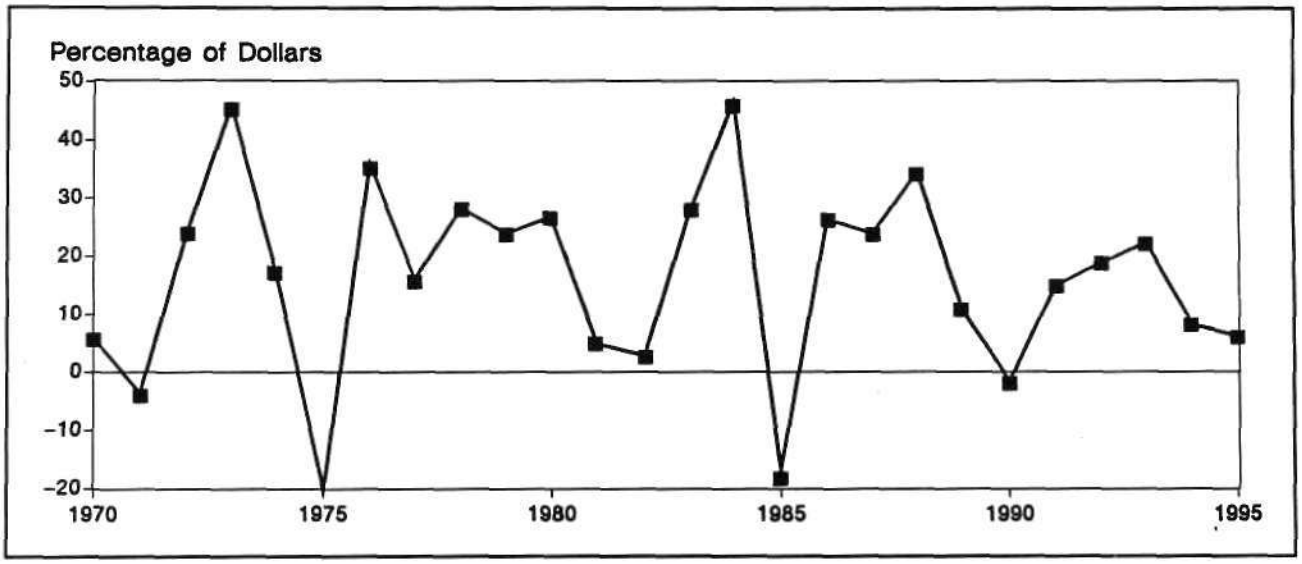
WORLDWIDE SEMICONDUCTOR INDUSTRY OUTLOOK: FOURTH QUARTER 1990

SUMMARY

The year 1990 has not been an easy one for the worldwide semiconductor industry. Although the three-quarter industry recession that began in the third quarter of 1989 had ended by the beginning of the second quarter of 1990, not all product families are equally healthy. Bipolar memory and logic remain in the doldrums. MOS memory prices continue to fall, while unit demand is stagnant to slightly up. The only product families exhibiting strength this year are MOS microcomponents, MOS logic, and analog integrated circuits.

Dataquest has modified its 1990 outlook slightly, to negative 1.3 percent worldwide growth. Longer term, we believe that the years 1991 through 1995 all will show positive annual growth; however, we believe that the magnitude of that growth and of the "silicon cycle" will be below historical patterns. Figure 1 shows annual worldwide semiconductor growth from 1970 through 1995.

FIGURE 1
Worldwide Semiconductor Consumption Growth—History and Forecast



Source: Dataquest (October 1990)

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GENERAL OUTLOOK

As a result of our surveys of semiconductor purchasers, we believe that buyers will take a more conservative attitude toward device procurement during the next six months. In general, lead times are short, availability is good, and prices are less volatile than they were six months ago. We believe that device availability will remain good through 1991. Our procurement survey also indicates that orders for semiconductors in September will grow approximately 14 percent from August levels.

We have observed a shortage in silicon wafer supply that will most likely last until 1992. Since 1985, silicon wafer manufacturers have made few new capital investments in response to severe pricing pressure in that market. Today's shortage is a direct result of that lack of investment. We believe that it may influence the strategic alliances of wafer suppliers and semiconductor manufacturers, especially those second-tier manufacturers that have not yet built long-term relationships with material suppliers.

Regional Outlook

In 1990, we expect the North American and Japanese markets to decline by 2.7 and 7.0 percent, respectively. Primarily, this decline is due to a poor first quarter, although moderate quarterly growth resumed in the second quarter. In 1990, Europe and Asia/Pacific-Rest of World (ROW) both will show moderate growth of 8.3 and 8.4 percent, respectively, the result of strong showings in the first half of the year, although growth has slowed considerably from first-half levels.

In Europe, local currency growth is expected to be *negative* 4.2 percent in 1990; however, the weakening of the dollar against European currencies will cause dollar growth to look unduly strong. Both Europe and Asia/Pacific-ROW are being affected now by lackluster demand from the PC industry, particularly from PC clone makers. Table 1 shows our quarterly forecast for the four major regional markets through 1991.

In the long term, we believe that semiconductor growth will slow from its historical rate. We forecast a worldwide compound annual growth rate (CAGR) of 14.0 percent from 1990 through 1995. The fastest-growing regions, as previously forecast, will be Asia/Pacific-ROW at 19.1 percent and Europe at 14.9 percent, followed by North America at 13.3 percent and Japan at 12.3 percent. Asia/Pacific-ROW will continue to gain share of the worldwide market, but at a slower rate than during the previous five years.

Figure 2 illustrates our long-term forecast for the four major regional markets.

Product Outlook

Memory is clearly an area of some concern, as it is by far the largest single family of semiconductor products. We anticipate extremely competitive pricing for 1Mb, 4Mb, and 256K DRAMs for the balance of 1990. The sluggish demand for 4Mb devices stems from the lack of design-ins, which is due partially to a shift to a larger package size and partially to the continuing price declines in 1Mb devices, which continue to make 1Mb DRAMs cost-effective. We expect a definite shift to the 4Mb device to occur about mid-1991. Again, the lack of strength in the PC clone market is having a negative effect on DRAM demand.

SRAMs are being abandoned in droves, as AMD, National Semiconductor, Philips, VLSI Technology, and others leave the market. We expect this occurrence to shore up pricing among the remaining suppliers. In addition, some new entrants have already announced their intentions to join the fray.

In the microcomponent arena, the first half of 1990 was very strong, particularly for 80386SX and DX microprocessors. The resulting shortages now have been worked through, and we now observe an apparent oversupply situation. PC chip set vendors are experiencing a slowdown in demand, particularly for 286 products. Combined, these indicators point to a slowdown in microcomponent revenue in the fourth quarter of this year, which will carry over into the first quarter of 1991.

Analog, discrete, and optoelectronic chips all are expected to show positive growth in 1990. Demand picked up strongly in the second quarter of 1990, and we expect it to continue. Within the analog segment, mixed-signal ICs are an area of strength; we expect this segment to be the fastest-growing portion of analog IC sales in the future.

Table 2 shows our quarterly outlook by product family. Figure 3 illustrates the long-term outlook by product family.

DATAQUEST ANALYSIS

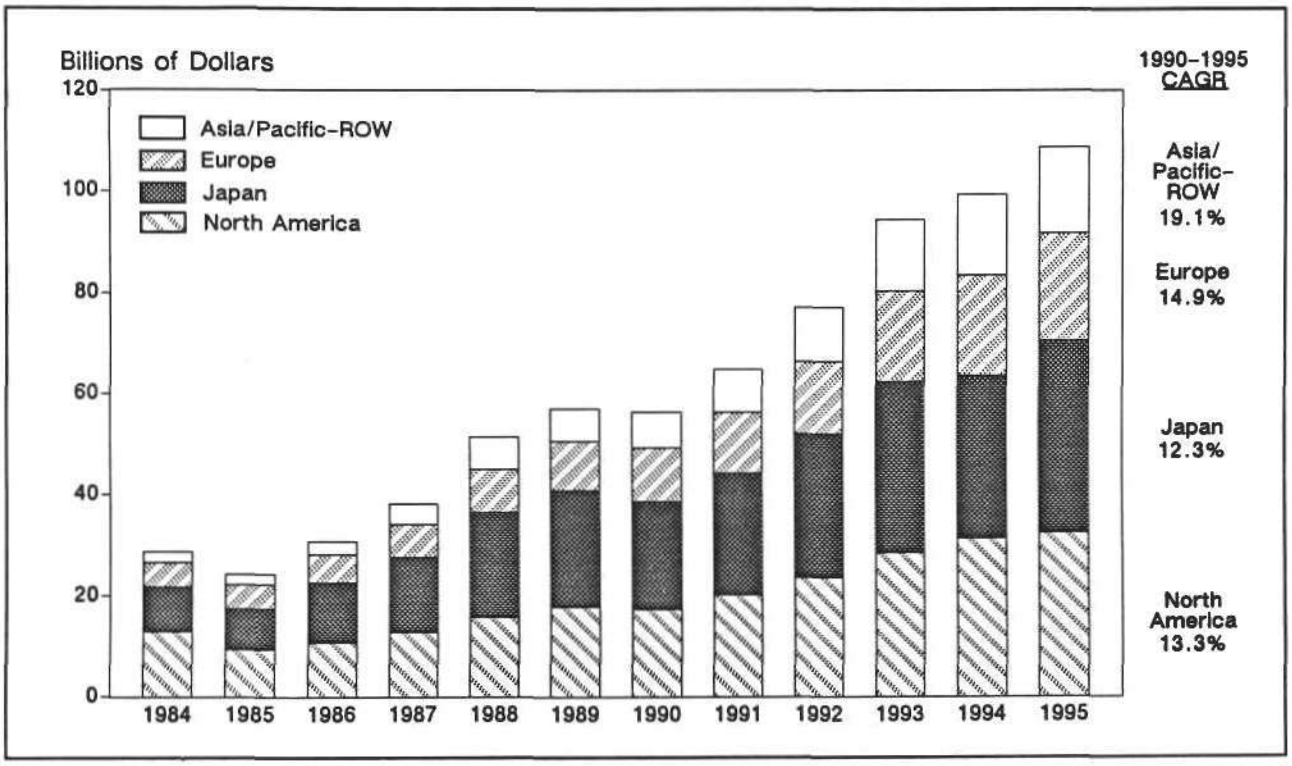
Dataquest believes that the worldwide semiconductor market has firmly emerged from its 1989-1990 recession and has been showing

TABLE 1
Quarterly Semiconductor Consumption by Region
(Millions of Dollars)

	Quarter 1990				
	First	Second	Third	Fourth	1990
Worldwide	13,443	13,915	14,226	14,885	56,469
Percent Change	(4.0)	3.5	2.2	4.6	(1.3)
North America	4,222	4,343	4,382	4,510	17,457
Percent Change	(3.9)	2.9	0.9	2.9	(2.7)
Japan	5,089	5,199	5,410	5,679	21,377
Percent Change	(9.7)	2.2	4.1	5.0	(7.0)
Europe	2,526	2,584	2,624	2,832	10,566
Percent Change	7.0	2.3	1.5	7.9	8.3
Asia/Pacific-ROW	1,606	1,789	1,810	1,864	7,069
Percent Change	(0.2)	11.4	1.2	3.0	8.4
	Quarter 1991				
	First	Second	Third	Fourth	1991
Worldwide	15,199	15,934	16,530	17,278	64,941
Percent Change	2.1	4.8	3.7	4.5	15.0
North America	4,696	4,981	5,199	5,481	20,357
Percent Change	4.1	6.1	4.4	5.4	16.6
Japan	5,693	5,898	6,135	6,289	24,015
Percent Change	0.2	3.6	4.0	2.5	12.3
Europe	2,896	3,012	3,018	3,192	12,118
Percent Change	2.3	4.0	0.2	5.8	14.7
Asia/Pacific-ROW	1,914	2,043	2,178	2,316	8,451
Percent Change	2.7	6.7	6.6	6.3	19.6

Source: Dataquest (October 1990)

FIGURE 2
Semiconductor Consumption Forecast by Region
(Millions of Dollars)



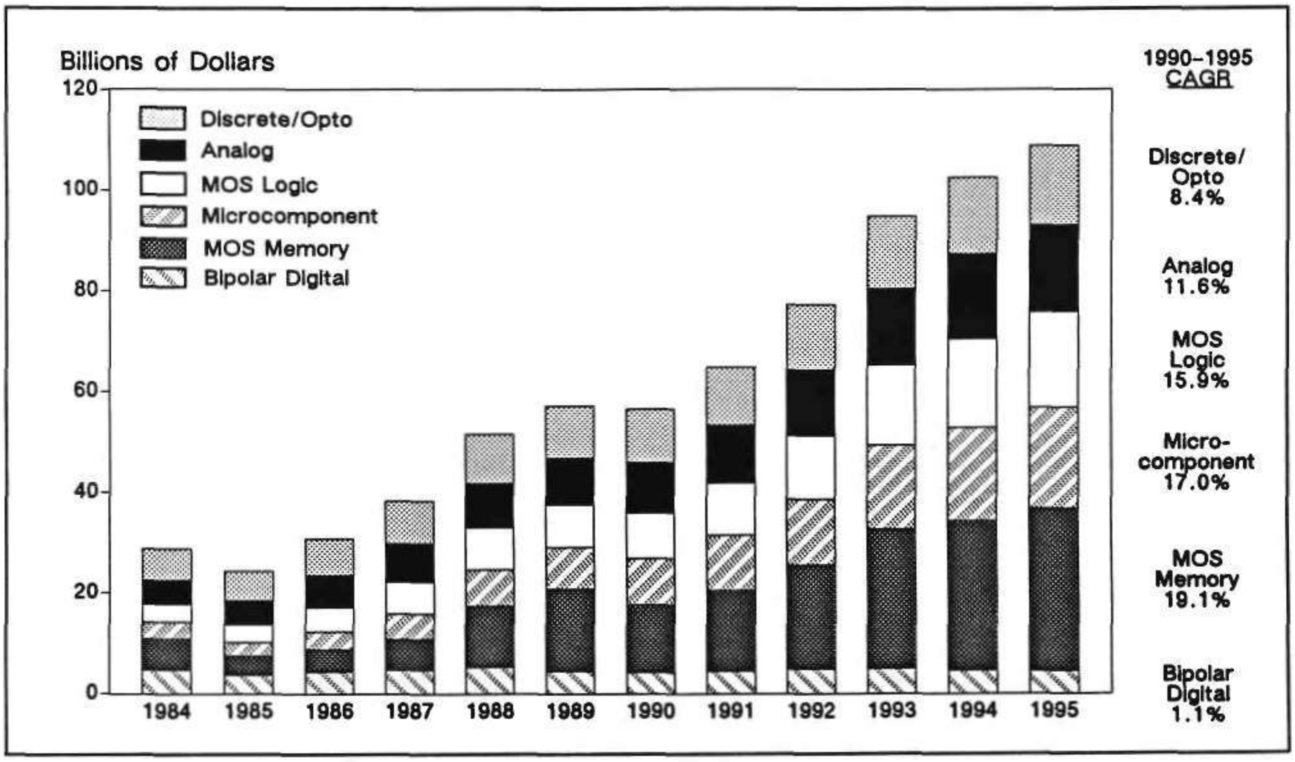
Source: Dataquest (October 1990)

Table 2
Quarterly Semiconductor Consumption by Product Family
(Millions of Dollars)

	Quarter 1990				
	First	Second	Third	Fourth	1990
Total Semiconductor	13,443	13,915	14,226	14,885	56,469
Percent Change	(4.0)	3.5	2.2	4.6	(1.3)
Bipolar Digital	1,053	1,074	1,062	1,064	4,253
Percent Change	(2.6)	2.0	(1.1)	0.2	(5.7)
MOS Memory	3,334	3,277	3,318	3,484	13,413
Percent Change	(11.9)	(1.7)	1.3	5.0	(18.0)
MOS Micro Device	2,073	2,260	2,394	2,471	9,198
Percent Change	0.2	9.0	5.9	3.2	12.1
MOS Logic	2,125	2,197	2,290	2,454	9,066
Percent Change	0	3.4	4.2	7.2	7.2
Analog	2,334	2,501	2,525	2,656	10,016
Percent Change	(1.9)	7.2	1.0	5.2	6.7
Total Discrete	1,895	1,938	1,943	2,030	7,806
Percent Change	(0.5)	2.3	0.3	4.5	1.9
Total Optoelectronic	629	668	694	726	2,717
Percent Change	(4.1)	6.2	3.9	4.6	3.4
	Quarter 1991				
	First	Second	Third	Fourth	1991
Total Semiconductor	15,199	15,934	16,530	17,278	64,941
Percent Change	2.1	4.8	3.7	4.5	15.0
Bipolar Digital	1,086	1,129	1,144	1,183	4,542
Percent Change	2.1	4.0	1.3	3.4	6.8
MOS Memory	3,679	3,921	4,096	4,308	16,004
Percent Change	5.6	6.6	4.5	5.2	19.3
MOS Micro Device	2,486	2,668	2,792	2,923	10,869
Percent Change	0.6	7.3	4.6	4.7	18.2
MOS Logic	2,456	2,568	2,642	2,757	10,423
Percent Change	0.1	4.6	2.9	4.4	15.0
Analog	2,648	2,756	2,971	3,098	11,473
Percent Change	(0.3)	4.1	7.8	4.3	14.5
Total Discrete	2,098	2,127	2,129	2,238	8,592
Percent Change	3.3	1.4	0.1	5.1	10.1
Total Optoelectronic	746	765	756	771	3,038
Percent Change	2.8	2.5	(1.2)	2.0	11.8

Source: Dataquest (October 1990)

FIGURE 3
Worldwide Semiconductor Consumption by Product Family (Millions of Dollars)



Source: Dataquest (October 1990)

moderate growth overall, characterized by stronger growth in microcomponents, MOS logic, and analog and slower growth in MOS memory and bipolar digital products. We expect the bipolar digital market to continue to decline over the long term, as competing CMOS and BiCMOS technologies take over market share. The memory market is beginning to recover. Certainly, the 4Mb DRAM has the potential to drive a mini-boom in that market if volume production and consumption emerge next year.

In the long term, we believe that the silicon cycle will continue to manifest itself, with the cycle's peak occurring in 1993. However, we believe that the overall industry growth will be lower than in past peak years, at 22.5 percent.

Asia/Pacific-Rest of World will continue to gain share of worldwide semiconductor consumption, growing to 15.6 percent of the world market in 1995 from 11.4 percent in 1989. Europe will also gain share, growing from 17.1 percent in 1989 to 19.5 percent in 1995. This growth will be due partially to the 1992 effect but also to the emergence during this forecast period of the new NICs (newly industrialized companies) in the form of the newly democratizing Eastern European countries.

Patricia S. Cox
Rebecca E. Burr

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Research Newsletter

FINAL 1989 WORLDWIDE SEMICONDUCTOR MARKET SHARE ESTIMATES BY APPLICATION SEGMENT

SUMMARY

This newsletter presents Dataquest's final estimates for 1989 worldwide application segment market share by semiconductor vendor. This is the second year Dataquest has conducted such research. The following is Dataquest's analysis based on this information:

- Data processing's share of semiconductor revenue grew a modest 7.8 percent to $23,301 million over $21,606 million in 1988 and remained the key application segment with approximately 40.7 percent of the total semiconductor revenue generated in 1989. Western European and Asia/Pacific-Rest of World (ROW) companies witnessed 1.0 and 1.4 percentage point increases in data processing market share, respectively, with the majority of their gains secured from the Japanese vendors.
- NEC retained its leadership position in data processing with an estimated 10.8 percent of the market and $2,515 million in revenue. It also was a strong player in five of the six application segments, with the bulk of its semiconductor revenue coming from data processing, consumer, and communications. NEC's mission statement is the concept of "C&C," the integration of computers and communications.
- In the consumer application segment, the second largest semiconductor revenue arena, North America- and Western Europe-based semiconductor manufacturers forfeited semiconductor revenue and market share to Japanese vendors.

Table 1 depicts each of the six worldwide application segments and their respective semiconductor revenue estimates in dollars and as percentages of the total market.

The industrial sector experienced considerable gains over 1988 semiconductor revenue, with growth of 18.6 percent. This growth was driven in part by a 13.0 percent growth in commercial aerospace electronic equipment production and approximately 6.0 percent growth in medical equipment production. Vigorous revenue increases also were posted by the communications segment, with a 14.9 percent increase over 1988. Dataquest believes that this increase is in direct response to standardization in the telecommunications industry and increased production of facsimile and cellular telephony.

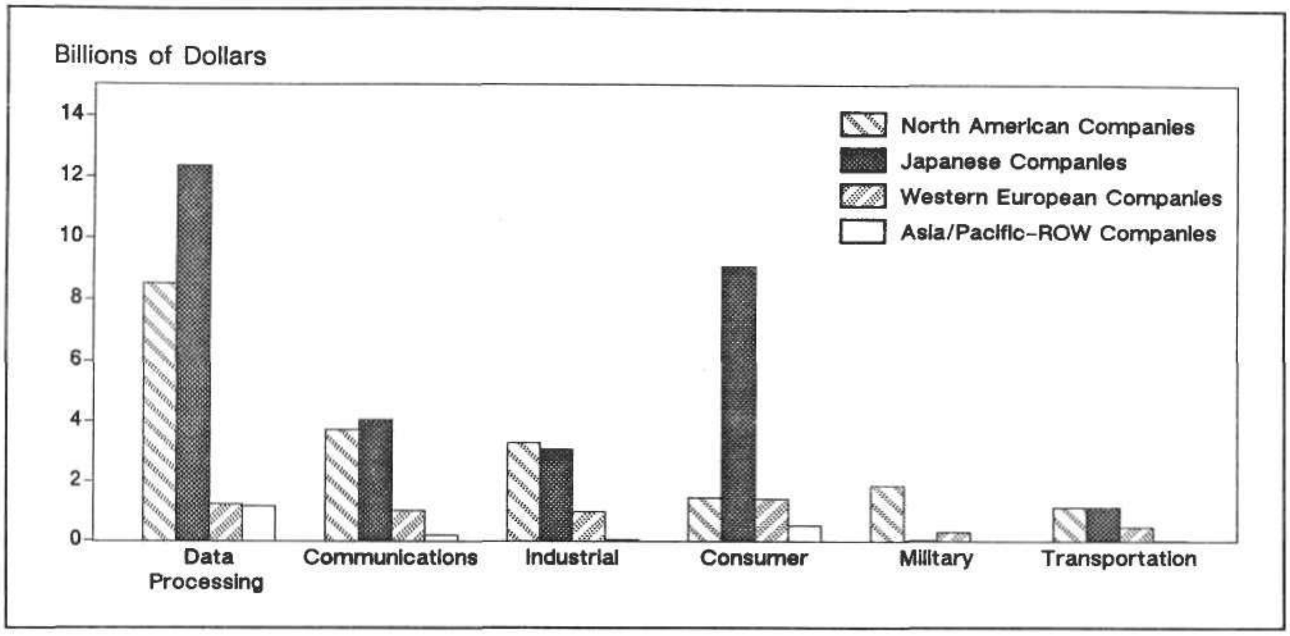
TABLE 1
Estimated 1989 Worldwide Semiconductor Revenue by Application Segment (Millions of Dollars)

Application Segment	Revenue	Percent of Market Share
Data Processing	23,301	40.7
Communications	8,999	15.7
Industrial	7,433	13.0
Consumer	12,523	21.9
Military	2,188	3.8
Transportation	2,769	4.8
Total	57,213	100.0

Note: Does not include North American captive revenue.
Source: Dataquest (August 1990)

Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398 / (408) 437-8000 / Telex 171973 / Fax (408) 437-0292

FIGURE 1
Estimated 1989 Worldwide Semiconductor Revenue by Company Base



Source: Dataquest (August 1990)

REGIONAL ANALYSIS

Figure 1 illustrates worldwide semiconductor revenue by segment and by company base. Japanese companies generated approximately 52.0 percent or $29.8 billion in semiconductor revenue in 1989. The highest levels of Japanese penetration were found in the data processing and consumer application segments, with 53.1 and 72.7 percent market share, respectively.

North America-based companies were in the vanguard of military applications with an estimated 84.9 percent of total military revenue. North American vendors also were well represented in five of the six application segments. The only market exhibiting soft performance in relation to its total revenue was consumer at 11.7 percent. The North American market yielded only an estimated 14.4 percent of worldwide consumer electronic equipment production in 1989.

European vendors ranked third, with revenue in five of the six segments. Their strongest application segment was consumer at $1,415 million, followed by data processing at $1,233 million.

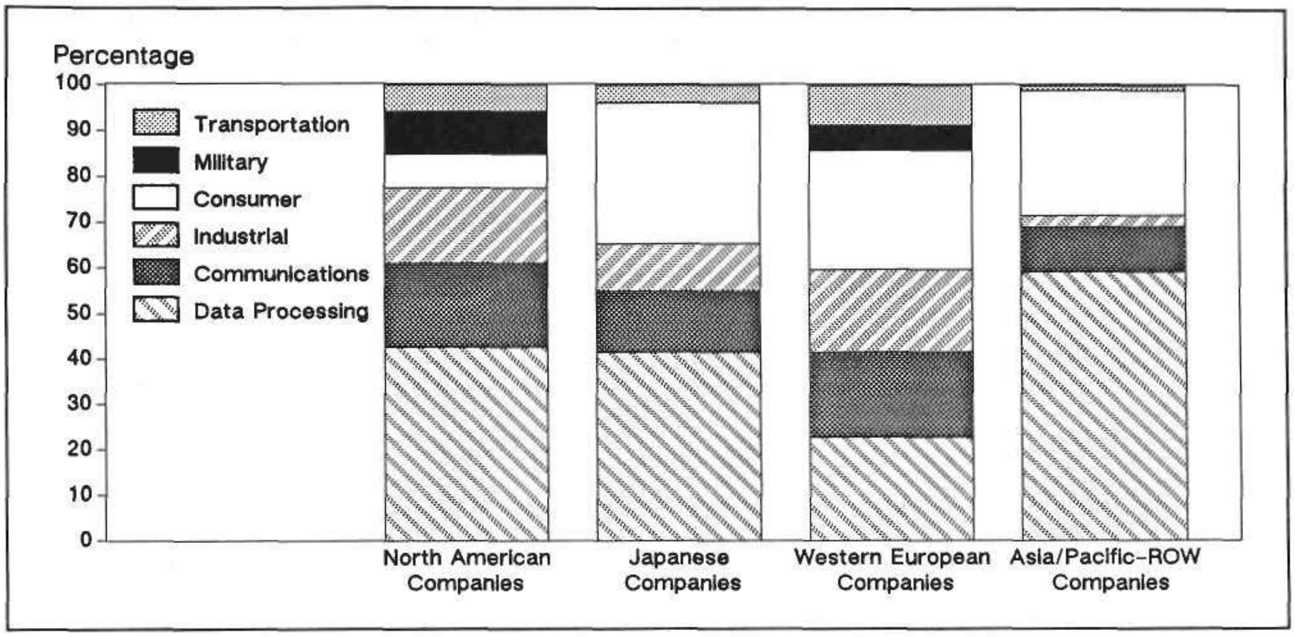
Asia/Pacific-ROW manufacturers realized the majority of their revenue from the data processing segment; approximately 51.7 percent of Asia/Pacific-ROW company revenue evolved from DRAM components.

Figures 2 and 3 present a regional and application market comparison on a percentage basis.

APPLICATION SEGMENT ANALYSIS

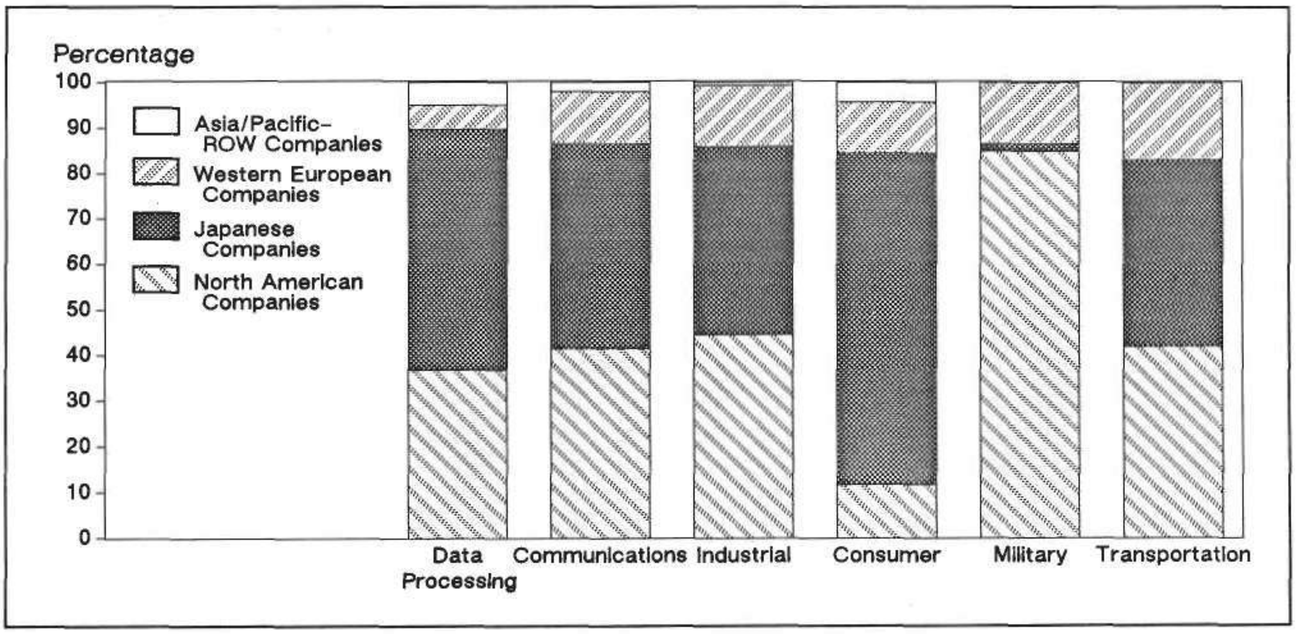
Tables 2 through 7 identify the top ten vendors within each of the six application segments, as well as their respective market shares in both dollars and percentages of total.

FIGURE 2
Estimated 1989 Market Share by Company Base



Source: Dataquest (August 1990)

FIGURE 3
Estimated 1989 Market Share by Application Segment



Source: Dataquest (August 1990)

Table 2
Estimated 1989 Worldwide Semiconductor Market Share Rankings—Data Processing Segment (Millions of Dollars)

Rank	Company	Revenue	Percent
1	NEC	2,515	10.8
2	Hitachi	2,030	8.7
3	Fujitsu	1,833	7.9
4	Intel	1,768	7.6
5	Toshiba	1,755	7.5
6	Texas Instruments	1,468	6.3
7	Mitsubishi	1,202	5.2
8	Motorola	906	3.9
9	Samsung	819	3.5
10	Advanced Micro Devices	706	3.0
	Subtotal—Top Ten Companies	15,002	64.4
	Other North American Companies*	3,669	15.7
	Other European Companies	1,233	5.3
	Other Japanese Companies	3,039	13.0
	Other Asia/Pacific-ROW Companies	359	1.5
	Subtotal—Others	8,300	35.6
	Total	23,301	100.0

*Does not include North American captive shipments.
Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1990)

Table 3
Estimated 1989 Worldwide Semiconductor Market Share Rankings—Communications Segment (Millions of Dollars)

Rank	Company	Revenue	Percent
1	NEC	953	10.6
2	Motorola	778	8.6
3	Toshiba	725	8.1
4	Fujitsu	702	7.8
5	AT&T	639	7.1
6	Hitachi	531	5.9
7	Texas Instruments	424	4.7
8	Philips-Signetics	317	3.5
9	SGS-Thomson	313	3.5
10	National Semiconductor	240	2.7
	Subtotal—Top Ten Companies	5,622	62.5
	Other North American Companies*	1,636	18.2
	Other European Companies	393	4.4
	Other Japanese Companies	1,154	12.8
	Other Asia/Pacific-ROW Companies	195	2.2
	Subtotal—Others	3,378	37.5
	Total	9,000	100.0

*Does not include North American captive shipments.
Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1990)

TABLE 4
Estimated 1989 Worldwide Semiconductor Market Share Rankings—Industrial Segment (Millions of Dollars)

Rank	Company	Revenue	Percent
1	Toshiba	754	10.1
2	Motorola	748	10.1
3	Mitsubishi	370	5.0
4	Hitachi	368	5.0
5	NEC	358	4.8
6	Texas Instruments	351	4.7
7	Philips-Signetics	311	4.2
8	National Semiconductor	300	4.0
9	SGS-Thomson	244	3.3
10	Fuji Electric	240	3.2
	Subtotal—Top Ten Companies	4,044	54.4
	Other North American Companies*	1,904	25.6
	Other European Companies	435	5.9
	Other Japanese Companies	999	13.4
	Other Asia/Pacific-ROW Companies	50	0.7
	Subtotal—Others	3,388	45.6
	Total	7,432	100.0

*Does not include North American captive shipments.
Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1990)

TABLE 5
Estimated 1989 Worldwide Semiconductor Market Share Rankings—Consumer Segment (Millions of Dollars)

Rank	Company	Revenue	Percent
1	Toshiba	1,425	11.4
2	Matsushita	1,349	10.8
3	NEC	1,067	8.5
4	Sanyo	1,001	8.0
5	Mitsubishi	836	6.7
6	Hitachi	823	6.6
7	Philips	737	5.9
8	Sharp	631	5.0
9	Sony	462	3.7
10	Rohm	377	3.0
	Subtotal—Top Ten Companies	8,708	69.5
	Other North American Companies*	1,461	11.7
	Other European Companies	678	5.4
	Other Japanese Companies	1,139	9.1
	Other Asia/Pacific-ROW Companies	537	4.3
	Subtotal—Others	3,815	30.5
	Total	12,523	100.0

*Does not include North American captive shipments.
Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1990)

Table 6
Estimated 1989 Worldwide Semiconductor Market Share Rankings—Military Segment (Millions of Dollars)

Rank	Company	Revenue	Percent
1	Harris	217	9.9
2	Texas Instruments	151	6.9
3	Motorola	146	6.7
4	National Semiconductor	145	6.6
5	Advanced Micro Devices	113	5.2
6	Analog Devices	87	4.0
7	SGS-Thomson	74	3.4
8	Intel	72	3.3
9	LSI Logic	60	2.7
10	Integrated Device Technology	60	2.7
	Subtotal—Top Ten Companies	1,125	51.4
	Other North American Companies*	808	36.9
	Other European Companies	222	10.1
	Other Japanese Companies	34	1.6
	Other Asia/Pacific-ROW Companies	0	0
	Subtotal—Others	1,063	48.6
	Total	2,188	100.0

*Does not include North American captive shipments.
Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1990)

Table 7
Estimated 1989 Worldwide Semiconductor Market Share Rankings—Transportation Segment (Millions of Dollars)

Rank	Company	Revenue	Percent
1	Motorola	366	13.2
2	Toshiba	271	9.8
3	Hitachi	222	8.0
4	Siemens AG	143	5.2
5	National Semiconductor	135	4.9
6	Texas Instruments	134	4.8
7	SGS-Thomson	130	4.7
8	NEC	122	4.4
9	Oki Semiconductor	117	4.2
10	Intel	111	4.0
	Subtotal—Top Ten Companies	1,751	63.3
	Other North American Companies*	389	14.1
	Other European Companies	199	7.2
	Other Japanese Companies	406	14.7
	Other Asia/Pacific-ROW Companies	24	0.9
	Subtotal—Others	1,018	36.7
	Total	2,768	100.0

*Does not include North American captive shipments.
Note: Columns may not add to totals show because of rounding.
Source: Dataquest (August 1990)

Data Processing

NEC retained the leading position within data processing for the second year, with estimated revenue of $2,515 million or nearly 10.8 percent of the total data processing market. NEC's revenue growth over 1988 for data processing was approximately 14.9 percent. Almost 72.0 percent of NEC's aggregate semiconductor revenue was derived from domestic consumption. Two additional Japanese vendors held second and third rankings in 1989—Hitachi with $2,030 million and 8.7 percent market share and Fujitsu with $1,833 million and 7.9 percent market share. Intel Corporation ranked number four, with $1,768 million in data processing revenue supported by its core microprocessor line of devices. Two players that swiftly ascended within the data processing market were Goldstar and Siemens, which exhibited growth rates of 128 and 190 percent, respectively, over their 1988 data processing revenue figures of $32 million and $218 million. *In both cases, revenue improvement was fueled principally by a tremendous jump in DRAM revenue.* In addition, both companies are business units of giant vertically integrated conglomerates which may, in part, provide certain competitive advantages over vendors whose sole enterprise is semiconductor manufacturing.

Communications

The top ten players in the communications market remained the same as in 1988, with Toshiba and Fujitsu making vigorous revenue gains of 21.0 and 19.8 percent, respectively. NEC, the industry leader, experienced a revenue gain of 11.1 percent over 1988. NEC's growth was strengthened by sales into digital switching systems, mobile cellular telephones, and paging systems. Motorola ranked second, with an estimated revenue of $778 million or 8.6 percent of the market. Motorola, itself a leader in communications equipment, is planning to expand this activity to 75.0 percent of its total turnover. Its in-house silicon usage should result in a distinct competitive advantage in communications equipment production.

Industrial

Toshiba retained its position as the top vendor in the industrial sector, with revenue of approximately $754 million or 10.1 percent of the total market. Its components derive strong utilization in the medical sector as well as in its medical equipment division. In addition, Toshiba's purchase of Diasonics, Inc.'s Magnetic Resonance Imaging (MRI) Division, a US producer of medical diagnostic equipment, should provide Toshiba with even greater synergism and an additional outlet for semiconductor technology in this application market. Motorola followed in second position, with almost equal revenue of $748 million or 10.1 percent. Motorola is involved in a partnership with IBM's synchrotron X-ray lithography technology.

A player that fell from the top ten was Harris Corporation, which dropped from the number ten position to number thirteen in 1989. Dataquest believes that this fall was due principally to the consolidation of GE Solid State and Harris and their respective product lines. The process resulted in the restructuring of its distribution channels and the elimination of redundancies in its product spectrum.

Consumer

Nine of the top ten players in the consumer sector were Japanese. In 1989, worldwide electronic equipment production was approximately $151,429 million, of which approximately 41.6 percent occurred in Japan. Toshiba and Matsushita dominated the application segment with $1,425 million and 11.4 percent and $1,349 million and 10.8 percent, respectively, of the total market. Toshiba's consumer product business line includes multifeatured upscale audio and video products as well as home appliances. Matsushita manufactures and markets consumer goods under the brand names of National, Panasonic, and Technics.

Military

Harris Corporation retained its undeniable leadership position in the military market, with approximately 9.9 percent share or $217 million in revenue. Its success has been supported by its capacity as a leading supplier of radiation-hardened (rad-hard) devices. Texas Instruments and Motorola were in the number two and three positions, with estimated military revenue levels of $151 million and $146 million, respectively. All three top players experienced a decline in revenue from 1988 levels. Dataquest believes that a trend toward slower growth in the military sector will result in the entrenched top-tier companies having their market share somewhat diminished by second-tier enterprises. This analysis and sampling is not as comprehensive as the study by Dataquest's MilAero Technology Service.

Transportation

Worldwide electronic equipment production for the automotive sector in 1989 was approximately $39,752 million; the largest regional market was Japan, followed by North America, with 49.9 and 28.4 percent, respectively.

Motorola, Toshiba, and Hitachi maintained their top rankings from 1988 with transportation revenue of $366 million, $271 million, and $222 million, respectively.

Motorola's revenue grew approximately 9.6 percent over 1988 although North American automotive sales contracted approximately 5.9 percent compared with 1988 figures. This fact reflects Motorola's progress in the penetration of foreign markets and the general trend toward higher electronics integration in vehicles.

Motorola's top ranking is due to its position as a leading OEM of antilock braking systems, control modules, and vehicle monitor modules. Toshiba's and Hitachi's high rankings result from both companies participating in their own domestic markets as well as in the North American transportation market. Japanese automobile manufacturers that purchase components for the North American marketplace have historically purchased their components from Japanese transplants.

Within the transportation segment, a mover that is worthy of mention is Siemens AG, which climbed from number thirteen in our 1988 survey to number four in 1989. Dataquest believes that Siemens' phenomenal revenue growth of approximately 95.9 percent can be attributed to three fundamental factors: the boom in European vehicle sales, a tightening of European vehicle emission standards that require the employment of electronic mixture controls, and the trend toward increased use of 8-bit microcontrollers and electronics in European automobiles.

Dataquest Conclusions

Dataquest believes that the world geopolitical climate will continue to drive the move toward a global economy and universal standards for electronic equipment production. Regional markets such as Western Europe, which has the potential for high growth but where trade friction poses a political concern, should encounter more foreign transplants infusing the markets' economies with capital in the form of integrated production capabilities.

Of the top ten players in the semiconductor market, six are based in Japan, three in North America, and one in Western Europe. Seven of these ten companies fit the broad definition of a vertically integrated conglomerate. All have broad, well-balanced product portfolios. These enterprises have the advantage of economies of scale over smaller market members, as well as having potential captive outlets for their products. This by no means implies that second-tier companies and aggressive start-ups cannot siphon market share from the larger electronics institutions of the world. Large players must balance their product spectrum, not becoming overly dependent on revenue from any one device family or application segment, whereas focused market players must continue to bring prompt, pertinent electronics solutions to market.

Niche market players such as Chips & Technologies, Cypress Semiconductor, and Xilinx, to list only a few, have seen tremendous gains in their revenue lines. Chips & Technologies' innovative chip sets for the data processing market have provided strong historic growth. Cypress Semiconductor's evenly distributed semiconductor revenue is the result of addressing numerous niche markets, providing a broad base of demand. The cornerstone of Xilinx's business is field programmable gate arrays (FPGAs), a product that provides users with a faster solution than standard gate arrays, resulting in faster time to market for the equipment producer.

Insightful product development and accurate timing should allow both large and small companies to continue to derive revenue and fuel both advancements in technology and increases in productivity.

Rebecca E. Burr

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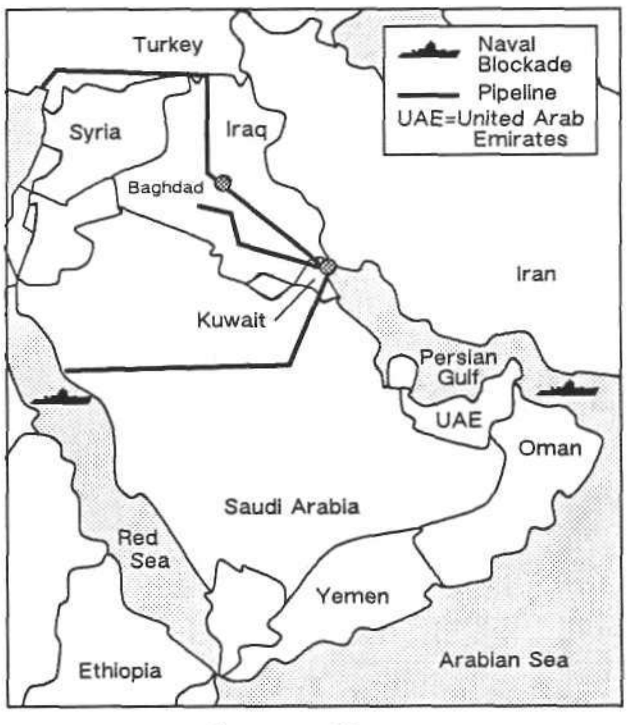
Research *Bulletin*

OIL CRISIS THREATENS ELECTRONICS RECESSION

The drama of the invasion of Kuwait by Iraq still is unfolding, but already some results of this crisis can be anticipated. Oil prices will be higher and the effects will ripple through world economies (see Figure 1).

The full impact can only be imagined at this point, because economic decisions yet to be made will affect the depth and dimension of the impact. However, a sustained crisis and continuing high oil prices could easily tip the already slowing US economy into recession for the latter part of this year. The length of time it takes to return to relative normalcy is the key to the level of economic impact.

FIGURE 1
Iraq's Oil Network



Source: Dataquest (August 1990)

Any sustained action, military conflict, or embargo that results in several months of oil shortages is likely to lead to recession in most regions of the world. But if the shortfall is made up by additional production from other sources, there will be substantially less impact.

US and world leaders reacted quickly through UN sanctions to minimize the impact. This quick response will help ameliorate the negative economic impact if the desirable results occur soon. US leaders are already evaluating options to keep the US economy stable.

But there already has been an impact. Although the United States normally imports only 5 percent of its oil from the Kuwait area, air fares already are going up by 10 percent or more. Service station gasoline prices in the United States are climbing, although no new, higher-priced oil has yet reached refineries.

The United States is actually in a better position than it was in 1974 or 1979. Inflation is much lower, there is no Vietnam peacetime adjustment, cars are more fuel efficient, reserves are up, options exist for alternative fuels, and there is much less friction with the Soviet Union.

One would expect Japan, which imports 99 percent of its oil, to suffer the most. But Japan learned its lesson from the 1974 and 1979 oil crises and today uses 50 percent less oil than it did in the 1970s. It currently has a five-month supply if the refineries operate at full capacity. Conservation methods such as lower industrial use and more fuel-efficient automobiles, are already in use. Japan also is seeking Far East sources of oil from areas such as Malaysia. And although the stock market is taking a thrashing, the price of gasoline at the pump has not budged in Japan.

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Several possible scenarios could spring from the present situation; however, Dataquest believes that the most likely scenario is that a shallow, two-quarter recessionary period will occur during the last part of 1990. It will affect all segments of the US, Japanese, and European economies, with the United States being affected the most deeply. Some industries will feel the impact more sharply than others.

In the United States, with the economy already slowing, we see consumer spending flattening and housing purchases stalling. Automobile sales, also weak, will slip further during the rest of 1990.

Japan, although marginally better off than the United States, will likely find consumer products hard hit. Consumer products are a large part of its exports. Japan's Central Bank will likely raise its discount rate to stave off a surge of inflation similar to what occurred as a result of previous oil shocks. Dataquest believes that this policy change will place heavier pressures on the US debt, accelerating the US economic slide below that of Japan.

Europe, because the Eastern European nations are so far behind in modernization and were counting heavily on cheap oil, will most likely have the longest recessionary run. This deprivation will most likely propel the European Community into an amalgamation more rapidly than planned.

The damage is already done to oil prices, which are unlikely to return to the level of two weeks ago—$20 a barrel. Markets will remain spooked in the wake of the crisis, and because there are many issues to be sorted out, the uncertainty is not likely to dissipate soon.

As a result, we can expect higher fuel prices to curtail leisure and casual business travel. We are likely to see prices on plastic goods and products leap and food prices climb because of higher-priced petroleum-based farm supplies such as fertilizer and pesticides.

The net effect is likely to be higher prices per product and lower productivity. As productivity slips, we probably will see capital spending decline and unemployment rise, although not to the double-digit rate of 1979.

All electronics producers are likely to suffer during this recession as opposed to past recessions when there was negligible impact. First, electronics products are so pervasive that any impact on other industries will affect electronics producers. For example, semiconductors are used in washers, dryers, automobiles, microwave ovens, air conditioning/heating units, industrial control equipment, office automation equipment, and consumer home electronics gear. Therefore, declining sales in any industry will impact semiconductor manufacturers.

Second, most US companies already have achieved productivity improvements from electronics through office automation and PCs. The majority of electronics equipment sales anticipated for this period are upgrades, which now will be subject to reevaluation. High payback capital investments still will qualify, but marginal payback investments are likely to be cut.

In the semiconductor segment, Dataquest believes that the analog producers will be hardest hit because so many US products go to industrial-type products. These manufacturers already are stressed from very low margins and slow sales, so we expect some consolidation as a result of this shallow recessionary period.

Under this possible scenario, memory chips could be significantly affected as well. Sales of consumer products, which incorporate large numbers of memory chips, are likely to slow from declining consumer confidence, higher interest rates, and lower discretionary income. This softening memory market probably will occur at the same time memory producers, predominantly Japanese, are adding 4Mb and 16Mb production capacity.

In this scenario, memory prices which have been soft all summer, will possibly free fall, pushing recovery out at least two more quarters. This event could push out the economic crossover from 1Mb to 4Mb DRAMs. Subsequently, 4Mb DRAMs probably would experience an even shorter life cycle as 16Mb megabit production draws closer.

Dataquest believes that the situation is still very fluid. The depth of the impact is difficult to foretell until the situation stabilizes. However, we are working on an in-depth newsletter that will examine the full impact of this situation on the semiconductor industry.

Marc Elliot
Terrance A. Birkholz

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Research Newsletter

SECOND QUARTER 1990 WORLDWIDE SEMICONDUCTOR INDUSTRY OUTLOOK: THE CORNER IS TURNED AMID MIXED SIGNALS

INTRODUCTION

In May 1990, the North American semiconductor market experienced its strongest bookings month ever, and both North American and European book-to-bill ratios have ascended into the stratosphere, at 1.14 and 1.17, respectively. In some quarters, euphoria reigns; in others, questions are asked about the sustainability of the sharp upturn in orders.

DRAM prices, never known for their stability, have been fluctuating, with strengthening one week followed by record low prices the next week.

Dataquest continues to forecast a flat market worldwide in 1990, with growth beginning in the second quarter and continuing through the second half of the year. We still expect the 1991 market to grow at approximately 16 percent, paced by the Asia/Pacific-Rest of World (ROW) region and Europe.

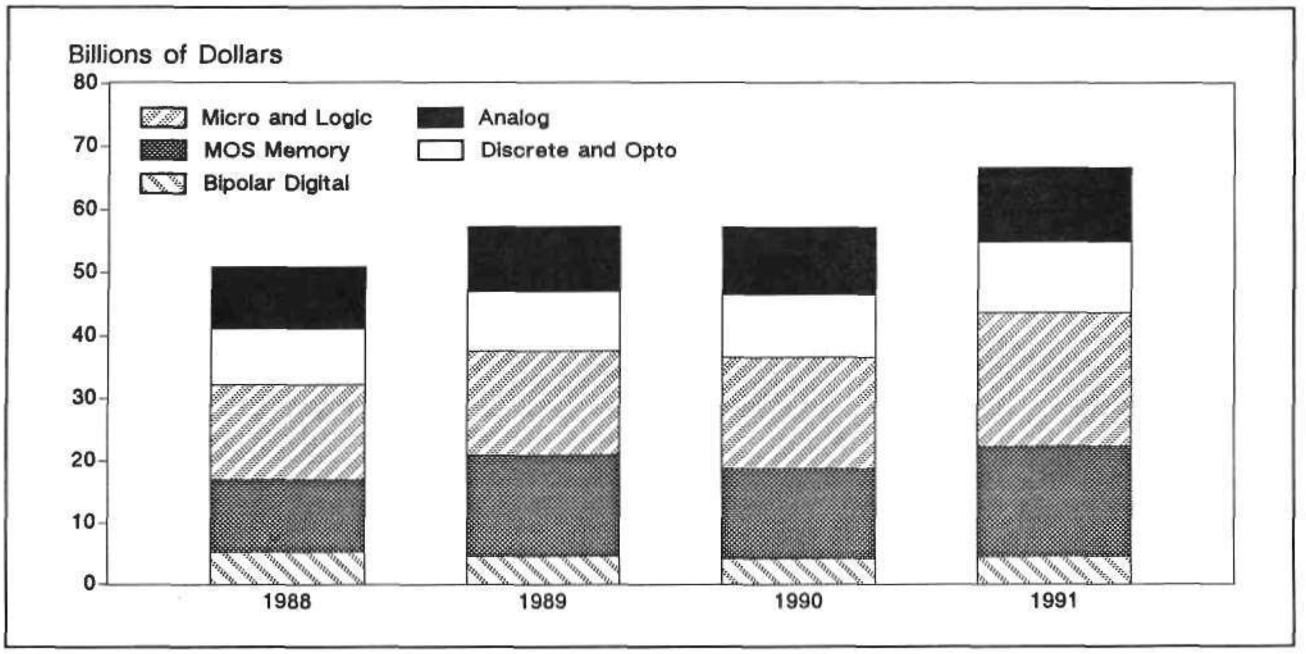
Figure 1 shows our projections for the worldwide semiconductor market through 1991, listed by major product category.

PRODUCT MARKETS

MOS Memory

As usual, the course of the overall semiconductor market depends to a large degree on MOS

FIGURE 1
Worldwide Semiconductor Revenue by Product Category (Millions of Dollars)



Source: Dataquest (June 1990)

Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398 / (408) 437-8000 / Telex 171973 / Fax (408) 437-0292

memory, particularly the 1-megabit DRAM. We believe that unit shipments will continue to grow during 1990; however, there seems to be a good deal of market confusion due to fluctuating production levels. One of the major challenges of 1990 will be for suppliers and users to adequately forecast demand and the necessary production levels to keep the market stable.

After the well-publicized DRAM production cutbacks that began at the end of 1989, we have learned that production has begun to increase again without fanfare.

February and March were tremendous bookings months in North America and Europe. In North America, first-tier buyers placed orders through December, thus locking themselves into volume commitments while leaving open the possibility of renegotiating prices if ASPs fall significantly. This approach reflects the uncertainty about supply capability. Second- and third-tier buyers are taking a wait-and-see attitude, however, with good reason: Prices have come down to very low levels, and spot prices are lower than booking prices.

The memory situation is less positive in Japan and Taiwan. The first quarter was not good in Japan; recently, however, bookings have begun to pick up, although prices appear to be low. Taiwan memory demand has been hampered by a lack of adequate microprocessor supply (mainly the 80386DX and SX). Intel's recent announcement that it will not sell an 80386 plant that had been up for sale should allow the company to better meet this MPU demand.

Logic

Commodity gate array pricing continues to be bad, with prices per gate severely depressed. Chip sets are impacting gate array revenue because they are being used as direct replacements for gate arrays. As a result of the increasing complexity of gate arrays, ASPs are still growing slightly, even with decreasing prices per gate.

Cell-based ICs are growing slowly also, although they are losing design wins to gate arrays. The CMOS complex programmable logic device market is experiencing rapid growth, while bipolar PLDs are not faring as well. High-speed bipolar PLDs have been on allocation in some regions, but the crunch now seems to be over.

Although CMOS ASIC prices are falling, ECL ASIC prices are stable, due to the small number of players in the market and the loyalty of users to their suppliers.

Standard logic is generally a flat market. Although some manufacturers are seeing record TTL bookings this year, we believe that this is due to shifting market share rather than to a growing market.

Analog, Discrete, and Optoelectronics

Commodity analog prices, which dropped severely in the second half of 1989, have stopped dropping. The consumer market—one of the largest applications for analog, discrete, and optoelectronics—is projected to be virtually flat in 1990, while the industrial market is growing at a slow rate.

The automotive market remains a growing market for analog, even though the number of cars produced remains flat, because of increased pervasiveness of electronics in automobiles. Japan in particular is poised to take advantage of this trend. Japanese automotive semiconductor content is still lower than that of the United States, giving the Japanese market even more room to grow.

REGIONAL MARKETS

Table 1 shows our quarterly forecast, by region, for 1990 and 1991. We forecast North America and Japan to have negative growth in 1990 of 3.5 percent and 3.1 percent, respectively. In contrast, we believe that Europe will experience 9.5 percent growth, due in large part to the strength of the European currencies—particularly the deutsche mark—against the US dollar. In local currency, we expect the European market growth to be between 2.0 and 3.0 percent. We also expect Asia/Pacific-ROW to grow at a positive rate of 7.1 percent.

North America

Our basic outlook for North America remains the same as our last forecast. Although May orders were very strong, hitting an all-time record, there are very mixed signals regarding the true market demand. There is also some concern about double ordering of DRAMs to ensure supply. In addition, DRAM prices seem to be falling faster than previously anticipated. We have slightly lowered our unit shipment forecast for DRAMs while dramatically lowering the pricing forecast.

TABLE 1
Worldwide Semiconductor Revenue by Region (Millions of Dollars)

	1989	Q1 1990	Q2 1990	Q3 1990	Q4 1990	1990
Worldwide	57,213	13,566	13,957	14,525	15,217	57,265
Percent Change	12.5%	(3.1%)	2.9%	4.1%	4.8%	0.1%
North America	17,937	4,244	4,169	4,347	4,552	17,312
Percent Change	13.2%	(3.4%)	(1.8%)	4.3%	4.7%	(3.5%)
Japan	22,997	5,196	5,434	5,707	5,950	22,287
Percent Change	10.7%	(7.8%)	4.6%	5.0%	4.3%	(3.1%)
Europe	9,755	2,527	2,672	2,665	2,814	10,678
Percent Change	14.9%	7.0%	5.7%	(0.3%)	5.6%	9.5%
Asia/Pacific-ROW	6,524	1,599	1,682	1,806	1,901	6,988
Percent Change	13.4%	(0.6%)	5.2%	7.4%	5.3%	7.1%
		Q1 1991	**Q2 1991**	**Q3 1991**	**Q4 1991**	**1991**
Worldwide		15,672	16,520	16,997	17,531	66,720
Percent Change		3.0%	5.4%	2.9%	3.1%	16.5%
North America		4,660	4,933	5,135	5,426	20,154
Percent Change		2.4%	5.9%	4.1%	5.7%	16.4%
Japan		6,095	6,334	6,505	6,564	25,498
Percent Change		2.4%	3.9%	2.7%	0.9%	14.4%
Europe		2,977	3,154	3,130	3,208	12,469
Percent Change		5.8%	5.9%	(0.8%)	2.5%	16.8%
Asia/Pacific-ROW		1,940	2,099	2,227	2,333	8,599
Percent Change		2.1%	8.2%	6.1%	4.8%	23.1%

Source: Dataquest (June 1990)

On the positive side, semiconductor buyers contacted in our most recent monthly purchasing survey have high expectations for their own sales activity over the next six months, giving credence to our forecast of 4 to 5 percent growth in each of the last two quarters of the year.

Japan

The Japanese semiconductor market declined dramatically in the first quarter of 1990, by 7.8 percent. This decline is due in part to depreciation of the yen by about 7 percent against the US dollar. The decline measured in yen was 1.3 percent. For 1990, the dollar decline from 1989 will be 3.5 percent; however, in yen there will be growth of approximately 4 percent.

Semiconductor exports from Japan have declined since the fourth quarter of 1989 (because of DRAM production cutbacks). As a result, a high proportion of Japanese production is being consumed domestically.

Europe

Europe is perhaps the most euphoric of all regional markets. This euphoria certainly is due to increased demand from companies preparing for a unified Europe in 1992, but it also comes from the prospects for developing markets in Eastern Europe.

In local currency, the European market will grow between 2.0 and 3.0 percent in 1990. In dollar terms, however, this translates to 9.5 percent growth, making Europe the fastest-growing regional market in 1990.

Backlogs in Europe have been strengthening as purchasers recover from a 12-month down cycle in inventory holdings, resulting in price stability and lengthening lead times. The order strength seen in the first few months of 1990 tended to be for short lead time requests, but now long-term orders are being placed.

The current market strength is largely being driven by PC manufacturers, and we forecast the European PC market to grow 25 percent in unit shipments in 1990.

Asia/Pacific-ROW

Optimism is picking up in Asia as the PC industry begins to stabilize and emerge from the slump caused by intense competition. We expect domestic demand to be very strong in Asia, particularly in South Korea with its population of 55 million people.

Factors that could hamper the growth of this region include severe labor unrest in South Korea; a fear of import tariffs being levied against Asian manufacturers by the European Community (which has already taken action against manufacturers of telephones and TVs); and threats of US action against Hong Kong, South Korean, and Taiwanese companies trying to get around tariffs by manufacturing in Thailand.

In addition, Asian equipment exports are still highly dependent on the US market in spite of increasing domestic demand. These exports are thus vulnerable to downturns in the US economy. As a result, Asian companies are beginning to refocus their sales efforts on their own region. Foreign companies can expect to encounter increased competition for market share in Asia.

We expect the Asia/Pacific-ROW market to grow 7.1 percent in 1990, representing the lowest growth rate in this region since 1985.

DATAQUEST ANALYSIS

Although the worldwide semiconductor market has definitely turned around, mixed signals still abound, as uncertainties of supply and demand are dealt with. DRAM pricing, lead times, microprocessor supply, and true equipment production plans all bear watching.

Evidently, Wall Street is convinced that high technology in general is on the move once again, as witnessed in part by the recent highly successful IPO of Xilinx, the stock price of which rose 50 percent in the first day of trading.

We believe that the optimism of both semiconductor suppliers and buyers cannot be ignored and that we will see a strong semiconductor market through the rest of 1990 and 1991.

Patricia S. Cox

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Research Newsletter

SEMICONDUCTOR CONSUMPTION TRENDS IN WORLDWIDE APPLICATION MARKETS

INTRODUCTION

This newsletter presents an overview of Dataquest's analysis of worldwide merchant semiconductor consumption by application segment. The purpose of this newsletter is to provide a long-term outlook of consumption trends by device family on an application segment basis. It includes an aggregate-level analysis of each application segment and identifies the leading factors that form the basis for variable levels of growth between semiconductor device families.

HOT MARKETS, HOT TRENDS, HOT DEVICES

Dataquest believes that data processing will continue to be the main impetus driving worldwide semiconductor consumption revenue. The data processing segment consumed an estimated 44.1 percent of all semiconductors in 1989, and we expect this proportion to increase to 47.9 percent in 1994. Data processing's movement toward decentralized computing and concurrent processing is a prominent factor in this trend. An additional market to watch is transportation, with a forecast compound annual growth rate (CAGR) of approximately 13.8 percent between 1989 and 1994. We expect consumer preferences for electronic automotive features to drive a shift in device consumption. Figure 1 shows Dataquest's total semiconductor consumption forecast by application segment for this period.

Data Processing Segment

Dataquest expects worldwide semiconductor consumption in the data processing segment to remain flat during 1990, although growth will resume in the latter part of the year. Long-term growth will remain strong, with a 16.5 percent CAGR from 1989 through 1994. Table 1 depicts estimated consumption by device type for data processing. The highest level of consumption growth is predicted for the Asia/Pacific-Rest of World (ROW) region. Consumption by low- and midlevel personal computers using 8086, 8088, and 80286 technology will continue to drive this market. The worldwide decline in bipolar vis-à-vis MOS can be attributed in part to the movement from centralized computing toward desktop computing where cost, performance, and power consumption are the main factors. For desktop systems in which speed alone is not the leading factor, BiCMOS will replace bipolar functions. The shift to desktop computing and the use of such things as smart peripherals, smart graphics cards, and smart printers also drive higher consumption of MOS function as well as analog devices. These devices require dedicated controller or logic functions coupled with additional memory. Finally, new "multimedia" features promise to vastly increase computing requirements and further reinforce the trend toward combined MOS and analog because of the needs for elaborate graphics and sound/voice integration.

Communications Segment

Dataquest forecasts a 14.1 percent CAGR from 1989 through 1994 for semiconductor consumption in communications applications. Table 2 reflects estimated semiconductor consumption by device for the communications market. We expect analog consumption to grow at a brisk 17.4 percent, due to two major factors: strong growth in premise telecom applications (especially cellular, networking, and facsimile) and marked growth within the Japanese and Western European communications industries. The Western European market

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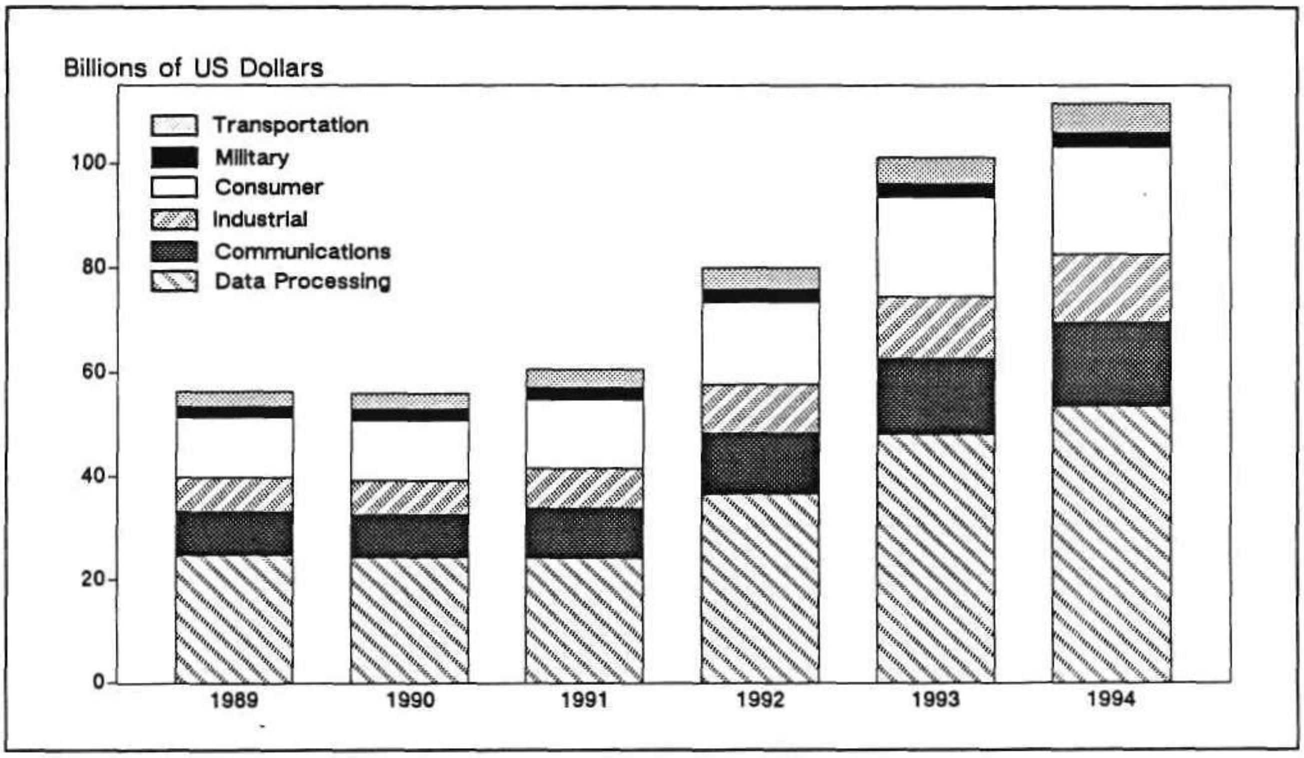
FIGURE 1
Worldwide Semiconductor Revenue Forecast by Application Segment



Source: Dataquest (June 1990)

TABLE 1
Worldwide Merchant Semiconductor Consumption Revenue—Data Processing (Millions of US Dollars)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	24,868	24,262	29,427	36,616	48,048	53,462	16.5%
Total IC	22,780	22,078	26,862	33,597	44,622	49,769	16.9%
Total Bipolar Digital	2,853	2,576	2,863	3,116	3,343	3,175	2.2%
Bipolar Memory	365	322	316	282	259	233	(8.6%)
Bipolar Logic	2,488	2,254	2,548	2,835	3,084	2,942	3.4%
Total MOS Digital	18,751	18,221	22,099	28,527	38,924	43,827	18.5%
MOS Memory	11,057	9,838	12,168	16,246	22,739	26,289	18.9%
MOS Micro	4,257	4,607	5,346	6,439	8,734	9,690	17.9%
MOS Logic	3,437	3,775	4,584	5,842	7,450	7,848	18.0%
Analog	1,177	1,281	1,900	1,954	2,356	2,767	18.6%
Discrete	1,699	1,754	2,030	2,355	2,626	2,753	10.1%
Opto	389	430	535	663	800	940	19.3%

Source: Dataquest (June 1990)

TABLE 2
Worldwide Merchant Semiconductor Consumption Revenue—Communications (Millions of US Dollars)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	8,348	8,279	9,624	11,740	14,728	16,115	14.1%
Total IC	6,639	6,499	7,616	9,361	12,005	13,169	14.7%
Total Bipolar Digital	448	372	400	433	466	454	0.3%
Bipolar Memory	28	22	21	17	15	16	(10.7%)
Bipolar Logic	420	350	379	416	451	438	0.9%
Total MOS Digital	4,764	4,601	5,376	6,703	8,819	9,538	14.9%
MOS Memory	2,133	1,785	2,046	2,587	3,431	3,742	11.9%
MOS Micro	1,033	1,094	1,240	1,474	1,924	2,086	15.1%
MOS Logic	1,598	1,721	2,090	2,643	3,463	3,710	18.3%
Analog	1,427	1,526	1,840	2,225	2,720	3,177	17.4%
Discrete	1,219	1,265	1,414	1,688	1,912	2,015	10.6%
Opto	490	516	594	690	811	931	13.7%

Source: Dataquest (June 1990)

will experience substantial benefits from standardization and the movement to a "pan-European" market slated for 1992—and from the resulting increased levels of competition. Strong growth in the MOS category is expected as a result of rising demand for protocol processors, voice/data compression in intelligent fax machines, modems, digital cellular, and ISDN hardware. Progressive, albeit slow, growth will be maintained by bipolar logic, due in large part to growing high-frequency requirements in the microwave, fiber-optic, and cellular-radio applications.

Industrial Segment

Dataquest projects that the worldwide semiconductor consumption revenue in industrial electronics will grow by a 14.7 percent CAGR from 1989 to 1994. All regions are expected to increase by more than 10.0 percent in this time frame, with the North America and Asia/Pacific-ROW regions exhibiting the strongest growth at 15.2 and 16.3 percent CAGR, respectively. Table 3 illustrates aggregate device consumption for the industrial sector. In North America, commercial aviation should reinforce the higher-than-average growth trend in MOS function and analog device consumption. With environmental issues becoming more consequential in nature, electronic metering and energy management systems in new building construction should also consume increasing amounts of MOS microcomponents and logic devices.

Consumer Segment

By Dataquest estimates, the consumer sector yielded the second-highest level of semiconductor consumption revenue in 1989. Dataquest believes that the consumer market will grow at a modest 12.5 percent CAGR from 1989 to 1994. Table 4 depicts the moderate worldwide semiconductor consumption growth foreseen for the consumer applications segment. We view Asia/Pacific-ROW as a key growth region for semiconductor consumption and expect an 18.4 percent CAGR from 1989 through 1994 for that area. As in the past, audio and video equipment will provide the base for the majority of semiconductor consumption. Standards for appliance efficiency and the demand for smart appliances also will lead to higher-than-average MOS device consumption rates. The expected high levels of consumption in Asia/Pacific-ROW primarily can be attributed to the substantial quantity of goods being manufactured for export.

Military Segment

Worldwide military semiconductor consumption revenue is expected to grow at a moderate 4.6 percent between 1989 and 1994. Growth has declined significantly from an estimated 9.5 percent CAGR for 1984 through 1989. Table 5 gives Dataquest's estimates of semiconductor consumption for military applications. Key factors contributing to Dataquest's forecast include a reduction

TABLE 3
Worldwide Merchant Semiconductor Consumption Revenue—Industrial (Millions of US Dollars)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	6,579	6,645	7,803	9,449	11,813	13,082	14.7%
Total IC	4,514	4,530	5,488	6,780	8,886	9,978	17.2%
Total Bipolar Digital	449	366	395	399	425	431	(0.8%)
Bipolar Memory	36	29	26	22	17	13	(18.5%)
Bipolar Logic	413	337	369	376	407	418	0.3%
Total MOS Digital	2,886	2,911	3,532	4,522	6,170	6,842	18.8%
MOS Memory	1,147	986	1,179	1,494	2,062	2,259	14.5%
MOS Micro	752	820	958	1,167	1,603	1,825	19.4%
MOS Logic	987	1,105	1,395	1,861	2,504	2,757	22.8%
Analog	1,179	1,252	1,561	1,860	2,292	2,705	18.1%
Discrete	1,610	1,633	1,765	2,044	2,226	2,322	7.6%
Opto	455	483	551	625	701	782	11.4%

Source: Dataquest (June 1990)

TABLE 4
Worldwide Merchant Semiconductor Consumption Revenue—Consumer (Millions of US Dollars)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	11,412	11,447	13,163	15,654	19,044	20,586	12.5%
Total IC	8,512	8,474	9,842	11,815	14,728	15,929	13.4%
Total Bipolar Digital	227	176	186	185	195	151	(7.9%)
Bipolar Memory	10	7	5	5	2	2	(27.5%)
Bipolar Logic	217	169	181	180	193	149	(7.3%)
Total MOS Digital	4,040	3,969	4,642	5,592	7,211	7,636	13.6%
MOS Memory	1,118	951	1,136	1,480	1,990	2,160	14.1%
MOS Micro	1,164	1,194	1,388	1,634	2,082	2,197	13.5%
MOS Logic	1,758	1,824	2,118	2,478	3,139	3,279	13.3%
Analog	4,245	4,329	5,015	6,038	7,322	8,143	13.9%
Discrete	2,107	2,184	2,422	2,814	3,160	3,375	9.9%
Opto	792	789	898	1,025	1,156	1,281	10.1%

Source: Dataquest (June 1990)

in the level of tension experienced in the 1980s between the NATO countries and the Eastern Bloc, the calming between warring factions in the developing world, and the improvement of existing defense systems in lieu of new system construction. The upgrading of existing systems accounts in part for the apparent decline in bipolar device use. In designs where power consumption constitutes a key factor, MOS device use should continue to grow at a strong 10.1 percent. Regionally, the highest levels of semiconductor consumption growth are forecast for Asia/Pacific-ROW at approximately 10.6 percent. It is Dataquest's opinion that the non-NATO nations of the world are moving toward domestic production, thus leading to higher consumption rates. The CAGR for Asia/Pacific-ROW and Japan in semiconductor consumption is expected to be more than double the worldwide average for this time period. Furthermore, certain markets in the region tend to have a high level of vertical integration and are choosing to produce weapons systems for domestic use alone.

Transportation Segment

As mentioned earlier, we expect consumption of semiconductors in the transportation market to grow at a CAGR of 13.8 percent between 1989 and 1994. Table 6 presents Dataquest's estimates of semiconductor consumption in the transportation segment. Higher levels of growth are expected in Europe, Japan, and Asia/Pacific-ROW where semiconductor content per vehicle has been historically lower than in North America. Factors such as improved fuel consumption efficiency and safety features such as ABS (antilock braking system) contribute to this rise in consumption. In Europe, specifically, new higher emission requirements are

Table 5
Worldwide Merchant Semiconductor Consumption Revenue—Military (Millions of US Dollars)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	2,285	2,349	2,425	2,542	2,692	2,864	4.6%
Total IC	1,828	1,891	1,957	2,060	2,193	2,348	5.1%
Total Bipolar Digital	462	439	402	370	341	314	(7.4%)
Bipolar Memory	76	67	59	52	47	43	(10.8%)
Bipolar Logic	386	371	343	318	294	271	(6.8%)
Total MOS Digital	922	1,007	1,100	1,214	1,345	1,489	10.1%
MOS Memory	359	392	426	469	520	576	9.9%
MOS Micro	210	228	249	276	306	338	10.0%
MOS Logic	354	387	424	469	520	576	10.2%
Analog	444	446	455	476	507	544	4.1%
Discrete	376	379	386	395	406	417	2.1%
Opto	80	80	82	87	93	100	4.5%

Source: Dataquest (June 1990)

Table 6
Worldwide Merchant Semiconductor Consumption Revenue—Transportation (Millions of US Dollars)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	2,868	2,987	3,427	4,080	4,979	5,484	13.8%
Total IC	2,196	2,301	2,660	3,187	3,993	4,424	15.0%
Total Bipolar Digital	142	121	124	110	113	101	(6.7%)
Bipolar Memory	19	14	12	9	8	4	(26.7%)
Bipolar Logic	123	107	112	101	105	97	(4.8%)
Total MOS Digital	1,428	1,530	1,790	2,188	2,823	3,138	17.1%
MOS Memory	328	320	363	446	580	647	14.6%
MOS Micro	666	724	834	985	1,257	1,380	15.7%
MOS Logic	434	486	592	757	986	1,111	20.7%
Analog	626	650	746	889	1,057	1,185	13.6%
Discrete	541	552	608	700	763	803	8.2%
Opto	131	134	159	193	223	258	14.5%

Source: Dataquest (June 1990)

a major factor driving increased levels of semiconductor consumption. In general, consumers' preference for electronic equipment gadgetry will ensure its movement from high-end into midrange vehicles as costs decline, thus ensuring elevated consumption. These trends reinforce strong growth in MOS function devices where intelligence and independent processing are factors and small size and low energy consumption remain key.

DATAQUEST ANALYSIS

Dataquest expects strong overall growth for all device categories, with the exception of the mature bipolar digital IC market; bipolar digital is being replaced slowly by CMOS and BiCMOS, where speed is not an overriding design consideration. The data processing segment's semiconductor consumption levels will be driven by commercial and consumer demand for decentralized, multitasking machines that can perform work more cost-effectively and efficiently.

All in all, Dataquest expects MOS digital devices to achieve better-than-average levels of consumption growth across all application segments. We expect bipolar digital device consumption to decline in applications where power or size is a factor and incremental cost is not. In conclusion, markets are demanding products that are more compact, more efficient, and more intelligent.

Rebecca Burr

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Research Newsletter

FINAL 1989 WORLDWIDE SEMICONDUCTOR MARKET SHARES

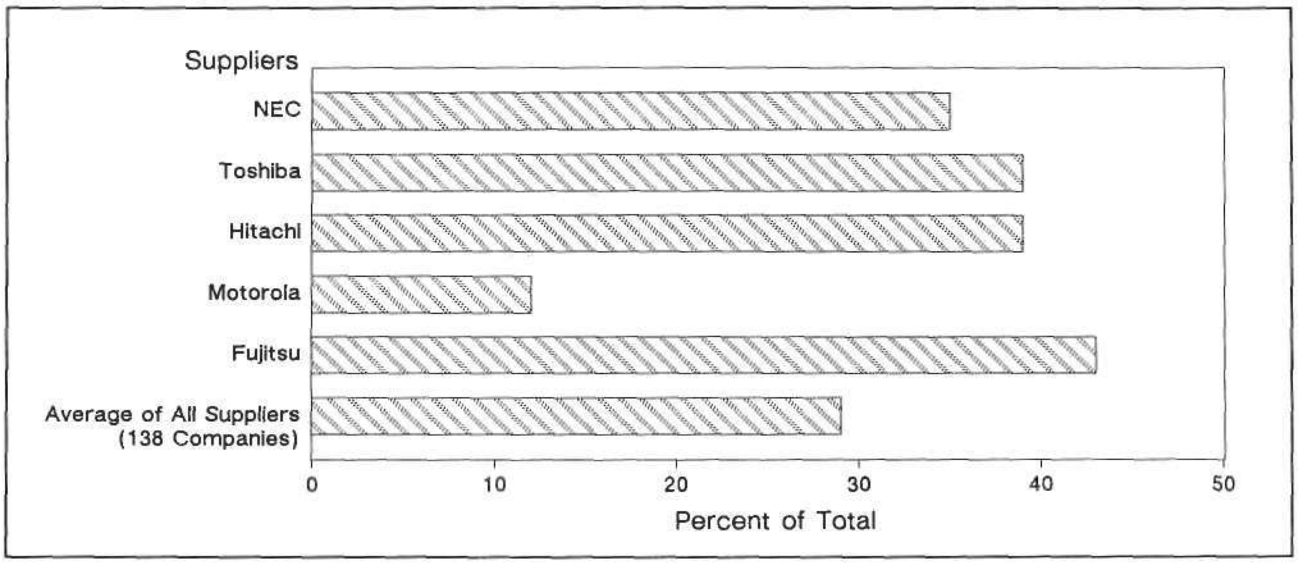
INTRODUCTION

Since publishing our preliminary 1989 worldwide semiconductor market share estimates in January, we have refined the data and added several companies to our database, mainly in the analog market.

Significant events of 1989 include the following:

- Japanese companies continued to gain share of the worldwide semiconductor market and now hold 52 percent of it, up from 51 percent in 1988.
- Asia/Pacific companies' market share grew to 3.5 percent.
- Japanese companies' share of the North American chip market grew to 26 percent, while North American companies' share of the Japanese chip market remained constant at 9 percent.
- The worldwide semiconductor market grew more than 12 percent in 1989 over 1988. MOS memory was clearly the market leader, growing 40 percent.
- Companies that are strong in MOS memory continued to dominate the market, as shown in Figure 1.
- NEC remains the number one semiconductor supplier in the world, followed by Toshiba, Hitachi, Motorola, and Fujitsu. Three North American companies (Motorola, TI, and Intel), one European company (Philips), and six Japanese companies are among the top ten.

FIGURE 1
Top Five Semiconductor Suppliers' Reliance on MOS Memory (MOS Memory as a Percent of Total Semiconductor)



0006974-1

Source: Dataquest
May 1990

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Table 1 shows 1989 semiconductor revenue by company base as sold into the five regions of consumption. Table 2 shows worldwide semiconductor revenue by product in 1988 and 1989.

TABLE 1
Final 1989 Market Share Analysis Total Semiconductor (Millions of Dollars)

	Regional Market					
Company Base	North America	Japan	Europe	Asia/ Pacific	ROW	Total World
North America	$11,715	$2,162	$4,032	$1,894	$175	$19,978
Percent of Regional Market	65%	9%	41%	31%	48%	35%
Percent of Company Sales	59%	11%	20%	9%	1%	100%
Japan	$4,574	$20,628	$1,924	$2,625	$58	$29,809
Percent of Regional Market	26%	90%	20%	43%	16%	52%
Percent of Company Sales	15%	69%	6%	9%	0	100%
Europe	$1,025	$130	$3,562	$607	$119	$5,443
Percent of Regional Market	6%	1%	37%	10%	32%	10%
Percent of Company Sales	19%	2%	65%	11%	2%	100%
Asia/Pacific	$623	$77	$237	$1,031	$15	$1,983
Percent of Regional Market	3%	0	2%	17%	4%	3%
Percent of Company Sales	31%	4%	12%	52%	1%	100%
World	$17,937	$22,997	$9,755	$6,157	$367	$57,213
Percent of Regional Market	100%	100%	100%	100%	100%	100%
Percent of Company Sales	31%	40%	17%	11%	1%	100%

Source: Dataquest
May 1990

TABLE 2
Worldwide Semiconductor Revenue (Millions of Dollars)

	1988	1989	Percent Change
Total Semiconductor	50,859	57,213	12.5%
Total Integrated Circuit	41,068	46,924	14.3%
Bipolar Digital	5,200	4,510	(13.3%)
Bipolar Memory	689	540	(21.6%)
Bipolar Logic	4,511	3,970	(12.0%)
MOS Digital	26,988	33,024	22.4%
MOS Memory	11,692	16,361	39.9%
MOS Microcomponent	7,144	8,202	14.8%
MOS Logic	8,152	8,461	3.8%
Analog	8,880	9,390	5.7%
Discrete	7,612	7,662	0.7%
Optoelectronic	2,179	2,627	20.6%

Source: Dataquest
May 1990

RANKINGS

Tables 3 through 7 list the top companies for the major product categories: total semiconductor, total integrated circuit, bipolar digital, MOS digital, and analog.

Among the top 20 companies, Siemens and Samsung experienced by far the highest growth, at 52 percent and 39 percent, respectively. In both cases, the companies' strong thrusts into the DRAM arena paid off handsomely in market share gains. Siemens moved from number 20 in 1988 to number 16 in 1989, while Samsung moved from number 18 in 1988 to number 14 in 1989.

TABLE 3
Final Estimated 1989 Worldwide Semiconductor Market Share Rankings Total Semiconductor (Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	NEC	4,543	5,015	10%	8.8%
2	2	Toshiba	4,395	4,930	12%	8.6%
3	3	Hitachi	3,506	3,974	13%	6.9%
4	4	Motorola	3,035	3,319	9%	5.8%
5	6	Fujitsu	2,607	2,963	14%	5.2%
6	5	Texas Instruments	2,741	2,787	2%	4.9%
7	8	Mitsubishi	2,312	2,579	12%	4.5%
8	7	Intel	2,350	2,430	3%	4.2%
9	9	Matsushita	1,883	1,882	0	3.3%
10	10	Philips	1,738	1,716	(1%)	3.0%
11	11	National Semiconductor	1,650	1,618	(2%)	2.8%
12	14	Sanyo*	1,083	1,365	NM	2.4%
13	12	SGS-Thomson	1,087	1,301	20%	2.3%
14	18	Samsung	905	1,260	39%	2.2%
15	15	Sharp	1,036	1,230	19%	2.1%
16	20	Siemens	784	1,194	52%	2.1%
17	17	Oki Semiconductor	947	1,154	22%	2.0%
18	13	Advanced Micro Devices	1,084	1,100	1%	1.9%
19	16	Sony	950	1,077	13%	1.9%
20	19	AT&T	859	873	2%	1.5%
		All Others	11,364	13,446	18%	23.5%
		North American Companies	18,586	19,978	7%	34.9%
		Japanese Companies	25,942	29,809	15%	52.1%
		European Companies	4,917	5,443	11%	9.5%
		Asia/Pacific Companies	1,414	1,983	40%	3.5%
		Total Market	50,859	57,213	12%	100.0%

*Prior to 1989, Sanyo revenue was understated.
NM = Not meaningful

Source: Dataquest
May 1990

Table 4
Final Estimated 1989 Worldwide Semiconductor Market Share Rankings Total Integrated Circuit (Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	NEC	3,884	4,321	11%	9.2%
2	2	Toshiba	3,316	3,774	14%	8.0%
3	3	Hitachi	2,729	3,218	18%	6.9%
4	5	Fujitsu	2,420	2,738	13%	5.8%
5	4	Texas Instruments	2,637	2,691	2%	5.7%
6	7	Motorola	2,259	2,519	12%	5.4%
7	6	Intel	2,350	2,430	3%	5.2%
8	8	Mitsubishi	1,975	2,185	11%	4.7%
9	9	National Semiconductor	1,575	1,548	(2%)	3.3%
10	11	Philips	1,281	1,250	(2%)	2.7%
11	10	Matsushita	1,328	1,244	(6%)	2.7%
12	14	Samsung	850	1,182	39%	2.5%
13	13	Oki Semiconductor	902	1,111	23%	2.4%
14	12	Advanced Micro Devices	1,084	1,100	1%	2.3%
15	15	SGS-Thomson	833	1,019	22%	2.2%
16	16	Sanyo	811	975	20%	2.1%
17	17	Sharp	751	902	20%	1.9%
18	20	Siemens	483	847	75%	1.8%
19	19	Sony	621	732	18%	1.6%
20	18	AT&T	688	716	4%	1.5%
		All Others	8,291	10,422	26%	22.2%
		North American Companies	15,990	17,400	9%	37.1%
		Japanese Companies	20,375	23,800	17%	50.7%
		European Companies	3,429	3,915	14%	8.3%
		Asia/Pacific Companies	1,274	1,809	42%	3.9%
		Total Market	41,068	46,924	14%	100.0%

Source: Dataquest
May 1990

TABLE 5
Final Estimated 1989 Worldwide Semiconductor Market Share Rankings Bipolar Digital (Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	Texas Instruments	940	671	(29%)	14.9%
2	2	Fujitsu	653	617	(6%)	13.7%
3	5	Hitachi	501	479	(4%)	10.6%
4	4	Advanced Micro Devices	536	474	(12%)	10.5%
5	3	National Semiconductor	550	458	(17%)	10.2%
6	6	Motorola	435	369	(15%)	8.2%
7	7	Philips	413	306	(26%)	6.8%
8	8	NEC	292	302	3%	6.7%
9	9	Mitsubishi	127	125	(2%)	2.8%
10	11	Plessey	94	122	30%	2.7%
		All Others	659	508	(23%)	11.3%
		North American Companies	2,761	2,221	(20%)	49.2%
		Japanese Companies	1,791	1,755	(2%)	38.9%
		European Companies	598	502	(16%)	11.1%
		Asia/Pacific Companies	50	32	(36%)	0.7%
		Total Market	5,200	4,510	(13%)	100.0%

Source: Dataquest
May 1990

Table 6
Final Estimated 1989 Worldwide Semiconductor Market Share Rankings MOS Digital (Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	NEC	3,123	3,604	15%	10.9%
2	2	Toshiba	2,639	3,100	17%	9.4%
3	3	Intel	2,328	2,420	4%	7.3%
4	4	Hitachi	1,885	2,407	28%	7.3%
5	5	Fujitsu	1,616	1,958	21%	5.9%
6	7	Motorola	1,399	1,705	22%	5.2%
7	6	Mitsubishi	1,453	1,676	15%	5.1%
8	8	Texas Instruments	1,271	1,603	26%	4.9%
9	11	Samsung	765	1,066	39%	3.2%
10	10	Oki Semiconductor	841	1,028	22%	3.1%
		All Others	9,668	12,457	29%	37.7%
		North American Companies	9,754	11,277	16%	34.1%
		Japanese Companies	14,494	18,006	24%	54.5%
		European Companies	1,684	2,135	27%	6.5%
		Asia/Pacific Companies	1,056	1,606	52%	4.9%
		Total Market	26,988	33,024	22%	100.0%

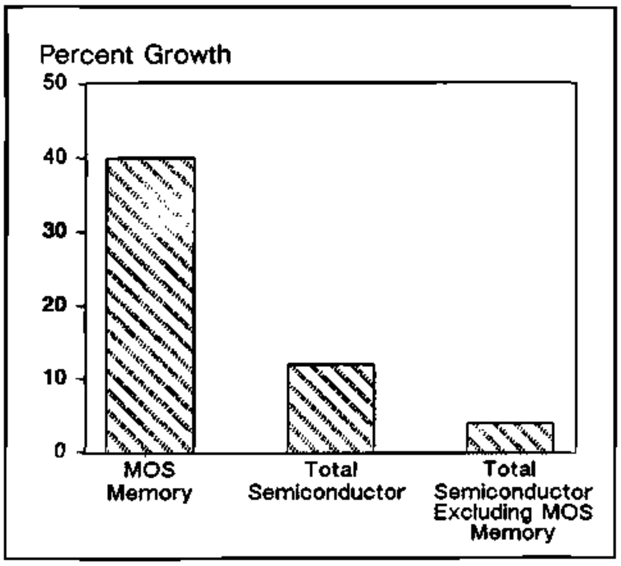
Source: Dataquest
May 1990

TABLE 7
Final Estimated 1989 Worldwide Semiconductor Market Share Rankings Analog (Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	Toshiba	569	572	1%	6.1%
2	2	National Semiconductor	540	558	3%	5.9%
3	3	Sanyo	471	530	13%	5.6%
4	5	Philips	466	522	12%	5.6%
5	7	Motorola	425	445	5%	4.7%
6	6	Texas Instruments	426	417	(2%)	4.4%
7	4	NEC	469	415	(12%)	4.4%
8	11	SGS-Thomson	352	393	12%	4.2%
9	9	Mitsubishi	395	384	(3%)	4.1%
10	8	Matsushita	423	376	(11%)	4.0%
		All Others	4,344	4,778	10%	50.9%
		North American Companies	3,475	3,902	12%	41.6%
		Japanese Companies	4,090	4,039	(1%)	43.0%
		European Companies	1,147	1,278	11%	13.6%
		Asia/Pacific Companies	168	171	2%	1.8%
		Total Market	8,880	9,390	6%	100.0%

Source: Dataquest
May 1990

FIGURE 2
MOS Memory: The Industry Driver
(Percent Growth in 1989)



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Source: Dataquest
May 1990

In a market that grew overall by 12 percent, Asia/Pacific companies' revenue grew 40 percent, paced by Samsung, with revenue representing 64 percent of the total.

As Figure 1 shows, four of the top five companies (the exception is Motorola) are heavily dependent on MOS memory revenue and are well above the average in their reliance on this, the fastest-growing segment of the semiconductor industry. The dramatic effect of memory on overall market growth in 1989 is shown in Figure 2.

DATAQUEST ANALYSIS

It remains clear to us that companies that participate in the volatile DRAM market continue to gain market share over the long term, although the past severe market downturns and questionable profitability of this market have caused many U.S. firms to leave it.

The other market that seems to ensure long-term market share gains is MOS microcomponents. This was the second fastest-growing market in 1989, as in 1988, and is an arena in which North American companies still predominate. Intel, the market leader, held almost one-quarter of the worldwide market for microcomponents in 1989; North American companies as a whole held 55 percent.

Our data also clearly show that the U.S. semiconductor industry's goal of achieving 20 percent market share in Japan is far from realization. However, in light of the plans that many Japanese purchasers have announced to increase their purchases of foreign semiconductors, this 1991 goal might conceivably be reached.

Note: Detailed data on the 138 companies included in our database will be published in Components Group service publications later this month. This information is currently available on-line.

Patricia S. Cox

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Research *Newsletter*

WORLDWIDE SEMICONDUCTOR INDUSTRY OUTLOOK, SECOND QUARTER 1990: OUT OF THE TROUGH

INTRODUCTION

The worldwide semiconductor industry recession, which began in the third quarter of 1989, has ended. Dataquest believes that the first quarter of 1990 was the final quarter of negative growth and that positive worldwide growth will resume in the second quarter of 1990.

The personal computer business, in the dumps during the second half of 1989, has begun to turn around dramatically, particularly in Europe. Semiconductor industry sources indicate that their orders from PC companies suddenly have rebounded. In addition, 1Mb DRAM production cuts by Japanese companies have resulted in a slowing of price attrition. Finally, 32-bit microprocessor demand remains high, particularly for the 80386 SX and DX, both of which have been on allocation for several months.

We expect semiconductor demand to continue to strengthen over the coming months. However, because of the recession from the third quarter of 1989 through the first quarter of 1990, the overall industry decline for 1990 will be 0.7 percent. We believe that growth will continue through 1993, which will be the peak year of this cycle, increasing by 26.5 percent. Notably, this peak year will be of lesser magnitude than the peaks of 1984 and 1988, which increased 47.5 percent and 33.0 percent, respectively. Although we expect semiconductor penetration in electronic equipment to continue to increase, the overall electronic equipment market is maturing and experiencing slower growth, and relationships between semiconductor suppliers and semiconductor users are smoothing out the bumps in the semiconductor demand curve.

Figure 1 shows actual worldwide semiconductor industry revenue compound annual growth rates (CAGRs) from 1977 through 1989 and forecast CAGRs from 1990 through 1994.

Table 1 compares our April 1989 forecast for 1990 with our current forecast.

Table 2 shows our worldwide semiconductor revenue forecast from 1989 through 1994.

REGIONAL TRENDS

From 1989 through 1994, we believe that the areas of Asia/Pacific and Rest of World (Asia/Pacific-ROW) together will represent the fastest-growing regional market for semiconductors, due to the immaturity of the market and the fast-growing economies of the region, which can still absorb considerable electronic equipment production growth through domestic demand. We believe that Europe will be the second-fastest growing region, mainly due to the "1992 Effect," which is driving trends to produce semiconductors locally in Europe for consumption there and also driving trends toward standardization across Europe for such things as cellular phone technology. We expect North America and Japan to grow at a slower rate—between 13 and 14 percent—because neither of these regions has the same impetus for growth as Asia or Europe.

North America

Dataquest still expects U.S. GNP to grow more slowly in 1990 than in 1989 and to resume stronger growth in 1991. Interest rates will be lower in 1990 as well, but they will increase in 1991.

Although we are now seeing a definite pickup in order activity, we still expect 1990 to be a slow year, with an annual semiconductor revenue decline of 3.1 percent. This decline can be largely attributed to the severe price declines of

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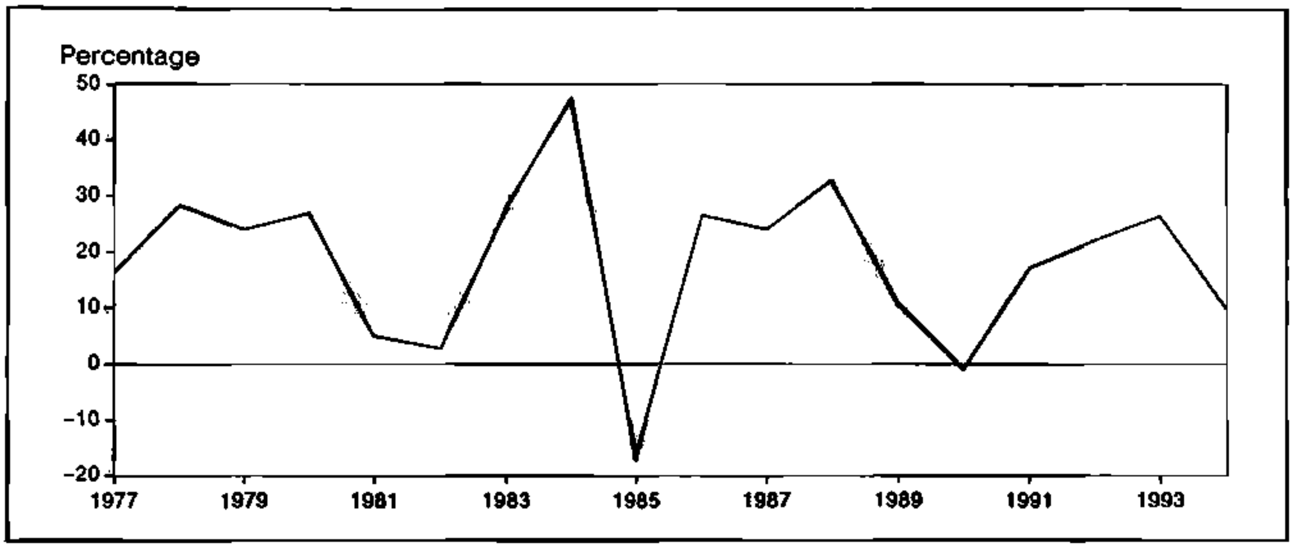
1Mb DRAMs that occurred in the second half of 1989 and the first quarter of 1990. Although the DRAM price free-fall has ended and DRAM unit growth will be strong, particularly in the second half of the year, MOS memory will decline 14.6 percent from 1989 to 1990.

Figure 1
Worldwide Semiconductor Revenue
Annual Percent Change



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Source: Dataquest
April 1990

Table 1
Comparison of 1989 and 1990 Forecasts* for Worldwide Semiconductor Revenue
(Percent Change by Geographic Region)

Region	Q1 1990	Q2 1990	Q3 1990	Q4 1990	Total 1990
North America 1989	(1.9%)	(0.3%)	2.3%	3.9%	(3.8%)
North America 1990	(4.4%)	(0.6%)	4.9%	5.4%	(3.1%)
Japan 1989	(2.8%)	3.5%	3.2%	4.5%	(1.3%)
Japan 1990	(4.1%)	1.0%	4.2%	5.3%	(2.0%)
Europe 1989	0.4%	2.2%	(1.3%)	4.9%	2.5%
Europe 1990	3.7%	1.8%	1.8%	5.6%	2.1%
Asia/Pacific-ROW 1989	1.2%	3.0%	3.2%	4.3%	6.5%
Asia/Pacific-ROW 1990	(1.3%)	5.9%	9.2%	6.1%	6.1%
Total World 1989	(1.5%)	2.0%	2.2%	4.3%	(0.5%)
Total World 1990	(2.6%)	1.2%	4.6%	5.5%	(0.7%)

*April 1989 and April 1990

Source: Dataquest
April 1990

TABLE 2
Worldwide Semiconductor Revenue by Geographic Region (Millions of Dollars)

Region	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
North America	17,707	17,165	19,951	24,045	30,539	33,519	13.6%
Percent Change	11.8%	(3.1%)	16.2%	20.5%	27.0%	9.8%	
Japan	22,908	22,449	26,051	31,577	39,316	43,240	13.5%
Percent Change	10.3%	(2.0%)	16.0%	21.2%	24.5%	10.0%	
Europe	9,537	9,737	11,376	13,905	17,454	19,162	15.0%
Percent Change	12.3%	2.1%	16.8%	22.2%	25.5%	9.8%	
Asia/Pacific-ROW	6,263	6,646	8,202	10,559	13,992	15,666	20.1%
Percent Change	8.9%	6.1%	23.4%	28.7%	32.5%	12.0%	
Total World	56,415	55,997	65,580	80,086	101,301	111,587	14.6%
Percent Change	10.9%	(0.7%)	17.1%	22.1%	26.5%	10.2%	

Source: Dataquest
April 1990

Japan

Japanese GNP is expected to grow more slowly than in 1989, between 4.0 and 4.9 percent, but it still will experience stronger growth than the GNPs of the United States and Europe. Capital spending plans in Japan are good this year. The yen-to-dollar exchange rate bears watching, as usual, because a sharp move in either direction could negatively impact Japanese semiconductor producers. The 1989 yen-to-dollar exchange rate was 138 yen per dollar; in 1990, it is 149 yen per dollar.

Semiconductor demand and supply are now coming into balance in Japan. Severe memory price declines have ended, and some products, such as CMOS standard logic, are in short supply. The industrial electronics sector is strong; in particular, production of personal computers is picking up.

A particularly promising sign is the beginning of a recovery in Japanese production of consumer electronics. In recent years, this sector was particularly hard hit by the movement of consumer equipment production offshore, particularly to Asia/Pacific, but also to North America and Europe. We believe that camcorder and color TV production in Japan will recover this year.

Europe

The major European economies are expected to have GNP growth higher than in the United States but below the growth rates of Japan and Asia/Pacific-ROW. The United Kingdom, however, is experiencing economic problems. A recent Dun & Bradstreet survey indicates that U.K. business expectations are at an extremely low level.

We expect the European semiconductor market to grow 2.1 percent in 1990, faster than the markets of either North America or Japan but slower than the market in Asia/Pacific-ROW. Personal computer makers recently have placed six months of orders with semiconductor suppliers in Europe, an event unexpected only two months ago. Undoubtedly, this surge in orders is partly due to the assumption that DRAM prices fell as far as they could in the first quarter, eliminating the need to "wait for next month" and perhaps causing PC makers to overstock at fire sale prices.

Despite a recent ruling by the General Agreement on Tariffs and Trade (GATT) indicating that European local content laws are not legal, the European Community Commission now has the opportunity to prove the need for such laws. Although this ruling implies that companies making electronic equipment in Europe need not purchase chips diffused in Europe, Dataquest believes that compelling reasons still exist for non-European companies to continue with their plans for both semiconductor and electronic equipment production in Europe.

Asia/Pacific-ROW

The Asian economies are expected to continue to grow faster than the economies of the other major regions of the world. This growth will fuel Asian domestic demand for all types of electronic

TABLE 3
Worldwide Semiconductor Revenue by Category (Millions of Dollars)

Category	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Semiconductor	56,415	55,997	65,580	80,086	101,301	111,587	14.6%
Percent Change	10.9%	(0.7%)	17.1%	22.1%	26.5%	10.2%	
Total IC	46,514	45,788	54,126	66,786	86,413	95,600	15.5%
Percent Change	13.3%	(1.6%)	18.2%	23.4%	29.4%	10.6%	
Bipolar Digital	4,644	4,085	4,379	4,620	4,899	4,640	0
Percent Change	(10.7%)	(12.0%)	7.2%	5.5%	6.0%	(5.3%)	
Bipolar Memory	591	489	435	382	348	307	(12.3%)
Percent Change	(14.2%)	(17.3%)	(11.0%)	(12.2%)	(8.9%)	(11.8%)	
Bipolar Logic	4,053	3,596	3,944	4,238	4,551	4,333	1.3%
Percent Change	(10.2%)	(11.3%)	9.7%	7.5%	7.4%	(4.8%)	
MOS Digital	32,783	32,234	38,535	48,745	65,295	72,479	17.2%
Percent Change	21.5%	(1.7%)	19.5%	26.5%	34.0%	11.0%	
MOS Memory	16,133	14,265	17,310	22,710	31,311	35,663	17.2%
Percent Change	38.0%	(11.6%)	21.3%	31.2%	37.9%	13.9%	
MOS Micro	8,081	8,668	10,021	11,982	15,915	17,525	16.7%
Percent Change	13.1%	7.3%	15.6%	19.6%	32.8%	10.1%	
MOS Logic	8,569	9,301	11,204	14,053	18,069	19,291	17.6%
Percent Change	5.1%	8.5%	20.5%	25.4%	28.6%	6.8%	
Analog	9,087	9,469	11,212	13,421	16,219	18,481	15.3%
Percent Change	2.3%	4.2%	18.4%	19.7%	20.8%	13.9%	
Total Discrete	7,561	7,775	8,628	10,008	11,093	11,683	9.1%
Percent Change	(0.7%)	2.8%	11.0%	16.0%	10.8%	5.3%	
Total Optoelectronic	2,340	2,434	2,826	3,292	3,795	4,304	13.0%
Percent Change	7.4%	4.0%	16.1%	16.5%	15.3%	13.4%	

Source: Dataquest
April 1990

equipment, including consumer equipment, computers, peripherals, and telecommunications equipment. In 1989, domestic consumption growth far outstripped export growth in most Asia/Pacific-ROW countries; we expect this trend to continue.

Even in the grim year of 1990, the Asia/Pacific-ROW semiconductor market will grow 6.1 percent, with a negative first quarter and strong quarterly growth thereafter.

PRODUCT TRENDS

The real story for 1990 is that virtually every other product category will outstrip the performance of MOS memory, with the exception of bipolar digital ICs, which continue to be replaced by CMOS and BiCMOS chips.

Although MOS memory will decline in 1990, over the long term we expect it to resume its historically high growth.

Dataquest has heard recently that Japanese companies are beginning to leave the standard logic market, thus opening up this market to the possibility of shortages—which already are occurring in Japan—and also opening up the market to U.S. and European participants.

Table 3 shows our worldwide forecast for the major semiconductor categories.

DATAQUEST ANALYSIS

We are gratified that our forecast appears to be coming true. For more than a year we have predicted that the second half of 1989 and the first quarter of 1990 would be periods of negative growth for the semiconductor industry, followed by increased growth. Now we are seeing clear signals of renewed industry health, with a definite pickup in order activity. We expect to see billings improve in the second quarter. Some companies are reporting to Dataquest that they experienced record bookings months in February and March.

The Japanese companies, by cutting their production of DRAMs, have forced memory out of its free-fall, paving the way for supply-demand balance. The resurgence of the personal computer market, combined with single-sourcing strategies by U.S. companies for 32-bit microprocessors, is keeping the microprocessor market healthy.

All in all, we are cautiously optimistic about the second quarter, and we continue to foresee stronger growth emerging in the last half of 1990.

Patricia S. Cox

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Research Newsletter

RECENT TRENDS IN START-UP ACTIVITY

SUMMARY

During the last 10 years, there has been an explosion of new activity in the semiconductor industry. Dataquest has identified 170 start-ups formed between 1979 and 1989, several of which already have become $100 million operations. In the next decade some may well become $1 billion companies. As we enter the 1990s there are several notable trends for semiconductor start-ups, including a general decline in start-up activity; consolidation of the industry marked by an increase in the number of mergers, acquisitions, and closures; a shift toward microcomponent products; and a trend toward fabless semiconductor vendors.

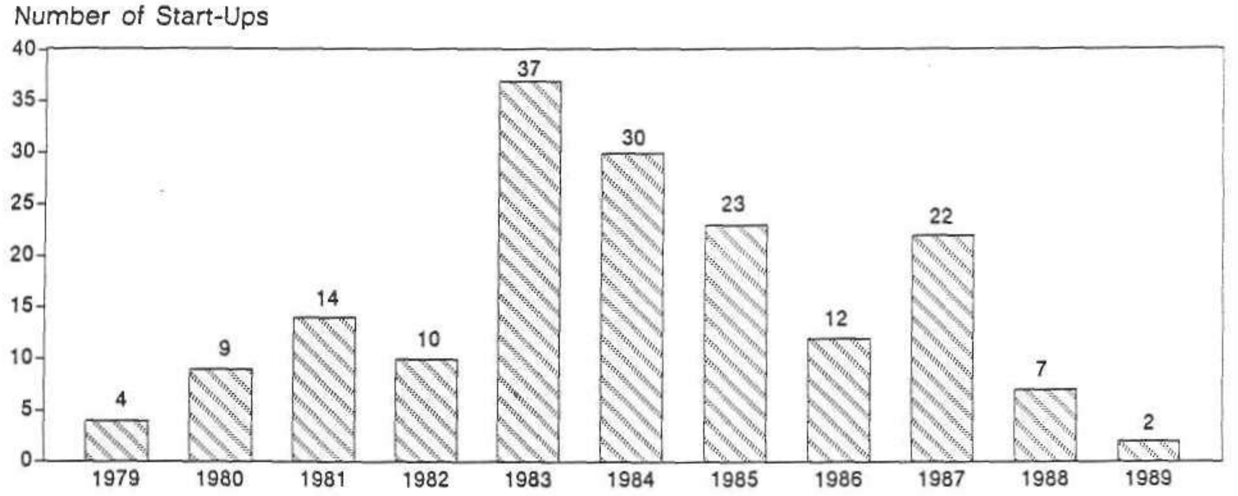
START-UPS SLOW DOWN

After reaching a peak in 1983, the number of companies that were started each year gradually declined through the latter half of the 1980s (see Figure 1). Three major reasons account for this drop in start-up activity: declining availability of venture capital, market crowding, and slumping industry conditions.

Beginning in 1987, the venture capital community has become increasingly disenchanted with the semiconductor industry. It is becoming extremely difficult for a new company to secure the venture financing necessary to bring a semiconductor product to market. Without venture funding, many start-ups never get off the ground. Start-ups therefore are turning to other sources of funding, including strategic alliances with larger corporations, other corporate investments, and private placements.

A second reason for the decline in start-up activity is market crowding. Many of the niches

FIGURE 1
Semiconductor Start-Ups by Year (1979-1989)



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Source: Dataquest
April 1990

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that start-ups have recently pursued are becoming quite crowded, causing prices and margins to fall. The markets for ASICs and fast SRAMs are especially full; consequently, fatality rates are rising and entry rates are falling. Start-ups, therefore, currently are searching for new niches to inhabit, and Dataquest expects start-up activity to be limited until a new market with significant growth potential is uncovered.

The third and perhaps most important reason for slow start-up activity is the general softness of the semiconductor industry. The level of start-up activity is strongly correlated to the general strength of the industry. The past two years, which have been slow growth years for the industry, also have been quite slow from the start-up activity standpoint. Most people are unwilling to start a company in an uncertain market.

INDUSTRY CONSOLIDATION

Historically, Dataquest has identified a period of consolidation, acquisition, and a shake-out of start-ups following each peak of start-up activity. While the number of start-ups has been declining, the number of mergers, acquisitions, and closures has increased in the last two years. In the last two years, 10 start-ups have closed, been acquired, or have merged. Table 1 lists the companies that were acquired, merged, or closed in 1988 and 1989.

PRODUCT TRENDS: MICROS ARE THE RISING STAR

In 1983, 19 ASIC start-ups were formed. Since 1985, only 8 new ASIC companies have emerged. As previously stated, the ASIC and memory niches have become crowded, and entry into these niches is limited. Recently, more start-ups are specializing in microcomponent products. Of all start-ups formed since 1986, one-third manufacture microcomponents. The most popular new microcomponent products have been PC logic and peripheral chip sets. Headland Technologies, formed by the merger of two small subsidiaries of LSI Logic (G-2 and Video Seven) manufactures PC graphics and logic chip sets. Other recent entrants into chip set markets include ACC Microelectronics, Hualon Micro-Electronics (Taiwan), Oak Technology, S3, and VIA Technologies.

Another microcomponent market that is attracting a great deal of attention is that of math coprocessors. Currently, two new start-ups, Cyrix and Integrated Information Technology, are manufacturing math coprocessors. These companies produce devices that are plug-compatible with

TABLE 1
Companies that Were Acquired or Closed in 1988 and 1989

Company	Closed/Acquired	Acquired By
Barvon Research	Acquired	Sipex
Exel Microelectronics	Acquired	Rohm
GAIN Electronics	Closed	
Intercept Microelectronics	Closed	
Krysalis	Acquired	National
Saratoga Semiconductor	Closed	
Sensym	Acquired	FASCO Sensors and Controls Group
Silicon Systems	Acquired	TDK
Tachonics	Closed	
Video Seven	Acquired	LSI Logic

Source: Dataquest
April 1990

Intel parts. Dataquest believes that this market is ripe for expansion, and we expect to see more new start-ups entering this market.

FABLESS SEMICONDUCTOR COMPANIES

Perhaps the most notable trend among semiconductor start-ups is the movement toward fabless ventures. Of the semiconductor companies started between 1979 and 1989, 60 percent do not have their own wafer fabrication facility. Of the semiconductor start-ups founded since 1985, 72 percent are fabless. Notable success stories among fabless vendors include Adaptec, Chips & Technologies, Cirrus Logic, S-MOS Systems, and Weitek. These fabless semiconductor operations subcontract wafer fabrication work to other firms, which serve as foundries. In addition, most of these start-ups subcontract assembly and packaging operations while maintaining in-house testing capabilities. Much of this foundry work is done in Asia, although some U.S. manufacturers offer significant foundry services.

There are several reasons why semiconductor manufacturers choose to operate without their own fabrication facility, including the following:

- Management has the opportunity to focus on the design and marketing aspects of the business, rather than worry about operating a fab.
- By not worrying about filling fab capacity or designing a fabrication process, a company can more easily define its product strategy using a marketing orientation rather than a production orientation.
- A company can choose the best available combination of technology, quality, and cost.
- A company can avoid the continual capital cost associated with operating a fab and the continuing expense of process development.

A partial list of fabless semiconductor vendors is shown in Table 2.

DATAQUEST CONCLUSIONS

Dataquest expects start-up activity to be limited in the near term. The lack of available capital is a heavy burden on start-up ventures. It is likely that we will see more strategic alliances involving start-ups and larger manufacturers. Such agreements are win-win propositions for the companies involved: the start-up gets needed funding or manufacturing capability, and the large corporation obtains access to new technologies developed by the start-up. Being acquired by another company provides existing companies another opportunity to gain necessary funding to continue operations. As long as semiconductor industry growth remains slow, we anticipate continuing consolidation marked by closures, mergers, and acquisitions.

TABLE 2
Fabless Semiconductor Companies

Company	Location
Actel Corp.	Sunnyvale, CA
Adaptec, Inc.	Milpitas, CA
Cirrus Logic, Inc.	Milpitas, CA
Cyrix Corp.	Richardson, TX
Integrated Information Technology	Santa Clara, CA
Lattice Semiconductor	Hillsboro, OR
Plus Logic	San Jose, CA
WaferScale Integration	Fremont, CA
Weitek Corp.	Sunnyvale, CA
Xilinx Inc.	San Jose, CA

Source: Dataquest
April 1990

The microcomponent market is one of the few areas where Dataquest expects some start-up activity in the next year or two. Many microcomponents traditionally have been sole-sourced parts. The high margins that exist in these markets are a significant attraction to market entry. Finally, we anticipate that fabless semiconductor companies will continue to be commonplace, especially in these uncertain times.

Note: The basis of this newsletter is a new report from Dataquest entitled *A Decade of Semiconductor Start-Ups—Third Edition*. The report contains 446 pages of industry analysis and individual profiles on 137 start-ups. The price of this report is $495. It can be ordered by contacting Patty Chang at (800) 624-3282.

Phil Mosakowski

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Research Newsletter

FIRST QUARTER 1990 WORLDWIDE SEMICONDUCTOR INDUSTRY OUTLOOK: STABILIZATION IS AROUND THE CORNER

INTRODUCTION

Dataquest believes that the worldwide semiconductor market will turn the corner in the second quarter of 1990, when positive growth will resume after three consecutive quarters of negative growth.

Our data indicate that semiconductor buyer inventory targets are turning slightly up, averaged monthly semiconductor orders are up, and inventory levels of communications equipment and instrumentation are falling in weeks of sales. In addition, the ratio of computer orders to semiconductor shipments is high.

We believe that the Japanese companies' announced cutbacks in DRAM production should help stabilize cascading DRAM prices.

REGIONAL MARKETS

North America and Asia-Pacific/ROW will have the strongest growth rates, according to our forecast. Japan and Europe will both experience negative growth. No region is expected to grow more than 3 percent. Our total semiconductor outlook for 1989 through 1991 is shown in Table 1.

North America

Since our last forecast, the computer industry has begun to emerge from its third quarter 1989 slump, semiconductor buyer optimism has improved, the computer book-to-bill and

TABLE 1
Worldwide Semiconductor Market Forecast 1989-1991 (Millions of Dollars)

	1989*	Q1 '90	Q2 '90	Q3 '90	Q4 '90	Total 1990
North America	17,604	4,479	4,524	4,501	4,591	18,095
Percent Change	11.1%	1.0%	1.0%	(0.5%)	2.0%	2.8%
Japan	22,175	5,261	5,461	5,503	5,866	22,091
Percent Change	6.8%	(4.1%)	3.8%	0.8%	6.6%	(0.4%)
Europe	9,707	2,240	2,305	2,360	2,509	9,414
Percent Change	14.3%	1.7%	2.9%	2.4%	6.3%	(3.0%)
Asia/ROW	6,349	1,538	1,578	1,620	1,680	6,416
Percent Change	10.4%	(1.8%)	2.6%	2.7%	3.7%	1.1%
Worldwide	55,835	13,518	13,868	13,984	14,646	56,016
Percent Change	9.8%	(2.2%)	2.6%	0.8%	4.7%	0.3%

(Continued)

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TABLE 1 (Continued)
Worldwide Semiconductor Market Forecast 1989-1991 (Millions of Dollars)

	Q1 '91	Q2 '91	Q3 '91	Q4 '91	Total 1991
North America	4,798	5,100	5,207	5,556	20,661
Percent Change	4.5%	6.3%	2.1%	6.7%	14.2%
Japan	6,060	6,133	6,446	6,594	25,233
Percent Change	3.3%	1.2%	5.1%	2.3%	14.2%
Europe	2,622	2,803	2,740	2,871	11,036
Percent Change	4.5%	6.9%	(2.2%)	4.8%	17.2%
Asia/ROW	1,756	1,886	1,950	2,116	7,708
Percent Change	4.5%	7.4%	3.4%	8.5%	20.1%
Worldwide	15,236	15,922	16,343	17,137	64,638
Percent Change	4.0%	4.5%	2.6%	4.9%	15.4%

*1989 data reflect the actuals collected in our preliminary 1989 market share survey. For more information, see the Dataquest Components Group Newsletter 1990-1, "Preliminary 1989 Worldwide Semiconductor Market Share Estimates: NEC and Toshiba Neck and Neck."

Source: Dataquest
February 1990

semiconductor book-to-bill have gone above parity, and semiconductor and computer orders have stabilized. In addition, our surveys show that several large U.S. companies are experiencing improved bookings; Intel posted record revenue in the last quarter of 1989. OEM inventories of semiconductors are low, and computer orders and the book-to-bill are improving.

In addition to these positive signs, the U.S. economy is expected to remain strong through 1991, business expectations are high, and real after-tax income has been rising since the beginning of 1989.

Although personal computer companies are experiencing difficult times right now, we believe that there are opportunities for growth in this area. The 386-based PCs are beginning to replace 286-based models as the majority of new PCs shipped, and notebook and laptop PCs continue to record strong growth. Other driving applications for semiconductors during 1990 and 1991 will include handheld communication devices, such as portable and cellular phones; laser printers; and hard disk drives.

Japan

Production of both electronic equipment and semiconductors continues to move offshore—mainly to Europe, but also to North America and Asia/Pacific.

Consumer purchases are lagging. The VCR, previously the pacesetter in this area, is moving very slowly now since 75 percent of Japanese homes now own VCRs. However, personal computers, word processors, and printers, as well as many gadgets, are now being bought for home use.

High growth markets for semiconductors in Japan are fax machines, telephones, answering machines, laser printers, and laptop and personal computers.

Political instability in China is casting a shadow over Japanese export sales of consumer items. Virtually every company selling into China suffered flat or negative sales growth in 1989. This situation is not expected to turn around until the second half of 1990.

The Japanese economy remains strong, with GNP growth forecast at 4.5 to 4.9 percent in 1990.

Europe

In a reversal of the normal state of affairs, the European market will grow more strongly in the second half of 1990 than in the first half, due primarily to the DRAM situation. DRAM prices are quite low due to excess inventories, slackened personal computer demand, and aggressive pushes for market share by the many competitors in the European marketplace.

Personal computers, the major DRAM consumer in Europe, are expected to experience production growth of only 23 percent in units in 1990, compared with normal levels of 30 to 40 percent. Again, fierce competition is occurring, particularly from foreign suppliers.

We believe that the European economies will grow more slowly than in 1989, but will still grow faster than the United States.

Asia/Pacific

Taiwanese companies continue to aggressively ship personal computers, with buyouts and marketing channels proving vital to their surge. Two U.S. PC companies—Dyna, a distributor, and Wyse, a manufacturer—were bought in 1989 by Taiwanese companies, Acer and Mitac-led Channel International, respectively. Acer has also recently purchased two European PC manufacturers—Ce-Tec Data Technology of Germany and Kangaroo Computer B.V. of the Netherlands—which have extensive distribution channels in Europe.

Partly to feed this internal demand, Taiwan will end 1990 with six semiconductor fabs, after entering the year with only one.

Domestic consumer demand in Asia continues to have high growth and will have to absorb additional volume due to decelerating exports.

Many of the estimated 60 percent of Hong Kong companies that have manufacturing or other operations in China are beginning to move these operations into other parts of Asia, particularly Thailand and Malaysia.

Product Trends

DRAM prices should be stable by the second half of 1990 and begin to rise in 1991. Unit demand is still high for 1Mb DRAMs, but 256K devices have fallen by the wayside. Total DRAM unit growth is expected to be less than 5 percent worldwide in 1990. Japanese companies are cutting back their DRAM production and shifting production to mask ROMs, for which demand is still quite good. More production cutbacks could occur soon, setting the stage for prices to rise faster.

Traditional CMOS gate arrays have become unprofitable commodity products, as many players try to capture market share advantage. Even high gate count parts are money losers. Although bipolar gate arrays are profitable, the customer base for such products is very narrow. Companies will continue to make traditional gate arrays in order to drive their interconnect and other technologies.

CMOS is fast replacing TTL in programmable logic devices (PLDs), but price erosion is rampant in both TTL and CMOS models. However, complex PLDs, such as field programmable gate arrays (FPGAs), continue to grow rapidly and are expanding into applications such as low-volume industrial applications and the military. These applications cannot justify gate arrays or cell-based ICs, which require medium to high-volume quantities to be cost effective.

Embedded gate arrays and cell-based ICs are forecast to dominate the high-density ASIC market as users continue to require ever greater functionality from the same amount of silicon real estate.

Microdevice prices continue to fall, as personal computer prices drop dramatically. We expect only single-digit growth in the microdevice category in 1990. Although laptops are still growing fast, they represent only 12 percent of the personal computer market.

Analog ICs experienced severe price declines in 1989, particularly in the commodity linear products. Commodity linear prices are now firming. In 1989, analog prices dropped while unit shipments grew. In 1990, the opposite will occur: prices will be firm, but unit shipments will decline from 1989. The net effect in both years is flat shipments in revenue terms. The automotive end market is now in a slump, but is targeted as a major growth area that could take off if auto sales pick up. Consumer end market sales will be flat in 1990.

Dataquest Conclusions

Clearly, 1990 will be a year of challenges for the global semiconductor industry. Market opportunities will be limited, particularly in the personal computer market. However, we believe that the worst is over, and that the stabilizing factors now occurring—such as inventory control, order improvement, and DRAM production control—are setting the groundwork for an industry recovery.

Combined with the favorable economic conditions that are predicted to persist through 1990 and 1991, we expect the industry to complete its recovery this year and grow at a modest clip in 1991.

Patricia S. Cox

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Research *Bulletin*

Dram! Foiled Again! U.S. Memories Nixed

SUMMARY

On January 15, 1990, Sanford Kane, president and CEO of U.S. Memories (USM), announced the consortium's dissolution. Mr. Kane said that it was particularly discouraging to him that the U.S. computer industry had made a tactical rather than a strategic decision about its participation in the global marketplace. He referred to U.S. Memories as a strategic approach that could have worked; but with the exception of solid support from IBM and Digital Equipment Corporation, there was inadequate response from the rest of the computer industry.

BACKGROUND

In forming U.S. Memories, Mr. Kane successfully mastered the challenges of producing a business plan, obtaining an agreement with IBM to license its 4Mb DRAM design and process technology, narrowing down the selection of a plant site, and obtaining a favorable opinion regarding the antitrust issues. But in the end, he could not convince enough DRAM users to cumulatively invest $500 million and guarantee to purchase at least 50 percent of USM's DRAM output. Even on its deathbed, USM made one final effort with a revised plan wherein the total equity investment required from the participating computer manufacturers was scaled down to $150 million. However, the purchase guarantees rose from 50 percent of USM's output to 75 to 80 percent of the output, and an additional $200 million of equity was to be raised from external institutional investors. This plan was submitted to 11 interested companies—the seven original investors (AMD, Digital, HP, IBM, Intel, LSI Logic, and National Semiconductor) and four others (AT&T, Compaq Computer, NCR, and Tandem Computers). At a meeting on January 10, the revised proposal could not garner sufficient support, so the decision was made not to go ahead with U.S. Memories.

CHRISTMAS TREES IN AUGUST: TIMING IS EVERYTHING

The speakers at the January 15 press conference said that the impetus for the formation of a U.S. Memories came from an "urgent request" from the AEA to the SIA that the domestic computer industry wanted an indigenous company that could supply 40 percent of its DRAM requirements within a reasonable time. USM's mission was, simply put, to provide a domestic source for an assured, stable supply of DRAMs while also offering an attractive return on investment. The computer companies' cry for a domestic supply of DRAMs was driven by the difficulties experienced from 1987 through the first half of 1989 when 1Mb DRAMs were scarce and expensive. However, as Dataquest predicted, by the time USM's funding effort had gained a full head of steam, the bottom had dropped out of the 1Mb DRAM market, and the industry was awash in parts. The passion for a domestic DRAM supplier had waned, and the computer manufacturers had forgotten about last year's problems.

DATAQUEST ANALYSIS

Rather than merely stating Dataquest's opinion, it may be more useful to our clients if we share the comments regarding USM's fate that we have received from our industry, investment banking, and venture capital clients. Most believe that the demise of USM does not signal the U.S. computer industry's inability to develop a domestic memory supply strategy, but rather, that the USM plan was the wrong approach.

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USM's failure seems to imply that the United States cannot effectively orchestrate a consensus commitment to resolve a common problem. Obviously, that position is endlessly arguable. The criticisms from Cypress, Micron, and others did not kill the deal, but they certainly didn't help, as they raised an entirely new set of questions. For example, a Wall Street investment banker asked us to cite one example of a successful IBM semiconductor spinout. There was unceasing and unresolved debate as to whether the solution to the United States' memory needs lie in government-backed consortia or in private enterprise. Not only was USM a pseudo-Japanese approach to the problem, albeit without the advantages that vertically integrated Japanese companies enjoy, but it was a way of doing business that seems alien to the entrepreneurial American psyche.

Dataquest is aware of other ongoing efforts to establish a sizable U.S.-based memory capability. Approaches such as that taken by Texas Instruments with its vendor alliances may also serve as a more workable (i.e., "acceptable") model. We believe that the 1990s will see a series of alliances between memory consumers and major U.S.-based memory producers that are willing to make significant investments; however, in more focused relationships.

The people of the United States have never mastered the ability to work together in a consortium except in times of dire national crisis. Even then, the cooperation was not nearly as altruistic as the historians would have us to believe. In the brief period of USM's existence, North American companies' worldwide semiconductor market share declined from 37 percent to 35 percent. How much worse do matters have to get before the leaders of U.S. government and industry realize that a national crisis is at hand? So U.S. Memories is dead, but not without some benefit. If nothing else, and this is a hollow victory, the plight of the U.S. semiconductor industry is now much better known throughout government, industry, and the American household than before USM's effort. On May 22, 1932, at Oglethorpe University, Franklin Delano Roosevelt stated that "this country....demands bold, persistent experimentation. It is common sense to take a method and try it. If it fails, admit it frankly and try another. But above all, try something." We probably will never know if USM was or was not the correct approach; however, we salute Sandy Kane and the original seven investors for having the courage and the vision to try and do something about the problem.

David L. Angel
O. Fred Jones
Patricia Galligan

P.S. Deja vu all over again: The leading story in the Business section of the January 17, 1990, *San Jose Mercury* was headlined "Japanese chip cut portends (DRAM) shortage."

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PRELIMINARY 1989 WORLDWIDE SEMICONDUCTOR MARKET SHARE ESTIMATES: NEC AND TOSHIBA NECK AND NECK

INTRODUCTION

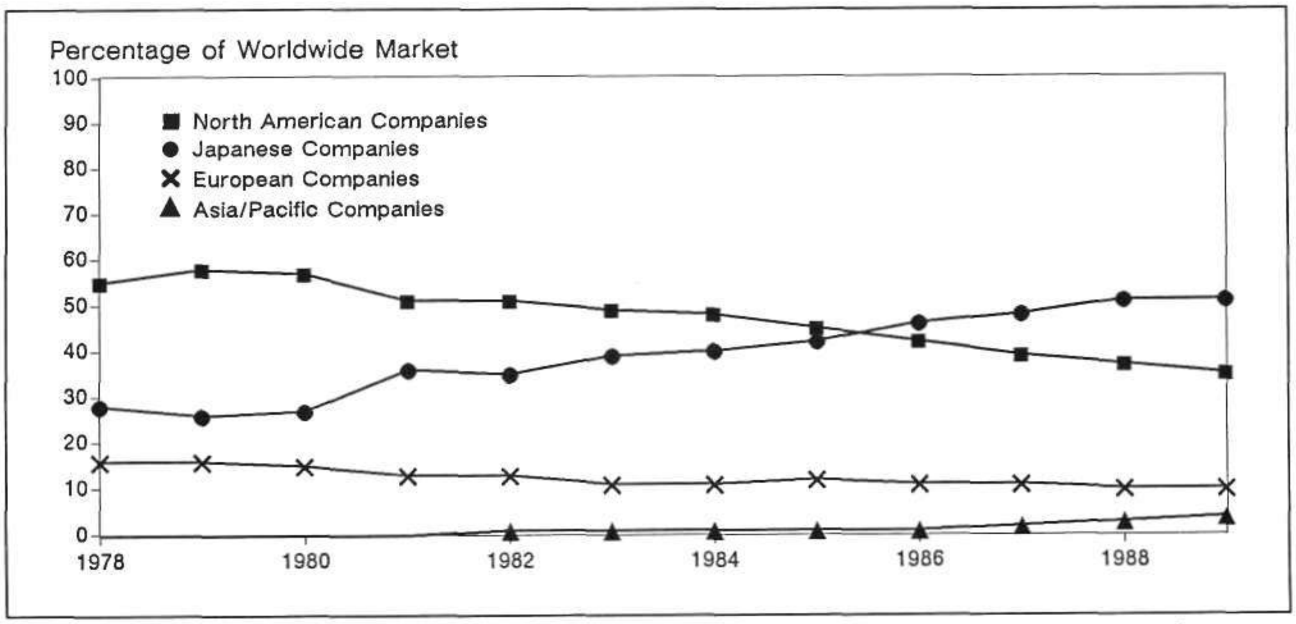
Dataquest has completed its preliminary analysis of 1989 semiconductor market shares for more than 120 semiconductor vendors worldwide. We have reached the following conclusions, based on surveys of these vendors:

- Japanese companies maintained a market share of 51 percent worldwide, the same as 1988, while North American companies dropped to 35 percent, Europeans stayed at 10 percent, and Asia/Pacific companies grew to 4 percent (see Figure 1).

- NEC remained the number one semiconductor supplier worldwide, with revenue of almost $5 billion! Toshiba was within 1.5 percent of the leader, with revenue of almost $4.9 billion.

Figure 1

Regional Shares of Worldwide Semiconductor Market



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Source: Dataquest
January 1990

Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398 / (408) 437-8000 / Telex 171973 / Fax (408) 437-0292

- Worldwide semiconductor shipments grew 10 percent in 1989, although significant variation existed between the different product segments.
- Asia/Pacific companies experienced by far the highest growth of any regional group, at 43 percent—four times faster than the worldwide average.
- Japanese companies now supply 24 percent of the North American semiconductor market, up from 21 percent in 1988, while North American companies have maintained a market share of 10 percent in Japan.

Table 1 lists shares of the world market and the four major regional markets by company base. Table 2 shows worldwide semiconductor shipments by product segment.

Table 1

Preliminary Estimated 1989 Semiconductor Market Share Analysis (Millions of Dollars)

	Regional Market				
Company Base	North America	Japan	Europe	Asia/ Pacific/ ROW	World
North America	$11,565	$ 2,147	$4,005	$2,056	$19,773
Percent of Regional Market	66%	10%	41%	32%	35%
Percent of Company Sales	58%	11%	20%	10%	100%
Japan	$ 4,303	$19,823	$1,913	$2,595	$28,634
Percent of Regional Market	24%	89%	20%	41%	51%
Percent of Company Sales	15%	69%	7%	9%	100%
Europe	$ 1,043	$ 123	$3,564	$ 682	$ 5,412
Percent of Regional Market	6%	1%	37%	11%	10%
Percent of Company Sales	19%	2%	66%	13%	100%
Asia/Pacific	$ 693	$ 82	$ 226	$1,016	$ 2,017
Percent of Regional Market	4%	0	2%	16%	4%
Percent of Company Sales	34%	4%	11%	50%	100%
World	$17,604	$22,175	$9,708	$6,349	$55,836
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	32%	40%	17%	11%	100%

Source: Dataquest
January 1990

Table 2

Worldwide Semiconductor Shipments
(Millions of Dollars)

	1988	1989	Percent Change
Total Semiconductor	$50,859	$55,836	9.8%
Total Integrated Circuit	$41,068	$45,935	11.9%
Bipolar Digital	$ 5,200	$ 4,644	(10.7%)
Bipolar Memory	$ 689	$ 591	(14.2%)
Bipolar Logic	$ 4,511	$ 4,053	(10.2%)
ASIC	$ 1,863	$ 1,869	0.3%
Standard Logic	$ 2,399	$ 1,911	(20.3%)
Other Logic	$ 249	$ 273	9.6%
MOS Digital	$26,988	$32,203	19.3%
MOS Memory	$11,692	$15,553	33.0%
MOS Microdevice	$ 7,144	$ 8,081	13.1%
MOS Logic	$ 8,152	$ 8,569	5.1%
ASIC	$ 5,836	$ 6,391	9.5%
Standard Logic	$ 1,215	$ 1,232	1.4%
Other Logic	$ 1,101	$ 946	(14.1%)
Analog	$ 8,880	$ 9,088	2.3%
Monolithic	$ 7,418	$ 7,714	4.0%
Hybrid	$ 1,462	$ 1,374	(6.0%)
Discrete	$ 7,612	$ 7,561	(0.7%)
Optoelectronic	$ 2,179	$ 2,340	7.4%

Source: Dataquest
January 1990

RANKINGS

Figure 2 lists the top 20 semiconductor suppliers worldwide. Overall, 1989 was a year of slow growth for the semiconductor industry. Total shipment growth was 10 percent, and the two leaders, NEC and Toshiba, grew 9 percent and 11 percent, respectively.

NEC, as the leading personal computer maker in Japan, is clearly the Japanese leader in the microprocessor and related device arena. However, Toshiba is now the largest supplier of MOS memory in the world. The two companies are almost equal in sales of MOS logic. Toshiba is stronger in analog and discrete, and NEC is much larger in bipolar digital logic.

Figure 2

Preliminary Estimated 1989 World Semiconductor Market Share Rankings
Top 20 Manufacturers

Company	1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
				(Millions of Dollars)			
NEC	1	1		4,543	4,964	9%	8.9%
Toshiba	2	2		4,395	4,889	11%	8.8%
Hitachi	3	3		3,506	3,930	12%	7.0%
Motorola	4	4		3,035	3,322	9%	5.9%
Fujitsu	5	6		2,607	2,941	13%	5.3%
Texas Instruments	6	5		2,741	2,787	2%	5.0%
Mitsubishi	7	8		2,312	2,629	14%	4.7%
Intel	8	7		2,350	2,440	4%	4.4%
Matsushita	9	9		1,883	1,871	(1%)	3.4%
Philips	10	10		1,738	1,690	(3%)	3.0%
National Semiconductor	11	11		1,650	1,618	(2%)	2.9%
SGS-Thomson	12	12		1,087	1,301	20%	2.3%
Samsung	13	18		905	1,284	42%	2.3%
Sharp	14	15		1,036	1,230	19%	2.2%
Siemens	15	20		784	1,194	52%	2.1%
Sanyo	16	14		1,083	1,132	5%	2.0%
Oki	17	17		947	1,125	19%	2.0%
Advanced Micro Devices	18	13		1,084	1,082	0	1.9%
Sony	19	16		950	1,077	13%	1.9%
AT&T	20	19		859	873	2%	1.6%

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Source: Dataquest
January 1990

Among the top 20 companies, Siemens, Samsung, and SGS-Thomson had the highest growth rates, at 52 percent, 42 percent, and 20 percent, respectively. Siemens and Samsung both jumped up 5 places in the rankings, while SGS-Thomson retained its number 12 ranking from 1988. Siemens' and Samsung's high growth is primarily attributable to MOS memory, particularly 1Mb DRAMs. SGS-Thomson, while not a player in the DRAM market, experienced extremely high growth in its sales of static RAMs, microdevices, and ASICs, due partially to its acquisition of Inmos.

The bipolar digital market has shrunk considerably this year, declining by 11 percent in total, as CMOS and BiCMOS begin to replace this technology.

MOS digital growth was strong at 19 percent. Toshiba was the number one supplier in a MOS memory market that grew 33 percent. The highest growth in MOS memory, however, was experienced by Siemens, which grew 184 percent on the strength of its 1Mb DRAMs. Intel remains the number one supplier of MOS microdevices, with almost 24 percent market share, as compared with number two NEC's almost 13 percent market share. The microdevice market was the second fastest growing of the major product segments. Toshiba surpassed NEC this year as the premier supplier of MOS logic. This market experienced lackluster growth of 5 percent.

The analog market grew only 2 percent. Although Toshiba remained number one, its sales declined by 1 percent. Harris' growth of 92 percent is due to its acquisition of GE Solid State. The discrete market declined 1 percent and the optoelectronic market grew 7 percent. Matsushita usurped Sony's position as number two, growing from the number five slot in 1988.

Tables 3 through 13 list the top suppliers in the product segments of total integrated circuit, bipolar digital, bipolar memory, bipolar logic, MOS digital, MOS memory, MOS microdevice, MOS logic, analog, discrete, and opto. The following notes apply to these tables:

- SGS-Thomson revenue includes Inmos revenue beginning in 1989.
- Harris revenue includes GE Solid State revenue beginning in 1989.

Table 3

Preliminary Estimated 1989 Worldwide Semiconductor Market Share Rankings Total Integrated Circuit (Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	NEC	3,884	4,346	12%	9.5%
2	2	Toshiba	3,316	3,829	15%	8.3%
3	3	Hitachi	2,729	3,179	16%	6.9%
4	5	Fujitsu	2,420	2,755	14%	6.0%
5	4	Texas Instruments	2,637	2,691	2%	5.9%
6	7	Motorola	2,259	2,522	12%	5.5%
7	6	Intel	2,350	2,440	4%	5.3%
8	8	Mitsubishi	1,975	2,253	14%	4.9%
9	9	National Semiconductor	1,575	1,548	(2%)	3.4%
10	10	Matsushita	1,328	1,237	(7%)	2.7%
11	11	Philips	1,281	1,224	(4%)	2.7%
12	14	Samsung	850	1,214	43%	2.6%
13	12	Advanced Micro Devices	1,084	1,082	0	2.4%
13	13	Oki Semiconductor	902	1,082	20%	2.4%
15	15	SGS-Thomson	833	1,019	22%	2.2%
16	17	Sharp	751	902	20%	2.0%
17	20	Siemens	483	887	84%	1.9%
18	16	Sanyo	811	864	7%	1.9%
19	19	Sony	621	720	16%	1.6%
20	18	AT&T	688	716	4%	1.6%
		All Others	8,291	9,425	14%	20.5%
		North American Companies	15,990	17,188	7%	37.4%
		Japanese Companies	20,375	22,969	13%	50.0
		European Companies	3,429	3,927	15%	8.5
		Asia/Pacific Companies	1,274	1,851	45%	4.0
		Total Market	41,068	45,935	12%	100.0%

Source: Dataquest
January 1990

Table 4

Preliminary Estimated 1989 Worldwide Semiconductor Market Share Rankings Bipolar Digital (Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	Texas Instruments	940	671	(29%)	14.4%
2	2	Fujitsu	653	622	(5%)	13.4%
3	4	Advanced Micro Devices	536	500	(7%)	10.8%
4	5	Hitachi	501	489	(2%)	10.5%
5	3	National Semiconductor	550	454	(17%)	9.8%
6	6	Motorola	435	369	(15%)	7.9%
7	7	Philips	413	350	(15%)	7.5%
8	8	NEC	292	345	18%	7.4%
9	9	Mitsubishi	127	128	1%	2.8%
10	11	Plessey	94	122	30%	2.6%
11	10	Toshiba	108	104	(4%)	2.2%
12	15	Sanyo	41	67	63%	1.4%
13	17	Siemens	36	58	61%	1.2%
14	13	AT&T	61	56	(8%)	1.2%
15	14	Raytheon	55	55	0	1.2%
16	12	Harris	62	50	(19%)	1.1%
17	16	Oki Semiconductor	38	48	26%	1.0%
18	18	Goldstar	32	32	0	0.7%
19	19	Chips & Technologies	30	24	(20%)	0.5%
20	21	Applied Micro Circuits Corp.	27	20	(26%)	0.4%
		All Others	169	80	(53%)	1.7%
		North American Companies	2,761	2,247	(19%)	48.4%
		Japanese Companies	1,791	1,817	1%	39.1
		European Companies	598	548	(8%)	11.8
		Asia/Pacific Companies	50	32	(36%)	0.7
		Total Market	5,200	4,644	(11%)	100.0%

Source: Dataquest
January 1990

Table 5

Preliminary Estimated 1989 Worldwide Semiconductor Market Share Rankings Bipolar Digital Memory (Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	Fujitsu	254	164	(35%)	27.7%
2	3	Advanced Micro Devices	104	133	28%	22.5%
3	2	Hitachi	119	111	(7%)	18.8%
4	7	National Semiconductor	35	56	60%	9.5%
5	4	Philips	58	46	(21%)	7.8%
5	6	NEC	44	46	5%	7.8%
7	N/M	Siemens	0	14	N/M	2.4%
8	8	Raytheon	14	12	(14%)	2.0%
9	5	Texas Instruments	50	5	(90%)	0.8%
10	9	Motorola	7	4	(43%)	0.7%
11	10	Harris	3	0	(100%)	0
		All Others	1	0	(100%)	0
		North American Companies	213	210	(1%)	35.5%
		Japanese Companies	417	321	(23%)	54.3
		European Companies	59	60	2%	10.2
		Asia/Pacific Companies	0	0	N/A	0
		Total Market	689	591	(14%)	100.0%

N/M = Not Meaningful

Source: Dataquest
January 1990

Table 6

Preliminary Estimated 1989 Worldwide Semiconductor Market Share Rankings Bipolar Digital Logic (Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	Texas Instruments	890	666	(25%)	16.4%
2	5	Fujitsu	399	458	15%	11.3%
3	2	National Semiconductor	515	398	(23%)	9.8%
4	6	Hitachi	382	378	(1%)	9.3%
5	3	Advanced Micro Devices	432	367	(15%)	9.1%
6	4	Motorola	428	365	(15%)	9.0%
7	7	Philips	355	304	(14%)	7.5%
8	8	NEC	248	299	21%	7.4%
9	9	Mitsubishi	127	128	1%	3.2%
10	11	Plessey	94	122	30%	3.0%
11	10	Toshiba	108	104	(4%)	2.6%
12	15	Sanyo	41	67	63%	1.7%
13	12	AT&T	61	56	(8%)	1.4%
14	13	Harris	59	50	(15%)	1.2%
15	16	Oki Semiconductor	38	48	26%	1.2%
16	17	Siemens	36	44	22%	1.1%
17	14	Raytheon	41	43	5%	1.1%
18	18	Goldstar	32	32	0	0.8%
19	19	Chips & Technologies	30	24	(20%)	0.6%
20	21	Applied Micro Circuits Corp.	27	20	(26%)	0.5%
		All Others	168	80	(52%)	2.0%
		North American Companies	2,548	2,037	(20%)	50.3%
		Japanese Companies	1,374	1,496	9%	36.9
		European Companies	539	488	(9%)	12.0
		Asia/Pacific Companies	50	32	(36%)	0.8
		Total Market	4,511	4,053	(10%)	100.0%

Source: Dataquest
January 1990

Table 7

Preliminary Estimated 1989 Worldwide Semiconductor Market Share Rankings MOS (Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	NEC	3,123	3,594	15%	11.2%
2	2	Toshiba	2,639	3,164	20%	9.8%
3	3	Intel	2,328	2,430	4%	7.5%
4	4	Hitachi	1,885	2,360	25%	7.3%
5	5	Fujitsu	1,616	1,981	23%	6.2%
6	6	Mitsubishi	1,453	1,738	20%	5.4%
7	7	Motorola	1,399	1,708	22%	5.3%
8	8	Texas Instruments	1,271	1,603	26%	5.0%
9	11	Samsung	765	1,088	42%	3.4%
10	10	Oki Semiconductor	841	1,000	19%	3.1%
11	9	Matsushita	875	850	(3%)	2.6%
12	12	Sharp	682	837	23%	2.6%
13	20	Siemens	327	656	101%	2.0%
14	15	SGS-Thomson	461	619	34%	1.9%
15	18	LSI Logic	375	550	47%	1.7%
16	13	National Semiconductor	485	536	11%	1.7%
17	14	Advanced Micro Devices	482	510	6%	1.6%
18	16	Philips	402	411	2%	1.3%
18	17	AT&T	380	411	8%	1.3%
20	19	Micron Technology	331	395	19%	1.2%
		All Others	4,868	5,762	18%	17.9%
		North American Companies	9,754	11,226	15%	34.9%
		Japanese Companies	14,494	17,194	19%	53.4
		European Companies	1,684	2,145	27%	6.7
		Asia/Pacific Companies	1,056	1,638	55%	5.1
		Total Market	26,988	32,203	19%	100.0%

Source: Dataquest
January 1990

Table 8

Preliminary Estimated 1989 Worldwide Semiconductor Market Share Rankings MOS Memory (Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	Toshiba	1,516	1,906	26%	12.3%
2	2	NEC	1,490	1,755	18%	11.3%
3	3	Hitachi	1,114	1,521	37%	9.8%
4	4	Fujitsu	1,067	1,308	23%	8.4%
5	5	Mitsubishi	966	1,211	25%	7.8%
6	6	Texas Instruments	834	1,093	31%	7.0%
7	7	Samsung	650	945	45%	6.1%
8	10	Sharp	344	476	38%	3.1%
9	9	Oki Semiconductor	353	471	33%	3.0%
10	8	Intel	392	426	9%	2.7%
11	17	Siemens	150	426	184%	2.7%
12	12	Motorola	236	410	74%	2.6%
13	11	Micron Technology	331	395	19%	2.5%
14	13	Matsushita	230	368	60%	2.4%
15	15	NMB Semiconductor	199	279	40%	1.8%
16	16	SGS-Thomson	185	269	45%	1.7%
17	14	Advanced Micro Devices	207	237	14%	1.5%
18	20	Hyundai	106	210	98%	1.4%
19	21	Sony	103	194	88%	1.2%
20	18	Integrated Device Technology	135	163	21%	1.0%
		All Others	1,084	1,490	37%	9.6%
		North American Companies	2,836	3,632	28%	23.4%
		Japanese Companies	7,597	9,783	29%	62.9
		European Companies	464	789	70%	5.1
		Asia/Pacific Companies	795	1,349	70%	8.7
		Total Market	11,692	15,553	33%	100.0%

Source: Dataquest
January 1990

Table 9

Preliminary Estimated 1989 Worldwide Semiconductor Market Share Rankings MOS Microdevices (Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	Intel	1,835	1,901	4%	23.5%
2	2	NEC	790	1,007	27%	12.5%
3	3	Motorola	699	803	15%	9.9%
4	4	Hitachi	525	550	5%	6.8%
5	5	Mitsubishi	381	445	17%	5.5%
6	6	Toshiba	346	401	16%	5.0%
7	7	Texas Instruments	234	252	8%	3.1%
8	9	Fujitsu	202	219	8%	2.7%
9	8	Matsushita	230	216	(6%)	2.7%
9	13	Chips & Technologies	130	216	66%	2.7%
11	11	National Semiconductor	150	172	15%	2.1%
12	14	SGS-Thomson	118	161	36%	2.0%
13	10	Advanced Micro Devices	183	160	(13%)	2.0%
14	12	Oki Semiconductor	134	148	10%	1.8%
15	16	Western Digital	100	135	35%	1.7%
16	15	Philips	114	122	7%	1.5%
17	18	Siemens	88	115	31%	1.4%
17	20	Harris	62	115	85%	1.4%
19	22	Sharp	54	112	107%	1.4%
20	17	Zilog	90	99	10%	1.2%
		All Others	679	732	8%	9.1%
		North American Companies	3,872	4,305	11%	53.3%
		Japanese Companies	2,817	3,260	16%	40.3
		European Companies	401	446	11%	5.5
		Asia/Pacific Companies	54	70	30%	0.9
		Total Market	7,144	8,081	13%	100.0%

Source: Dataquest
January 1990

Table 10

Preliminary Estimated 1989 Worldwide Semiconductor Market Share Rankings MOS Logic (Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	2	Toshiba	777	857	10%	10.0%
2	1	NEC	843	832	(1%)	9.7%
3	5	LSI Logic	357	530	48%	6.2%
4	3	Motorola	464	495	7%	5.8%
5	7	Fujitsu	347	454	31%	5.3%
6	6	Oki Semiconductor	354	381	8%	4.4%
7	8	AT&T	317	358	13%	4.2%
8	11	Hitachi	246	289	17%	3.4%
9	4	Matsushita	415	266	(36%)	3.1%
10	12	Texas Instruments	203	258	27%	3.0%
11	9	Sharp	284	249	(12%)	2.9%
12	10	Philips	253	235	(7%)	2.7%
13	13	National Semiconductor	200	226	13%	2.6%
14	40	Harris	33	210	536%	2.5%
15	15	Seiko Epson	190	201	6%	2.3%
16	16	SGS-Thomson	158	189	20%	2.2%
17	17	VLSI Technology	151	167	11%	1.9%
18	19	Sanyo	142	165	16%	1.9%
19	20	ITT	135	146	8%	1.7%
20	18	Yamaha	151	130	(14%)	1.5%
		All Others	2,132	1,931	(9%)	22.5%
		North American Companies	3,046	3,289	8%	38.4%
		Japanese Companies	4,080	4,151	2%	48.4
		European Companies	819	910	11%	10.6
		Asia/Pacific Companies	207	219	6%	2.6
		Total Market	8,152	8,569	5%	100.0%

Source: Dataquest
January 1990

Table 11

Preliminary Estimated 1989 Worldwide Semiconductor Market Share Rankings Analog (Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	Toshiba	569	561	(1%)	6.2%
2	2	National Semiconductor	540	558	3%	6.1%
3	5	Philips	466	463	(1%)	5.1%
4	3	Sanyo	471	450	(4%)	5.0%
5	7	Motorola	425	445	5%	4.9%
6	6	Texas Instruments	426	417	(2%)	4.6%
7	4	NEC	469	407	(13%)	4.5%
8	11	SGS-Thomson	352	393	12%	4.3%
9	10	Sony	386	388	1%	4.3%
10	9	Mitsubishi	395	387	(2%)	4.3%
11	8	Matsushita	423	374	(12%)	4.1%
12	13	Analog Devices	340	337	(1%)	3.7%
13	12	Hitachi	343	330	(4%)	3.6%
14	18	Harris	146	280	92%	3.1%
15	14	Rohm	271	277	2%	3.0%
16	15	AT&T	247	249	1%	2.7%
17	22	Siemens	120	173	44%	1.9%
18	16	Sanken	157	156	(1%)	1.7%
19	17	Fujitsu	151	152	1%	1.7%
20	19	Burr-Brown	144	141	(2%)	1.6%
		All Others	2,039	2,150	5%	23.7%
		North American Companies	3,475	3,715	7%	40.9%
		Japanese Companies	4,090	3,958	(3%)	43.6
		European Companies	1,147	1,234	8%	13.6
		Asia/Pacific Companies	168	181	8%	2.0
		Total Market	8,880	9,088	2%	100.0%

Source: Dataquest
January 1990

Table 12

Preliminary Estimated 1989 Worldwide Semiconductor Market Share Rankings Total Discrete (Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	Toshiba	864	844	(2%)	11.2%
2	2	Motorola	752	775	3%	10.2%
3	3	Hitachi	707	685	(3%)	9.1%
4	4	NEC	571	550	(4%)	7.3%
5	5	Philips	432	442	2%	5.8%
6	7	Mitsubishi	310	347	12%	4.6%
7	6	Matsushita	377	330	(12%)	4.4%
8	8	Rohm	287	301	5%	4.0%
9	9	Fuji Electric	279	290	4%	3.8%
10	10	SGS-Thomson	254	282	11%	3.7%
11	12	Sanken	207	213	3%	2.8%
12	11	Sanyo	210	211	0	2.8%
13	13	Siemens	201	210	4%	2.8%
14	14	International Rectifier	192	190	(1%)	2.5%
15	15	General Instrument	164	170	4%	2.2%
16	17	ITT	146	154	5%	2.0%
17	16	AT&T	161	147	(9%)	1.9%
18	N/M	Harris	0	120	N/M	1.6%
19	20	Sony	112	110	(2%)	1.5%
20	19	Powerex	115	105	(9%)	1.4%
		All Others	1,271	1,085	(15%)	14.3%
		North American Companies	2,171	2,127	(2%)	28.1%
		Japanese Companies	4,056	4,014	(1%)	53.1
		European Companies	1,250	1,261	1%	16.7
		Asia/Pacific Companies	135	159	18%	2.1
		Total Market	7,612	7,561	(1%)	100.0%

N/M = Not Meaningful

Source: Dataquest
January 1990

Table 13

Preliminary Estimated 1989 Worldwide Semiconductor Market Share Rankings Total Optoelectronic (Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	Sharp	285	328	15%	14.0%
2	5	Matsushita	178	304	71%	13.0%
3	2	Sony	217	247	14%	10.6%
4	3	Toshiba	215	216	0	9.2%
5	4	Hewlett-Packard	213	213	0	9.1%
6	7	Fujitsu	105	100	(5%)	4.3%
7	8	Siemens	100	97	(3%)	4.1%
8	6	Rohm	109	96	(12%)	4.1%
9	N/M	Optek	N/A	77	N/M	3.3%
10	10	Telefunken Electronic	74	76	3%	3.2%
11	9	NEC	88	68	(23%)	2.9%
12	11	Hitachi	70	66	(6%)	2.8%
13	12	Sanyo	62	57	(8%)	2.4%
14	14	Quality Technologies	40	38	(5%)	1.6%
15	13	Texas Instruments	41	36	(12%)	1.5%
16	15	OKI Semiconductor	36	33	(8%)	1.4%
17	17	Honeywell	30	31	3%	1.3%
18	18	Mitsubishi	27	29	7%	1.2%
19	20	Motorola	24	25	4%	1.1%
20	19	Philips	25	24	(4%)	1.0%
		All Others	240	179	(25%)	7.6%
		North American Companies	425	458	8%	19.6%
		Japanese Companies	1,511	1,651	9%	70.6
		European Companies	238	224	(6%)	9.6
		Asia/Pacific Companies	5	7	40%	0.3
		Total Market	2,179	2,340	7%	100.0%

N/A = Not Available
N/M = Not Meaningful

Source: Dataquest
January 1990

DATAQUEST ANALYSIS

The year 1989 was a lackluster one for the worldwide semiconductor industry. Declines in computer, communications, and automotive shipments and the resulting large semiconductor inventories and decreased demand caused dramatic price declines in many product segments, most notably dynamic RAMs.

Just as in 1988, MOS memory and microdevices were the product segments to be in to increase market share, because of strong shipments in the first half of the year.

During 1989, Japanese companies increased their dependence on exports, growing their collective market share in North America while only maintaining their market share worldwide.

European companies maintained their worldwide market share as well, and several—notably SGS-Thomson and Siemens—experienced substantial growth.

Asia/Pacific companies, led by Samsung, continued their upward march, gaining a point of worldwide market share (the only regional group to do so) and outperforming the average industry growth by four times. However, their emphasis on dynamic RAMs could be a liability in 1990, due to the dramatic price declines currently occurring.

North American companies dropped their worldwide market share by almost two percentage points, demonstrating that a strong and competitive DRAM presence is still necessary to maintain or grow market share in today's semiconductor market.

Patricia S. Cox

Note: An overview of Dataquest semiconductor product category definitions is attached to this newsletter as Appendix A.

APPENDIX A

OVERVIEW OF DATAQUEST SEMICONDUCTOR PRODUCT CATEGORY DEFINITIONS*

Total Semiconductor	IC + Discrete + Optoelectronic
Total Integrated Circuit	Bipolar Digital + MOS Digital + Analog
Bipolar Digital	Memory + Logic
Memory	ECL RAM, ROM, and PROM
Logic	ASIC + Standard Logic + Other Logic
MOS Digital	Memory + Microdevice + Logic
Memory	DRAM + SRAM + Nonvolatile + Other MOS Memory
Microdevice	MPU + MCU + MPR + DSP
Logic	ASIC + Standard Logic + Other Logic
Analog	Monolithic + Hybrid Analog/Linear
Total Discrete	Transistor + Diode + Thyristor + Other Discrete
Total Optoelectronic	LEDs, LED Displays, Laser Devices, Optoelectronic Couplers, and Sensors (excludes LCD Displays and Incandescent and Fluorescent Lamps and Displays)

*Detailed definitions are available from the author of this newsletter.

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6461	1.	DELCO-TI Alliance: Power Devices and Microcontrollers Merge Grandbois/Feb
6482	2.	Analog Circuits Dominate at ISSCC '90 Grandbois/Mar
6529	3.	Delta-Sigma A/D Converters Will They Sweep Away the Others? Grandbois/Mar
6725	4.	Analog ICs In Decline. What Happened in '89? Grandbois/Apr
7167	5.	Power Transistor: Market Strength In An Era of Integration Grandbois/June
7619	6.	Line Geometries of Gate Arrays and DRAMs converge Burns/August

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Research Newsletter

LINE GEOMETRIES OF GATE ARRAYS AND DRAMS CONVERGE

INTRODUCTION

Line geometries of DRAMs have long been the benchmark by which the industry has judged its lithography needs. However, in recent years, the line geometries of gate arrays have been shrinking almost as fast as those of DRAMs. For example, in 1984, the line geometry of the average gate array and the leading-edge gate array lagged the line geometry of the average and leading-edge DRAMs by about two years. This lag is much shorter now, and Dataquest expects it to be less than one year by 1995.

MARKET-DRIVEN CONVERGENCE

Different Manufacturing Strategies Lead to the Same End

The reasons for this convergence are market driven on the gate array side. The number of usable gates is a competitive feature of gate arrays. There are several different strategies whereby manufacturers can increase the number of usable gates—one depending on shrinking line geometries.

If the percentage of total gates actually used (gate utilization) is constant, a manufacturer can increase the number of used gates by increasing the number of total gates. On the other hand, if a manufacturer is able to increase the gate utilization rate, the number of gates used can be increased without increasing the number of total gates. Table 1 lists the different strategies open to manufacturers in order to increase usable gates.

Strategies Can Be Mixed

These strategies are not exclusive. Manufacturers differ, however, on the mix of strategies that they adopt. Japanese manufacturers, for example, tend to emphasize increasing the number of available gates by shrinking line geometries and increasing die size. This is a technique that they have used very successfully in the DRAM market.

It is interesting to note that because manufacturers can mix the strategies listed in Table 1, a successful gate array manufacturer does not have to follow "the leading edge" in order to be successful. The important factor is the mix of strategies and how they work in bringing the customer the most usable gates in the fastest time. The smaller line geometries and maximum levels of metal are only means to this end.

FORECAST FOR LINE GEOMETRIES

Our forecast for the line geometries of DRAMs and gate arrays is shown in Figure 1. The forecast for leading-edge gate arrays is the smallest geometry that will be used by those manufacturers that follow the strategy of shrinking line geometries in order to increase the available number of gates. Those manufacturers that opt for the strategy of optimizing routing efficiency can get by with a smaller number of total gates and larger line geometries.

The year in which the leading-edge DRAM generation begins is the year in which that density sells 1 million units. The year that a leading-edge gate array family begins is the year in which that density reaches $1 million in sales.

DATAQUEST CONCLUSIONS

The choice of strategy to increase the number of usable gates has major implications for

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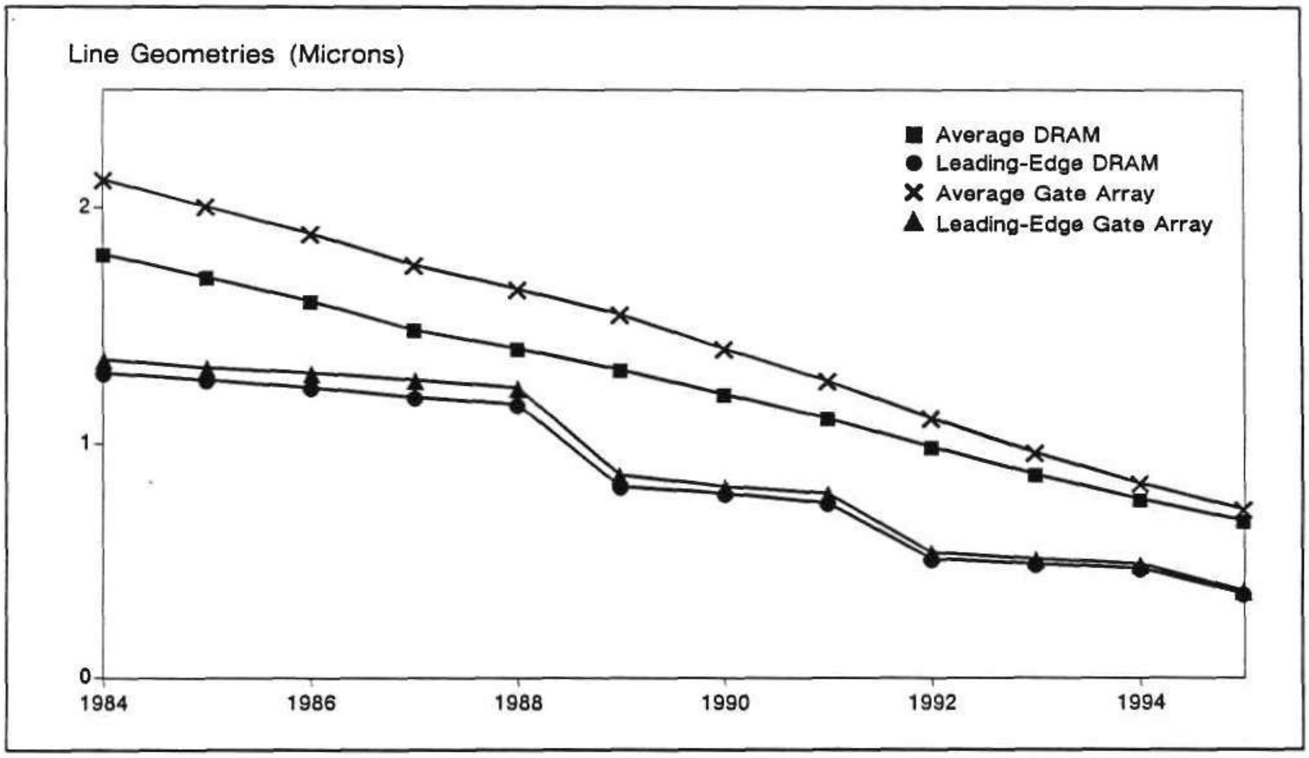
TABLE 1
Strategies of Increasing Usable Gates

Strategy	Characteristics
Decrease line geometry	Increases total available gate count Capital (lithography) intensive Uses base wafers Quick turn
Increase chip size	Increases total available gate count Design intensive Uses base wafers Quick turn
Increase levels of metal	Increases usable gates Capital (deposition/etch) intensive Smaller die Uses base wafers Quick turn
Develop more efficient routing algorithms	Increases usable gates Design intensive Smaller die Uses base wafers Quick turn
Add functional blocks, such as memory and peripherals	Design intensive Does not use base wafers All mask levels unique to functional block Is customer/system specific Circuit is optimized for function Not quick turn

Source: Dataquest (August 1990)

FIGURE 1
Converging Tecnologies—ASICs and DRAMs



Source: Dataquest (August 1990)

manufacturing and for equipment vendors. Shrinking line geometries and increasing levels of metalization are capital-intensive strategies. They are also strategies that rely on the use of base wafers. A manufacturer can mass produce base wafers and thereby drive down the cost. This should be an option only to those manufacturers certain that they can be the low-cost producers.

There are three strategies that are design intensive rather than capital intensive. These strategies increase die size and optimize routing algorithms using base wafers and would therefore have to compete in a mass-produced standard-product market. They, too, would have to be low-cost producers; however, because they are design intensive, they would not have the capital burden that small line geometries and increasing levels of metal would carry.

Finally, there is the strategic option of embedded functions. This option is design and capital intensive. But it does not use base wafers and, hence, is not a commodity product. Using embedded functions allows manufacturers to follow a niche rather than a commodity marketing strategy.

Clearly, no one strategy is head and shoulders above the rest. Dataquest believes that prudent manufacturers will be both design and capital intensive and will demand the maximum of uptime and throughput and the minimum of setup time from their vendors.

George Burns

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Research Newsletter

POWER TRANSISTORS: MARKET STRENGTH IN AN ERA OF INTEGRATION

SUMMARY

The control of power for lighting, motors, and other electrical equipment still is the domain of discrete power devices. Less than 22 percent of the semiconductor power control market by revenue is supplied by power ICs. The demand for high currents and high voltages is still best and most cost-effectively met by power discrete transistors and power thyristors. Although many find the power discrete marketplace less exciting than that of other semiconductors, it represents a keystone for the growth of embedded control and application-specific smart power ICs. It has demonstrated a growth rate consistent with that of ICs and a continued offering of new products and technologies to answer the needs of the marketplace.

POWER CONTROL MARKET

The total power control semiconductor market (which excludes power diodes) is divided into three main product types—power transistors and thyristors, which comprise the discrete side and power ICs, which are considered to be part of the analog IC category. Table 1 lists the revenue and growth rates associated with each of these constituent product types.

Power ICs, with a 22 percent market share, still have considerable room for growth. Smart power, the combination of logic and power transistors on an IC, supplies less than 8 percent of the total power control semiconductor market.

Definition of Power

Power semiconductors are defined as discrete devices or ICs that can control one or more amps of current, dissipate one or more watts of power, or are capable of operating with voltages exceeding 100 volts. In the discrete area, transistors that do not meet these criteria are designated as small-signal transistors.

Power Transistors

As a dominant part of the power control market and with a continued strong growth rate, power transistors are expected to retain their dominant position in power control throughout the upcoming decade. The power transistor market

TABLE 1
Total Power Control Device Market

	1989 Revenue ($ Millions)	1989-1994 Forecast CAGR
Power Transistors	2,278	11.9%
Thyristors	594	6.4%
Power Integrated Circuits	785	13.9%
Total Power Control Semiconductors	3,657	11.4%

Source: Dataquest (June 1990)

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grew at a compound annual growth rate (CAGR) of 12.9 percent in the five-year period from 1984 to 1989. Power transistors have shown a strong growth trend in recent years as automotive electronics, motor controllers, switching power supplies, and other electronic controls have multiplied.

Dataquest expects power transistors to grow by an 11.9 percent CAGR from 1989 through 1994. These figures represent a continued strong growth rate, although the slow growth of 1989 to 1990 lowered the CAGR somewhat. Figure 1 shows power transistor revenue for the past five years (1984 to 1989) as well as the forecast revenue for the next five-year period (1990 to 1994).

Bipolar versus MOSFET Transistors

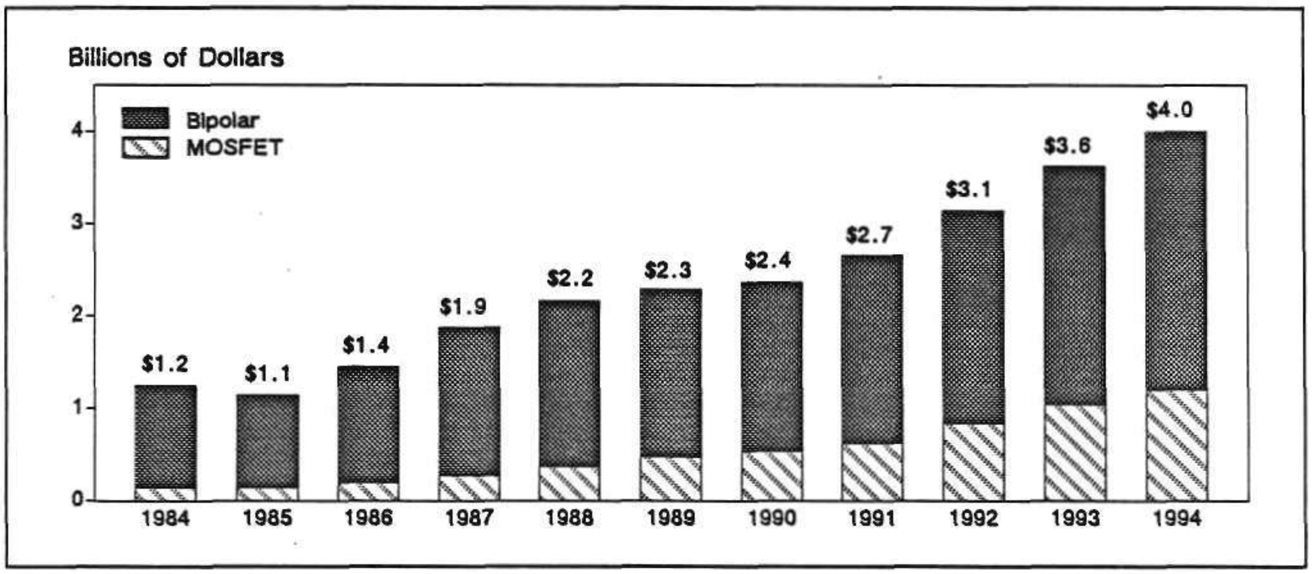
Although they have been touted as bipolar killers for more than a decade, MOSFET power devices are only now making a dent in the bipolar market with a 20 percent share in 1989. Significant price reductions, coupled with new and improved product offerings within the past few years, have helped increase the applications and usage of these products.

Why the trend toward power MOSFETs? Because of their shorter rise and fall times, power MOSFETs can switch substantially faster than bipolar power transistors, resulting in higher efficiency and lower power dissipation in switching applications. However, not all applications need high switching speeds. In some cases, the high switching speed of the MOSFET can create destructive voltages when driving inductive loads (dI/dt) that were not present in a bipolar implementation. Additional advantages of power MOSFETs are high-input impedance and gain and a simple interface with standard logic circuits. However, the bipolar power transistor is still the preferred technology for high-voltage, high-current applications because of its low ON-state saturation voltage, which is significantly lower than the ON resistance of MOSFETs. The problem is that power MOSFETs have an ON resistance (R_{ON}) that increases geometrically (to the 2.6th power) with the voltage rating.

The more recently introduced insulated gate bipolar transistor (IGBT) offers a solution to this ON resistance dilemma for MOSFETs. The IGBT combines the high-impedance input characteristics of the MOS transistor with the low-saturation voltage of the bipolar transistor. The bipolar action in the current path of the IGBT offers a low-resistance path, even with a high-voltage capability. Although IGBTs are slower than their MOSFET counterparts, they interface just as readily with MOS logic while reducing the power loss and dissipation problems that the high ON resistance would normally cause. Because of this capability, IGBTs are helping expand the market for MOSFET devices.

IGBTs are also called COMFETs (COnductivity Modulated FETs), MBTs (MOS-Bipolar Transistors), or GEMFETs. Dataquest classifies IGBTs within the general MOSFET category.

FIGURE 1
Power Transistor Revenue History and Forecast



Source: Dataquest (June 1990)

The difference between bipolar and MOS power transistors is summarized in Table 2. This table emphasizes the mixed bipolar/MOS performance characteristics of IGBTs.

Smart Power Transistors

Some power MOSFETs are offered with an additional control terminal that provides a "sense" output to monitor the current through the device. This current sensing allows the control electronics to compensate for inductance and monitor current overloads and provides a smart power system with improved features and performance.

POWER TRANSISTOR FORECAST AND HISTORY

Table 3 shows the five-year revenue history and forecast for both bipolar and MOS power transistors. The MOSFET segment of the power transistor market is growing rapidly and is expected to account for 30.0 percent of total power transistor revenue by 1994, as shown in Table 4. Power MOSFET revenue is expected to grow at a 20.3 percent CAGR from 1989 through 1994. In contrast, bipolar power transistors should grow at only a 9.2 percent CAGR during the same time frame. Figure 1 illustrates these different growth trends.

POWER TRANSISTOR MARKET SHARE

Dataquest estimates that the top ten worldwide suppliers of power transistors accounted for 68.7 percent of the $2.28 billion market in 1989. The estimated top 20 suppliers are shown in Table 5.

Many of these companies are involved in both bipolar and MOSFET power transistors to various degrees. Table 6 shows the estimated market share ranking for the top ten MOSFET power transistor suppliers, and Table 7 shows a similar listing for bipolar power transistor suppliers.

MOSFET Prices Dive

MOSFET average selling prices (ASPs) declined dramatically during the past year. As these power devices move out of the realm of niche products into a more mainstream power position, the pressure on selling price increases. In addition to this normal ASP decline as MOSFETs compete for bipolar sockets, the slow 1989 market caused many vendors to cut prices rapidly. International Rectifier (IR) and Samsung, in particular, made strong moves to gain market share.

Two casualties of this pricing battle have been IR and Siliconix. IR essentially mortgaged the company for power MOSFET business and has been in tight financial straits for the past three

TABLE 2
Performance Comparison: Bipolar versus MOS Power Transistors

Feature	Bipolar	MOSFET	IGBT
Control Parameter	Current	Voltage	Voltage
Switching Speed	Low-Medium	Fast	Low
Speed Temperature Sensitivity	High	Low	High
ON Resistance	Low	High	Low
Ruggedness	High	Moderate	Moderate
Input Impedance	Low	High	High
Interface to Logic	Complex	Simple	Simple
Thermal Runaway	Yes	No	Yes
Can Parallel Devices	No	Yes	No
ESD Sensitivity	None	Some	Some

Source: Dataquest (June 1990)

years. A major competitor, Siliconix, which also invested heavily in a 6-inch fab for power MOSFET production, has been reeling from its losses of the past year and recently filed for Chapter 11 protection from its creditors (including IR royalty payments). Siliconix raised prices on its power MOSFET line, which will further reduce its participation in this market. A recent settlement between Siliconix and IR regarding patent infringement resulted in a $12 million payment by Siliconix to IR over a two-year period.

Figure 2 illustrates the ASP decline for MOSFETs over the past five years. Mature bipolar devices, on the other hand, actually have shown ASP increases over this same period. Although MOSFETs may not reach price parity with bipolar devices any time soon, prices are expected to continue declining over the next five years.

Table 3
Worldwide Power Transistor Revenue (Millions of Dollars)

			1984-1989 Actuals				CAGR
	1984	1985	1986	1987	1988	1989	1984-1989
Bipolar	1,095	993	1,246	1,598	1,778	1,801	10.5%
MOSFET	145	143	196	273	375	477	26.9%
Total	1,240	1,136	1,442	1,871	2,158	2,278	12.9%
Annual Growth		(9.2%)	26.9%	29.8%	15.3%	5.5%	
			1989-1994 Forecast				**CAGR**
	1989	1990	1991	1992	1993	1994	1989-1994
Bipolar	1,801	1,820	2,025	2,300	2,585	2,800	9.2%
MOSFET	477	540	675	840	1,040	1,200	20.3%
Total	2,278	2,360	2,700	3,140	3,625	4,000	11.9%
Annual Growth		3.6%	14.4%	16.3%	15.4%	10.3%	

Source: Dataquest (June 1990)

Table 4
Worldwide Power Transistor Revenue (Percentage of Total by Type)

				1984-1989 Actuals		
	1984	1985	1986	1987	1988	1989
Bipolar	88.3%	87.4%	86.4%	85.4%	82.4%	79.1%
MOSFET	11.7%	12.6%	13.6%	14.6%	17.6%	20.9%
				1989-1994 Forecast		
	1989	1990	1991	1992	1993	1994
Bipolar	79.1%	77.1%	75.0%	73.2%	71.3%	70.0%
MOSFET	20.9%	22.9%	25.0%	26.8%	28.7%	30.0%

Source: Dataquest (June 1990)

DATAQUEST CONCLUSIONS

Electronic power control, whether for complex systems or simple electronics, embedded or accessible, is growing strongly and carrying both ICs and discrete devices with it. IC solutions to power control applications are limited in their capabilities and require significant cost trade-offs. Because of this, the discrete power transistor market continues to grow at a rate only slightly below that of the IC marketplace. This strong growth, coupled with the issues of MOS/bipolar competition, the proper partitioning/positioning of ICs and power discretes, and a continuing stream of technology developments, brings to the discrete market the same dynamics more commonly seen in the IC arena.

Gary Grandbois

TABLE 5
Estimated 1989 Market Share for Power Transistors

Rank	Company	Percent Share	Revenue (Millions of Dollars)
1	Toshiba	13.3%	302
2	Motorola	13.0	297
3	NEC	8.3	190
4	SGS-Thomson	7.0	160
5	Hitachi	5.5	125
6	Mitsubishi	4.8	110
7	Philips	4.6	105
8	Matsushita	4.5	102
9	Sanyo	4.2	96
10	Harris	3.4	78
11	Fuji Electric	3.4	78
12	Sanken	2.8	63
13	International Rectifier	2.7	62
14	Siemens	2.5	58
15	KEC	2.2	49
16	Texas Instruments	2.0	45
17	Samsung	1.9	44
18	Siliconix	1.4	32
19	Rohm	1.3	30
20	Shindengen Electric	1.2	28
	Others	10.0	224
	Total	100.0%	2,278

Source: Dataquest (June 1990)

Table 6
Estimated Top Ten Suppliers of Power MOSFETs Ranked by Revenue

Rank	Company
1	Motorola
2	International Rectifier
3	SGS-Thomson
4	Toshiba
5	Siliconix
6	NEC
7	Samsung
8	Harris
9	Fuji Electric
10	Hitachi
Total MOSFET Revenue	$477 million

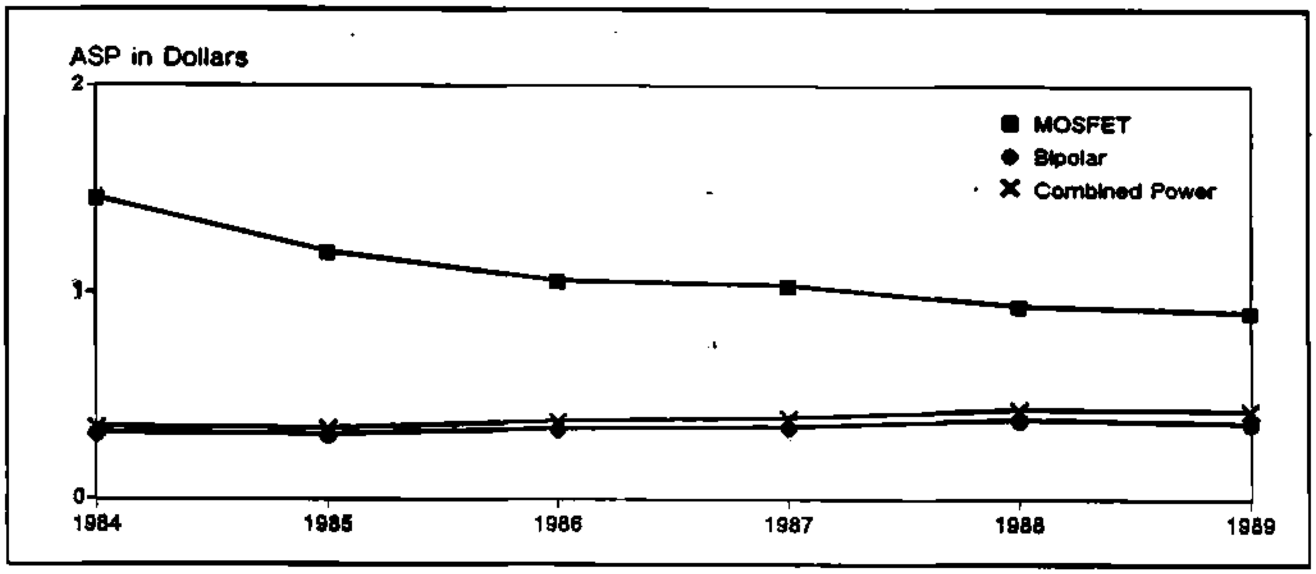
Source: Dataquest (June 1990)

Table 7
Estimated Top Ten Suppliers of Bipolar Power Transistors Ranked by Revenue

Rank	Company
1	Toshiba
2	Motorola
3	NEC
4	Hitachi
5	SGS-Thomson
6	Mitsubishi
7	Philips
8	Matsushita
9	Sanyo
10	Sanken
Total Bipolar Revenue	$1,801 million

Source: Dataquest (June 1990)

Figure 2
Power Transistor ASP Trend



Source: WSTS, Dataquest (June 1990)

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Research Newsletter

ANALOG ICs IN DECLINE: WHAT HAPPENED IN '89?

SUMMARY

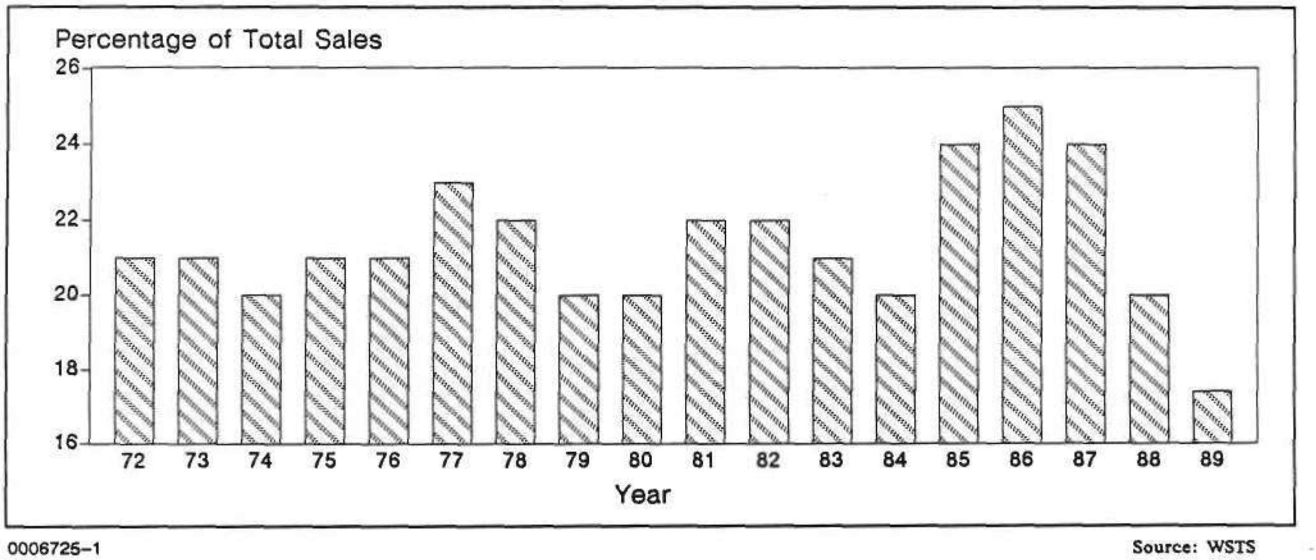
The year 1989 was a tough one for many analog suppliers. More than a tough year, it was an historic year in which analog IC segments experienced a significant downturn while many of the digital segments had a softer landing. This effect was the opposite of past trends where the stability of the analog IC market had made it more insulated from market deterioration than the more volatile digital IC market. Figure 1 shows the 18-year history of analog as a percentage of total IC revenue based on World Semiconductor Trade Statistics (WSTS) data. Although the Dataquest analog percentage for 1989 is not as severe (19 percent of total ICs), the trends are similar. Never in the previous 17 years did the analog segment slip below a 20 percent annual share, nor did analog show a revenue decline greater than that of the digital segments. On the contrary, it was expected that analog would show relative strength in the downturn. For many analog IC suppliers, this was one of the expected payoffs for the fragmented nature of the market and the comparatively poorer performance in market upturns than the digital sector experienced.

THE ANALOG IC MARKET

What Happened?

Analog ICs showed a slump in unit consumption from late 1988 through the first quarter

FIGURE 1
Analog and Total IC Revenue Comparison



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Source: WSTS
Dataquest
April 1990

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of 1989. When consumption increased in the March-through-December period of 1989, a reduced rate of growth was apparent (see Figure 2).

In addition to the basic decline in consumption, a number of notable market occurrences also helped to drive the analog market revenue below that of the general IC market. These include the following:

- Declining average selling price (ASP) for commodity linears
- Declining consumer-specific IC consumption
- Weak demand in the computer, military, and industrial markets
- Increased competition in "hot" products
- Growing confusion in product categorization

A significant ASP decline in commodity linears (largely op amps and regulators) starting in mid-1988 flattened revenue growth in 1989 despite the fact that unit growth continued through 1988 and 1989. This phenomenon is illustrated in Figure 3 and was examined in the SIS newsletter entitled *Analog ICs: Declining ASPs Lead Slowdown.*

Consumer-specific IC consumption declined as the consumer market for VCRs, camcorders, CD players, and other entertainment products softened. A weakening demand for facsimile machines, which nearly have become consumer products, added to the malaise.

Weak demand in the computer market (for disk drive support ICs and RS-232 transceivers), the military market (for many standard products), and the industrial market (for data-acquisition components and interface components) reduced unit sales and helped drive ASPs down. A weak demand for disk drive components in the first half of 1989 was countered as the demand crept up in the second half.

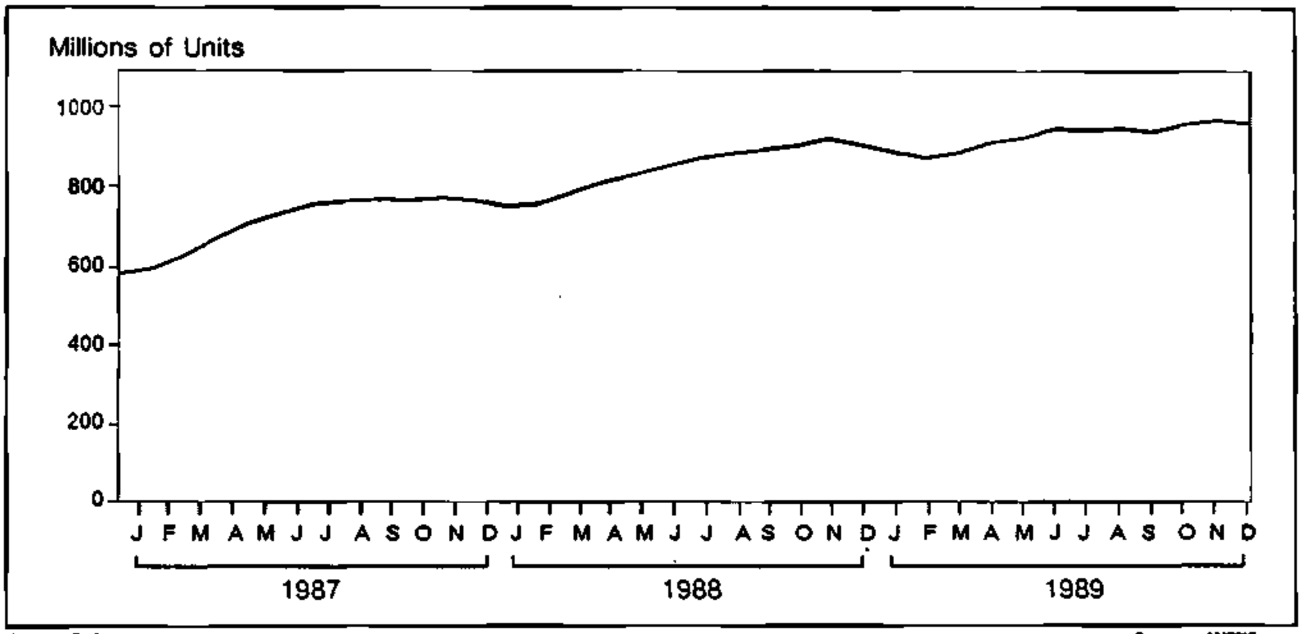
Competition increased for some of the popular products of 1988. Palette DACs and digital audio DACs were two of the more noticeable winners in the 1988 market. In 1989, an avalanche of competitive products brought down ASPs, severely impacting the data converter segment.

Growing confusion in reporting IC sales has amplified the analog problem. Although WSTS is showing a far more severe change than Dataquest in analog IC growth, data gathering is becoming more difficult for both as many of the mixed-signal ICs and interface components increasingly are being reported as MOS logic.

The 1989 Result

The result of these factors is illustrated in the line graph in Figure 4. Note that the divergence of

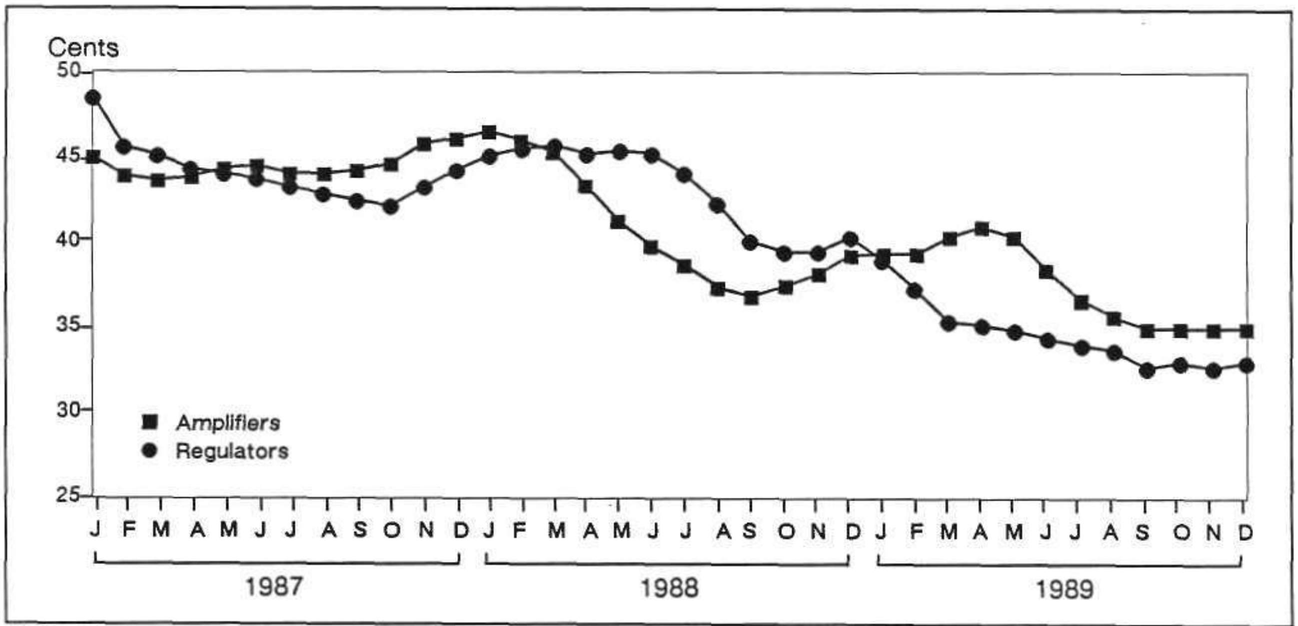
FIGURE 2
Analog Unit Sales by Month (1987-1989)



0006725-2

Source: WSTS
Dataquest
April 1990

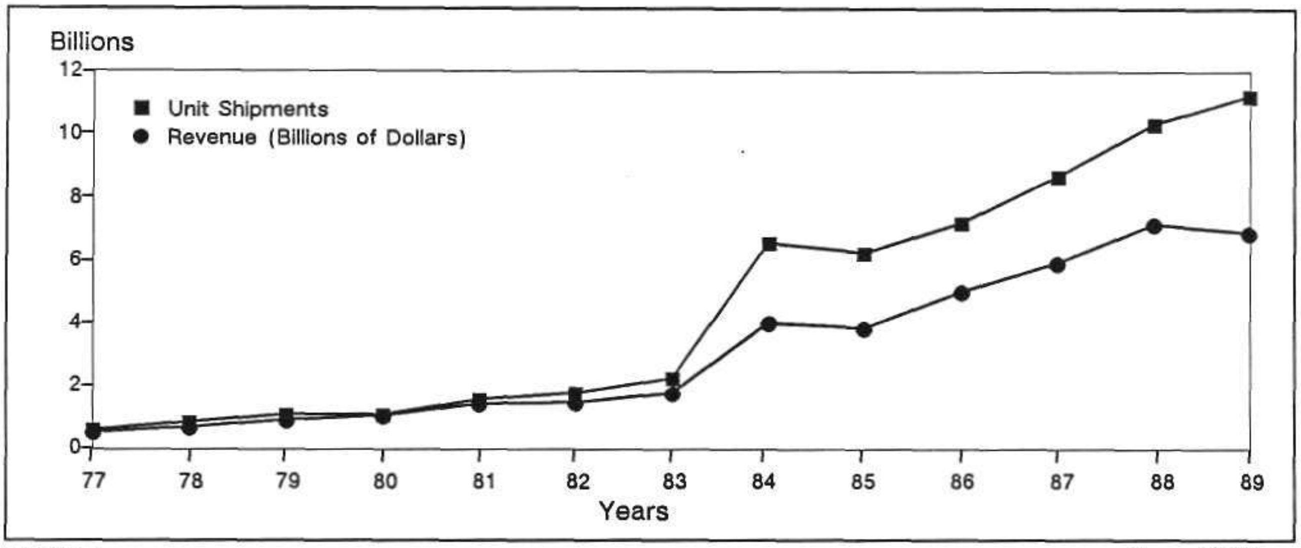
FIGURE 3
Average Selling Prices for Amplifiers and Regulators (1987-1989)



0006725-3

Source: WSTS
Dataquest
April 1990

FIGURE 4
Analog IC Unit Shipment and Revenue History



0006725-4

Source: WSTS
Dataquest
April 1990

sales by unit shipments and revenue starting in 1984 signaled a continuing decline in selling prices that accelerated greatly in 1989. This rapidly deteriorating ASP masked a moderate growth in units in 1989, to show a revenue decline.

DATAQUEST CONCLUSIONS AND MARKET OUTLOOK

Does the decline in 1989 portend the long-anticipated demise of analog ICs as digital electronics take over? No! Dataquest views 1989 as an anomaly rather than the precursor of a decline in analog IC growth or of accelerating reduction in selling prices. As of March 1990, analog bookings are strengthening, ASPs generally are not declining, and the end-application markets are warming up. Although we have been forecasting a 4.4 percent growth for 1990 over 1989, present trends indicate that growth may be even stronger than we originally forecast.

Although analog ICs may not be a declining portion of the IC market, analog ICs are in transition as the product mix moves more strongly away from functional block products toward more complex application-specific ICs (ASICs). Mixed analog and digital ICs, and especially mixed-signal ASICs, will increase the problem of product categorization and tracking. The result is that more and more mixed-signal ICs will be reported as digital ICs. These traceability problems will result in Dataquest and WSTS data diverging more as time goes on.

These more complex ICs, with increased analog integration, will reverse the general trend toward sagging ASPs, providing increased analog revenue growth, and bringing unit growth more into line with revenue. Despite this upward pressure on selling prices, we expect commodity linear op amps, regulators, and interface ICs to continue their downward trend.

Gary Grandbois

Dataquest

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Research Newsletter

DELTA-SIGMA A/D CONVERTERS: WILL THEY SWEEP AWAY THE OTHERS?

INTRODUCTION

New analog-to-digital (A/D) converters embodying the delta-sigma converter technique have appeared recently. These products are notable not only for their impressive specifications, but also because they provide a stronger link to the digital IC realm and especially to digital signal processing (DSP). Because of this digital tie-in, the delta-sigma technique is being touted as the preferred replacement for all nonvideo converters. This newsletter examines some of the claims and explores the potential A/D converter market that delta-sigma converters may be able to penetrate.

THE A/D CONVERTER MARKET

The A/D converter (ADC) market, like all analog markets, shows a broad spectrum of products to meet a wide range of resolution, signal bandwidth, signal level, output format, and cost requirements (see Figure 1). Dataquest segments this market into the following three broad performance categories:

- Display converters (low-speed, high-resolution, integrating converters)
- General-purpose converters (moderate-speed converters with a wide range of resolutions, usually successive approximation ADCs)
- Flash and half-flash converters (high-speed, low-resolution converters)

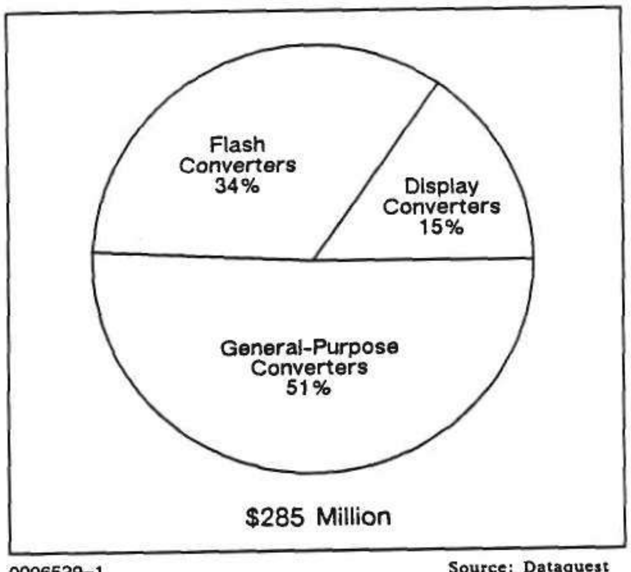
This segmentation fits well with an examination of the potential market for the delta-sigma converter because the display and flash converter markets are not reasonable markets for the delta-sigma product.

THE DELTA-SIGMA PRODUCT

Delta-Sigma Conversion Technique

Delta-sigma is a closed-loop integrating conversion technique. As shown in Figure 2, it consists essentially of a 1-bit DAC (switch and current source), a difference node (hence the delta), an analog integrator (hence the sigma), and a comparator to decide where the difference signal has driven the integrator. This circuit is contrasted in Figure 2 with a successive-approximation (SA) converter, which requires a DAC with the same resolution as required by the conversion in order to rebuild (or approximate) the input signal. The difference between the two systems lies in the fact

FIGURE 1
1989 ADC Market by Converter Type



0006529-1

Source: Dataquest
March 1990

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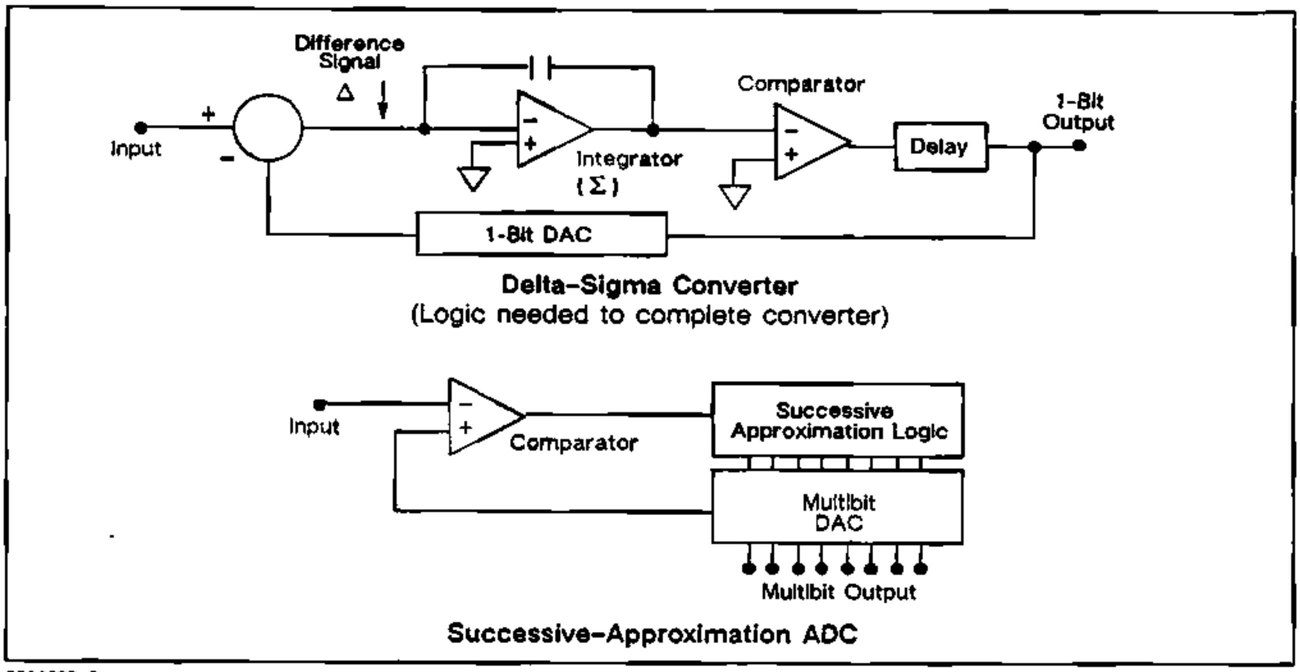
that the delta-sigma converter has a simple DAC and complex logic, while the SA converter has a complex DAC and simple logic. In addition, the SA converter requires only 17 clocking cycles to complete a 16-bit conversion, while the delta-sigma continually tracks the signal and would require more than 65,000 cycles to digitize a new signal to 16 bits.

Table 1 lists features, limitations, advantages, and disadvantages of the delta-sigma converter.

FIGURE 2
Comparison of Converters



0006529-2

Source: Dataquest
March 1990

TABLE 1
Delta-Sigma Advantages/Disadvantages

Features	Application Benefits
Advantages	
Inherent sampling	No S/H needed
Inherent monotonicity	No missing codes
No bit trimming needed	Consistent code sizes (DNL)
Synergy with digital filters*	Easy anti-aliasing filter
Low analog content*	Easily integrated into digital IC and low drift
MOS compatible with digital	Easily integrated into digital MOS
Disadvantages	
Limitations	**Application Problems**
Long latency (time delay)	Not useful in controller applications
Idle patterns	Inconsistent outputs
Cannot be time-shared	Dedicated to a single input
Limited to 100-KHz BW	Not a high-speed converter
Bandwidth specific	Not a general-purpose product (very application specific)

Source: Dataquest
March 1990

The delta-sigma converter features marked with an asterisk in Table 1 represent the real advantages of delta-sigma converters over competing types. The single-bit output of the delta-sigma modulator simplifies digital filter design. This synergy with digital filters is the main reason that this relatively old conversion technique has experienced a new groundswell of enthusiasm by IC and system designers. Simply put, delta-sigma and DSP were made for each other in open-loop applications. The downside of this synergy is that the DSP digital filter currently consumes a large amount of chip area. Expectations of finer geometries and more efficient architectures seem to blunt this criticism, however.

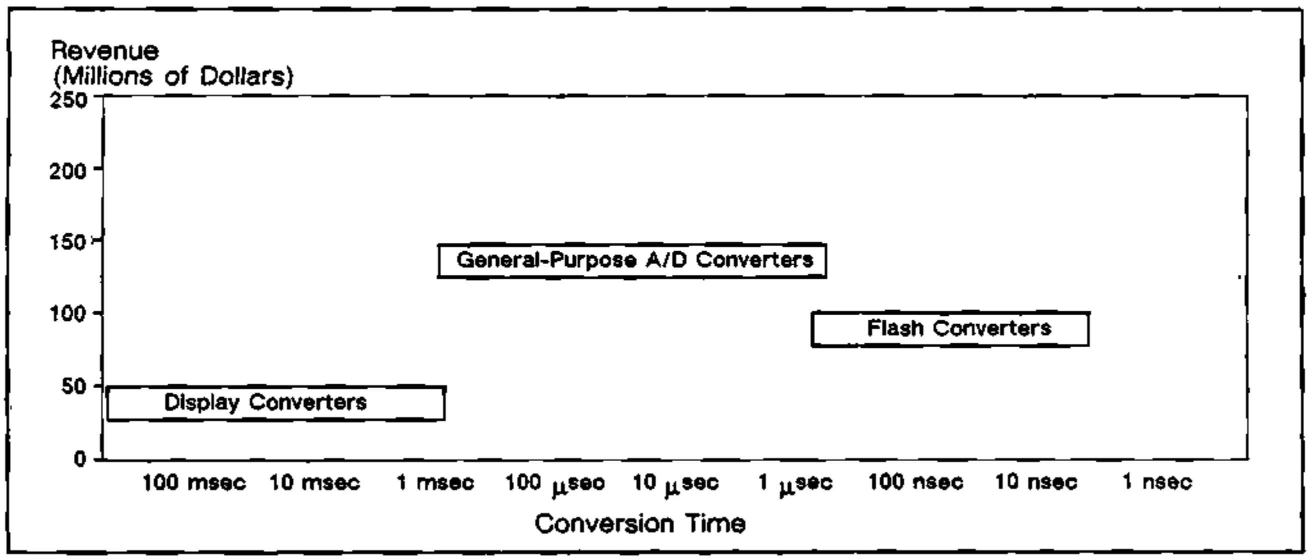
Delta-Sigma Market Potential

As of 1989, delta-sigma sales were still relatively low (less than $6 million). Neither the flash portion of the market nor the display ADC converter portion is reasonably accessible to the delta-sigma converter. Although the delta-sigma converter can operate down in the dual-slope display-converter speed and resolution range, the dual-slope converter already offers many of the same virtues as delta-sigma. In addition, the dual-slope converter is inexpensive, accurate, and well understood. In reality, only portions of the general-purpose ADC market are left available for the delta-sigma.

Of the $146 million invested in general-purpose converters, it is estimated that more than 60 percent are time-shared. These converters either embody analog signal multiplexers or are used with them, leaving at best approximately 40 percent (or $60 million) of the market available for delta-sigma converters. Many of the disadvantages of successive approximation converters are minimized by the use of capacitor arrays in a charge redistribution scheme. It is unlikely that delta-sigma can corner the total remaining $60 million portion of the market, even if delta-sigma converters are cost-competitive enough to use on a per-channel basis to eliminate time-sharing. Figures 3 and 4 show Dataquest's estimation of the impact of the delta-sigma converter on the ADC market in 1989 and 1994, respectively.

In general, Dataquest believes that two major portions are contributing to the growth of the delta-sigma converter market: a 25 percent piece of the general-purpose ADC market and the newly emerging audio and DSP-specific applications. Although these pieces create a potential for $180 million in sales revenue by 1994, potentials rarely are achieved. A prudent revenue forecast for delta-sigma converters would be approximately $110 million in 1994. This forecast does not include the many telecommunications products in which delta-sigma converters would be used. These products tend to be very specific to telecommunications and are not readily categorized as converters,

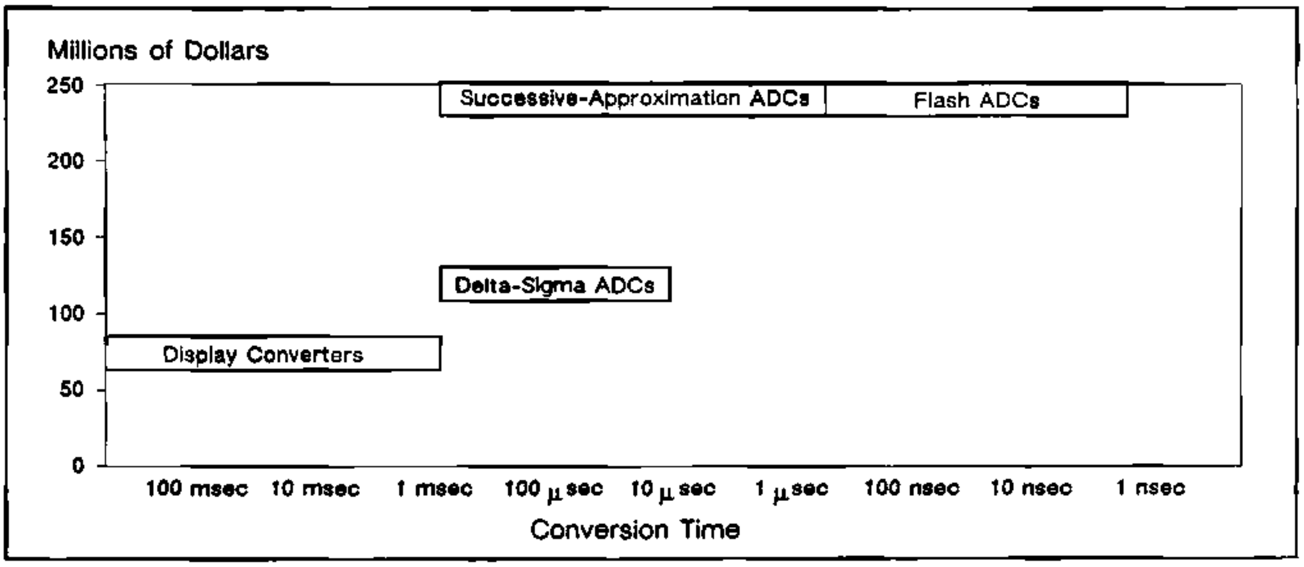
FIGURE 3
ADC Revenue and Conversion Rate by Converter Type—1989



0006529-3

Source: Dataquest
March 1990

FIGURE 4
Estimated ADC Revenue and Conversion Rate by Converter Type—1994



0006529-4

Source: Dataquest
March 1990

as they contain many different functional blocks. ISDN U-Interface transceivers, SLIC processors, modems, and cellular radio modulators are a few of the telecom applications in which delta-sigma may become a major A/D converter technique. However, chip area considerations for the digital filter represent the limiting factor for design wins.

DATAQUEST CONCLUSIONS

Dataquest believes that delta-sigma will take its place as a major A/D converter technique for voice-band and audio applications, but it is unlikely to cause the extinction of any alternative technique. SA converters are evolving also; capacitive arrays improve bit matching while error correction and self-calibration features maintain accuracy. We expect the SA technique to diminish somewhat as delta-sigma converters pick up application-specific segments of the market. More likely, the delta-sigma/DSP synergy will create new applications and markets for delta-sigma ADCs rather than dominating old ones.

Gary Grandbois

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Research Newsletter

ANALOG CIRCUITS DOMINATE AT ISSCC '90

INTRODUCTION

Analog ICs made a strong showing at the International Solid-State Circuits Conference (ISSCC) held in San Francisco, California, last month. Although papers presented at the sessions covered a broad spectrum of semiconductor circuit types, this newsletter focuses on analog and mixed-analog/digital IC trends. Highlights of selected sessions are covered, followed by tables showing the appearance of process technology within the papers. Processing is segmented by product type, by presenting company, and by analog supplier ranking.

SESSION HIGHLIGHTS

Data Converters

The analog-to-digital converter (ADC) speeches covered subranging and recycling conversion techniques used to achieve video speeds at 10 bits of resolution. A paper on 16-bit charge redistribution and 18-bit capacitor-array/resistor-ladder successive approximation converters covered general-purpose converters with lower rates but higher resolution. A sigma-delta converter with 20-bit resolution and a three-stage filter showed the capabilities of this technique for a 32 kilosamples/sec audio converter.

An 18-bit audio digital-to-analog converter (DAC) that combines three different D/A conversion techniques showed high resolution in the DAC.

Analog Devices, Inc. continues to emphasize BiCMOS data converters. It presented three BiCMOS papers this year, one on DACs and two on ADCs.

Oversampling Data Converters

This panel session explored the advantages and disadvantages of the sigma-delta ADC and its role in the future of data converters. Although some panelists believe that sigma-delta converters will displace all converters for bandwidths below 100 kHz, other panelists were quick to point out the problems of latency (time delay through the converter), overload recovery, bandwidth-specific operation (not a general-purpose ADC), and the inability to multiplex the input.

It was fairly well agreed upon that the sigma-delta converter will become the standard for telecommunications and audio applications, especially in complex mixed-signal ICs, because of its synergy with digital filtering techniques.

High-Speed Analog

Higher-speed analog and mixed-signal ICs are needed to handle television broadcast frequencies in the terrestrial UHF and higher-frequency satellite bands. Although the highest frequencies are handled by GaAs ICs, wide bandwidth, mixed-signal silicon ICs are only now starting to appear. Hitachi presented a paper that demonstrated a mixed-analog/digital TV tuner that operates in the UHF spectrum. At these frequencies, digital crosstalk can be a severe problem. The low-voltage, current-mode operation of ECL/I^2L circuits combined with oxide-isolated analog functions minimizes this crosstalk.

Imagers and Sensors

Higher-resolution sensors continue to be demonstrated at this year's ISSCC. In addition, signal processing embedded in the sensor itself

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may reduce some of the applications for video digital signal processing (DSP). Papers in this session discussed pixel amplification, self-shuttering, convolution, and pipelined signal processing integrated with the image sensor. The integrated signal processor was configured to perform a simple edge-detection algorithm in real time.

Display technology advances discussed at ISSCC included the combination of thin-film transistors (TFT) on quartz and glass liquid-crystal display (LCD) structures. A TFT-LCD display with 1.6 million transistors (and a like number of pixels) on a 14 x 14-inch quartz structure was demonstrated by Xerox's Palo Alto Research Center (PARC). This product uses polysilicon CMOS TFTs, which allow for the integration of large-scale analog and digital functions on the display itself. Op amp and buffer circuits also were discussed.

STATISTICS ON PRESENTATIONS

Geographic Breakdown

The geographic origin of the papers presented in the analog and digital sessions differed. The analog (including mixed-signal) sessions contained 43 papers, 25—or 58 percent—of which were of U.S. origin. The digital sessions showed the opposite in that 58 percent of the papers were of non-U.S. origin. These proportions are essentially the same as seen at the 1989 conference. As a point of reference, at the 1979 conference, 75 percent of the analog papers were of U.S. origin. Table 1 shows the detailed breakdown by company region of origin at this year's event.

The representation in the mixed analog/digital papers (58, 26, and 16 percent for North America, Japan, and Europe, respectively) closely correlates with the mixed-signal revenue by regional home

TABLE 1
Papers by Region of Company

Region	Analog and Mixed	Digital	Total
North America	25	17	42
Japan	11	20	31
Europe	7	4	11

Source: Dataquest
March 1990

base of the IC manufacturer (58 percent, 22 percent, and 19 percent, respectively).

Of a total of 37 nonsensor analog papers, 48 percent were on CMOS, 24 percent on bipolar, and 19 percent on BiCMOS/BCD (The 1989 conference showed 61, 15 , and 23 percent, respectively). This strong improvement in bipolar presence is largely due to the dominance of the bipolar power-driver ICs in the analog power sessions.

Table 2 shows the number of papers presented at each session and the process technology used. This table displays the preferences in process technology relative to product type.

Table 3 shows the number of papers presented by each participating company or organization and the process technology used.

Table 4 takes the data from Table 3 and orders the companies using Dataquest's 1989 ranking by analog IC market share. These are the top 15 analog suppliers in descending order of rank.

Only 21 of the 43 analog papers were presented by the top 15 suppliers. This result is not surprising, considering the fragmentation of the analog market. Analog Devices, Philips, and Texas Instruments were well represented by three or more papers each. Six of the seven analog BiCMOS/BCD papers were given by the top 15 analog suppliers (Telefunken was the exception).

TABLE 2
Number of Papers by Product Type and Process

	Process						
	Bipolar	CMOS	BiCMOS	BCD	GaAs	CCD	Other
Analog Sessions							
Telecommunications ICs		5					
High-Speed Analogs	3	2			1		
High-Speed Signal Processors		2					
Emerging Circuits		1	1			1	
A/D Converters	1	3	3				
High-Speed Communications		1					
Data Acquisition/Filtering	1	3	2				
Image Sensors and Displays		3				3	
Innovative Circuit Designs	1	1			1		
Analog Power ICs	3			1			
Total Analog	9	21	6	1	2	4	
Digital Sessions							
Telecommunications ICs		1					
High-Speed Signal Processors		2	2				
Emerging Circuits	1						1
High-Speed Communications					2		1
Innovative Circuit Designs			1				
Microprocessors		6					
Nonvolatile and Fast SRAMs	1	5	1				
Application-Specific ICs	1	4	1				
Static RAMs	1	5	1				
DRAMs and Embedded Memories		4					
Total Digital	4	27	6		2		2
Total (all papers)	13	48	12	1	4	4	2

Source: Dataquest
March 1990

Table 3
Number of Papers by Company and Process

Company or Organization	Number of Papers Total	Number of Papers Analog	Process Bipolar	Process CMOS	Process BiCMOS	Process BCD	Process GaAs	Process CCD
Alcatel	1	1		1				
ANADIGICS	1						1	
Analog Devices	4	4	1		3			
AT&T	3	3		3				
Bellcore	1			1				
Crystal Semiconductor	1	1		1				
Fujitsu	7	1	2	2	1			
Hewlett-Packard	2	1	1	1				
Hitachi	5	2	1	3			1	
IBM	5			4	1			
Linear Technology	1	1	1					
M.I.T.	2	2						2
Matsushita	4	2		2	2			
Mitsubishi	3	1		3				
Motorola	2			2				
National Semiconductor	2	2		1		1		
NEC	5	1		4	1			
NHK	1	1						1
NTT	1						1	
Oki Electric	1	1		1				
Oregon State Univ.	2	2		1			1	
Philips/Signetics	5	3	1	4				
Phylon Communications	1	1		1				
Price, J.E. (Consultant)	1		1					
SEEQ, Inc.	1			1				
SGS-Thomson	1			1				
Siemens	1	1	1					
Sony Corp.	2	2	1					1
SRI International	1	1		1				
Stanford University	2		1		1			
Sun Microsystems	1			1				
Swiss Center (CSEM)	1	1		1				
Telefunken	2	1			2			
Texas Instruments	5	4	2	2	1			
Toshiba	2			2				
Univ. of California	2	2		2				
Xerox	2	1		2				
Total	84	43	13	48	12	1	4	4
Percentage of Total	100	51	15	57	14	1	5	5

Note: Two papers, one covering Josephson junctions and one covering HEMT ICs, are not shown

Source: Dataquest March 1990

TABLE 4
Presenting Companies by Analog Rank

Company or Organization	Number of Papers Total	Number of Papers Analog	Process Bipolar	Process CMOS	Process BiCMOS	Process BCD	Process GaAs	Process CCD
Toshiba	2			2				
National Semiconductor	2	2		1		1		
Philips/Signetics	5	3	1	4				
Sanyo								
Motorola	2			2				
Texas Instruments	5	4	2	2	1			
NEC	5	1		4	1			
SGS-Thomson	1	*		1				
Sony Corp.	2	2	1					1
Mitsubishi	3	1		3				
Matsushita	4	2		2	2			
Analog Devices	4	4	1		3			
Hitachi	5	2	1	3			1	
Harris								
Rohm								

*Shared a mixed-signal telecommunications paper with National.

Source: Dataquest
March 1990

DATAQUEST CONCLUSIONS

Analog papers made their traditional strong showing at this conference. Although analog and mixed-analog/digital ICs account for less than 20 percent of IC revenue and 39 percent of all IC units sold, papers on these topics represented 51 percent of papers that were presented. The conference underscores the fact that analog still is strongly oriented toward the product definition and circuit design disciplines.

The BiCMOS process made another strong showing in the data converter papers at ISSCC. Seven papers discussed BiCMOS/BCD products at this year's conference versus the four presented last year. Three of the seven BiCMOS/BCD papers were from Analog Devices Inc., showing its commitment to this process for mixed-signal ICs.

The delta-sigma converter came up for discussion in telecommunications and data converter sessions as new (and rediscovered old) conversion techniques are being explored to optimize products for voice-band, high-quality audio and video markets. Sigma-delta is likely to be a major force in mixed-signal products that need conversion at rates below 100 kHz.

The need for high resolution in capturing and displaying images is driving the semiconductor optoelectronics technology at a furious pace. Electronic imaging will enable and unleash many computer, medical, industrial, and consumer products. Signal processing at both the imager and the display may displace signal processing in the traditional IC format.

Intelligent power ICs for automotive applications were highlighted by both the high-side switch driver presentations and the February 14 announcement of the TI/Delco alliance to develop microcontroller-based intelligent power ICs.

The technical papers presented at the 1990 ISSCC demonstrate that IC bandwidths, functionality, mixed analog/digital integration, and even the concept of what constitutes an analog IC continue to enlarge and change.

Gary Grandbois

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Research *Bulletin*

DELCO-TI ALLIANCE: POWER DEVICES AND MICROCONTROLLERS MERGE

SUMMARY

Intelligence and power, attributes rarely combined in most human endeavors, seem to be about to merge in power ICs. Although the designations "smart" or "intelligent" for power ICs have been applied to virtually any power IC in recent years, most mergers between power and digital function have resulted in products that are significantly less than "smart." The smart power ICs presented at the recent International Solid State Circuits Conference (ISSCC) combined power drivers with random logic for digital interfaces, chip diagnostics, and device protection schemes. These products are attractive peripherals for a microprocessor but embody very little intelligence in their ability to control the applications at hand. A recently announced Delco-Texas Instruments (TI) alliance revives the promise of intelligent power and offers interesting directions for microcontroller products.

THE ALLIANCE

Delco and TI have signed an agreement to jointly define and develop a new generation of microcontrollers for automotive applications. This agreement will combine Delco's expertise in automotive product definition with TI's expertise in mixed analog/digital and power semiconductor technology. The resulting products will merge microprocessor, power devices, and analog signal-processing circuitry for specialized automotive controllers. This program represents an expansion of the technology partnership that originated in 1983 and resulted in the development of the TMS370 configurable microcontroller family. TI brings a strong presence to the merged process technologies needed for intelligent power, as well as the configurable microcontroller core. The initial products defined by this alliance will be designed with the EPIC™ process. BiCMOS and other more exotic processes also will be made available.

SMART POWER IN THE AUTOMOTIVE MARKET

Dataquest estimates that the 1989 smart power market was $248 million, or approximately 32 percent of the total monolithic power IC market. The North American share of the smart power revenue was about $100 million. Within the North American market segment, smart power ICs are focused mainly at the emerging automotive market and the disk drive controller market. Although the automotive market was less significant than the computer market in 1989, emerging automotive power applications show the greatest growth and market potential and are ripe for power controller ICs. Automotive applications will require ICs that can drive motors, actuators, annunciators, and displays using microprocessor-based intelligence. A few of the applications are as follows:

- Injector drivers
- Multiplex drivers
- Display/instrument drivers
- Lighting control
- Alternator regulation
- Airbag systems
- Traction control and ABS
- Transmission control
- Suspension actuators
- Motor controllers and drivers
- Actuators for items such as doors, locks, mirrors, and seats

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TABLE 1
Smart Power IC Forecast by Market North America (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1988-1993 CAGR
Computer	33	38	41	46	53	61	13%
Automotive	16	24	32	42	54	70	35%
Industrial	15	16	17	18	19	21	7%
Consumer	0	0	1	1	2	2	N/A
Telecommunications	16	19	21	23	26	30	13%
Military/Aerospace	2	3	3	4	4	4	14%
Total	82	100	115	134	158	188	18%

N/A = Not Applicable

Source: Dataquest February 1990

Table 1 contrasts the forecast growth for smart power ICs in the North American automotive market with the growth that other markets in that region. Note that the 35 percent growth in the automotive sector is twice that of the smart power market in general. New products resulting from mixed-mode technologies and closer vendor/user relationships should do much toward driving this growth.

DATAQUEST CONCLUSIONS

Dataquest believes that user/vendor alliances and sophisticated process technologies are paving the way for the merging of powerful digital controllers with power drivers on a single IC. Intelligent power may yet become a meaningful term as power devices and microcontrollers merge into application-specific mixed-mode ICs. It may be questionable as to whether or not processors and power can be merged cost effectively on a single IC. The partitioning of intelligence and power into chip sets or the use of combinations of discretes and ICs are not likely to be phased out soon. However, embedded controllers with power outputs should speed the development of new applications, provide intelligent solutions to present automotive controllers, and provide a look into the future of intelligent power in other market segments.

Gary Grandbois

ASIC NEWSLETTERS
1990

6378	1.	Gate Array Market Sets Records in 1989 Lewis/Feb
6517	2.	North American Suppliers Dominate 1989 Cell-Based IC Market Lewis/Mar
6550	3.	Gate Arrays Capture Lions Share of 1989 ASIC Market Lewis/Mar
6745	4.	CMOS and Complex PLDs Continue Their Meteoric Rise Banks/Apr
6829	5.	Chip Sets and Aggressive Pricing Drive New ASIC Forecast Lewis/Apr
5 74~~8~~3	6.	Complex PLDs - - What It Takes To Win Banks/July
7619	7.	Line Geometries of Gate Arrays and DRAMs Converge Banks/July
8055	8.	Designing for Dollars: Win with FPGAs Mosakowski, Banks/Sept
8072	9.	Synopsys and Siemens Expand Their EDA Offering While H.P. Contracts Galligan/Sept
8452	10.	"Embedded Gate Arrays: The Best of Both Worlds" Lewis/Oct
8490	11.	Submicron Process Geometries Pose New Challenges for EDA Vendors Galligan/Sept
8529	12.	Dataquest Slashes Gate Array Design Start Forecast Lewis/Nov
8708	13.	PLDs Come of Age Banks/Oct
8709	14.	Cell-Based ICs - VLSI Technology Is Still Number One Banks/Oct
9033	15.	Time to Market: The ASIC Advantage Banks,Galligan/Dec
9073	16	FPGAs: The User's Perspective Galligan/Dec

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Research Newsletter

FPGAs: THE USER'S PERSPECTIVE

FPGAs ADDRESS MARKET NEED

Because of their cost-effectiveness and versatility, gate arrays have enjoyed considerable market success, catapulting the market from a mere $135 million in 1981 to today's estimated $4 billion. However, the industry is also driven by the desire to reduce its risk in terms of both NRE costs and time to market. Although gate arrays offer considerable economies of scale when ordered in high volume, in today's fast-moving markets, the increased emphasis is on time to market because of ever-diminishing product life cycles. Many companies cannot afford the time delays associated with custom masked gate array production.

On the other hand, although standard products represent a low risk and offer ready availability, they tend to be poor conduits for product differentiation. Another product alternative is the PLD, which, although a standard product, is customizable by the user. However, until recently, these devices did not offer sufficiently high levels of integration to address even the lowest gate array density requirements. The shortcomings of these various product implementations represented a challenge that some companies viewed as opportunities. In 1985, Xilinx introduced a new product concept to the market, which has been coined field-programmable gate arrays (FPGAs). The advent of FPGAs held the promise of addressing some of these basic product issues. FPGAs are used as replacements for multiple TTL and PAL parts and also are affecting low-density/low-volume gate array designs today. They could potentially impact medium-density/medium-volume gate array designs. Dataquest expects the FPGA market to experience rapid growth, increasing from a $61 million market in 1989 to $510 million in 1994, a compound annual growth rate of 52.9 percent.

FPGAs: A DESCRIPTION

FPGAs are user-programmable like PLDs but are like gate arrays in that device performance is a function of the fixed delays of the logic elements as well as the variable delays of the interconnect paths. The implications of the variable interconnect delays are significant because they necessitate timing analysis of the circuit.

The basic architecture of an FPGA consists of its logic block function, interconnection structure, and I/O block design. The block diagrams in Figure 1 show the implementations of the differing architectures of the leading suppliers to this market—Xilinx and Actel, respectively.

Actel's product portfolio is based on antifuse technology, and Xilinx's products are implemented in SRAM technology. These fundamentally different approaches mean that the Xilinx solution requires a dedicated EPROM to configure the FPGA in start-up mode. An FPGA may share an EPROM already on-board or one EPROM may be shared among several FPGAs. Although Xilinx uses a two-chip approach, it has the advantage of offering dynamic reprogrammability. On the other hand, the Actel single-chip solution is not reprogrammable. This inability to reprogram raises the importance of test-built-in circuitry to facilitate factory testing.

THE USER'S VIEW

Things have changed radically in the FPGA market since its inception in 1985. Many are just learning how to use FPGAs. Basing assumptions on data and experience from first-generation products may mean that users could be summarily

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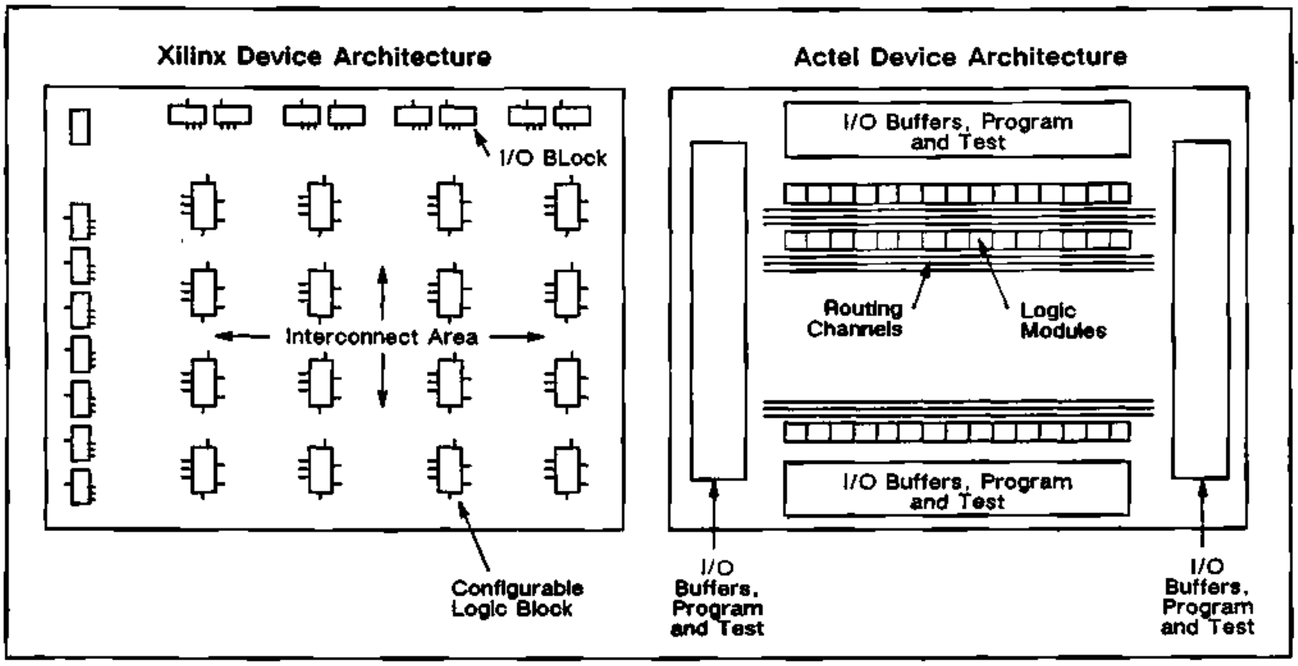
Figure 1
Block Diagrams of Xilinx and Actel Product Architectures



Source: Actel Corporation, Xilinx, Inc.

dismissing FPGAs as a viable product alternative. Dataquest decided to reassess market acceptance of the product by polling a number of FPGA users for their opinions. Below, we present a summary of the results of our informal survey. For convenience, we have grouped the responses according to the following key issues: turnaround time, reduced risk, performance, technology, density, cost, and tools. Generally, users were satisfied with FPGAs as a design solution. High on their wish lists were (of course) denser, faster parts at a lower cost. But as things continue to change rapidly in this market, the expectation is that some of these items will be forthcoming.

Turnaround Time

Perhaps the number one issue among FPGA users we spoke to was time to market, which was an overriding consideration in many product decisions. Incorporating an FPGA into a product design often allows the company to design, demonstrate, and manufacture in a timely manner.

Reduced Risk

The prospect of reduced risk through FPGAs is an important benefit. FPGAs offer reduced risk on at least two fronts. On one hand, they offer an alternative to the upfront design time, potential risk, and expense incurred in a gate array implementation. On the other hand, as a long-term strategy, the use of FPGAs facilitates a more aggressive product strategy. System companies that frequently experience design changes quite far along in the design of a system value FPGAs for the flexibility they ensure in their product designs. A company can introduce several high-risk products to the marketplace, migrating the successful ones to a gate array implementation while replacing unsuccessful products with new ones. This ability to react quickly to the market mitigates the downside when taking an aggressive approach to product introduction and gives a company the opportunity to prove its product and technology.

Performance

With system clocks running at 50 MHz, speed was an important user criterion. Some users chose to do hand routing to eke out some extra speed. Many users did not choose to incorporate FPGAs in the speed-critical portions of their design. New product announcements from FPGA suppliers show that they are also tackling the issue of system performance by incorporating enhanced system features on-chip.

Technology

Users of both Actel and Xilinx products espoused the merits of their chosen solution. Their different approaches represent an exercise in trade-offs. For example, there is a trade-off between cell size and device performance. The larger kernel of Xilinx's logic blocks can increase performance, but a larger cell size does entail the risk that, in some cases, the cell may not be fully utilized. Actel users, however, laud its minimum building-block approach, whose granularity facilitates migration to a gate array. Although Xilinx places no restrictions on the number of interconnections that can be made, Actel aims for greater timing predictability by limiting the number of connections between blocks. Some Xilinx product users thought of the product's volatility as a feature because it enables dynamic programming.

Density

From an integration standpoint, FPGAs compete with low gate-count gate arrays. However, the issue of utilization of FPGAs is not a straightforward one. A large number of users could not describe their utilization in gate terms, instead referring to utilization of logic modules and CLBs (configurable logic blocks)—terminology employed by Actel and Xilinx, respectively. Most users estimated that their logic block utilization was in the 85 to 95 percent range. This does not translate exactly into a gate count because use of the entire block internally must also be determined. One experienced Xilinx user hazarded the view that actual total gate usage most likely averaged about 55 to 60 percent, while an Actel user estimated usage at about 75 to 80 percent of the total gates. Different applications affected these percentages quite substantively.

FPGA companies continue to work on increasing product density. Actel has introduced a next-generation product family, the Act-2 family, claiming as many as 8,000 usable gates. According to Xilinx, its next-generation product, the XC4000 family, will provide up to 20,000 usable gates. Sample shipments of the first family member offering 5,000 equivalent gates will commence in the first quarter of 1991.

Cost

With first- and second-generation parts costing between $15 and $50 (and even less in very high volumes) and recent products listing for several hundred dollars, the device cost for FPGAs is considered to be quite high. From the survey feedback we received, there is a perception among users that Actel products are more expensive than those from Xilinx. However, it is very difficult to assess the accuracy of this perception because the complexity of a comparative price-per-gate analysis is compounded by the fact that each supplier counts gates differently.

Xilinx positions its products as the volume solution and has been forthcoming about price reductions on its older-generation products. Although Xilinx offers a hardwired Logic Cell Array (LCA), the company does not actively promote a path to a gate array alternative. This point is a major distinction between the two companies' philosophies. Actel has aggressively aligned itself with other merchant semiconductor suppliers to facilitate the route to gate arrays. For a cost-reduction approach, Dataquest still expects volume shipments or products with long life cycles to migrate to gate arrays. Moreover, although it is possible that not as many users will avail themselves of this migration path as inquire about it, it is an option that assuages users' concerns about the cost of going to volume production. With the next-generation product announcements and new suppliers entering the market, it can be expected that price competition will beset this market, too, in the future.

Tools

Generally, users indicated that tools for these devices were at least adequate. As a long-term strategy, product experts agreed that the best design approach is to manage the schematic in order to ensure automatic forward compilation. The automatic place-and-route tools for Actel products were viewed favorably. Companies that use EDA tools to perform schematic capture for Actel products like the easy migration this approach provides to gate arrays. Many users were acquainted with Xilinx products and expressed dissatisfaction with their tools. Perhaps because Xilinx was first with product to market, it is not fair to compare more recent product support for Actel products with what was initially offered for Xilinx products. Xilinx has been addressing the issue of EDA tools, and although no one we spoke to could comment on the new tools, we believe that they are considerably more user-friendly than before. Users are not only becoming increasingly more sophisticated in their needs but also becoming more ambitious. In response to customer feedback, the company has recently announced the XACT 4000, a completely redefined development system promising 100 percent automatic place and route.

DATAQUEST CONCLUSIONS

FPGA suppliers should keep in mind that their gate array competitors are a moving target. Leading gate array vendors profess themselves unconcerned by the competitive threat posed by FPGAs as the gate array vendors target high gate-count users. Gate array vendors continue to keep the pressure on their FPGA competitors by continued improvements in turnaround times as well as by offering very economical silicon and sophisticated tools.

Although more expensive than gate arrays on a per-gate basis, FPGAs can provide greater flexibility and can prove more economical in terms of time, test, and inventory savings. However, the user must be willing to accept trade-offs. The attractiveness of FPGAs in their current stage of evolution relies on a delicate balance between economic and engineering savings to offset considerably higher prices and less-than-optimum performance. The justification for using an FPGA can evaporate quite rapidly if the savings do not materialize. The realization of the time-to-market advantage lies in the ease of use of the tools. Poor, user-hostile tools can cause users to forfeit the time-to-market advantage achievable through FPGAs, and trying to compete with gate arrays on the basis of price and performance is not a winning platform for FPGAs. In Dataquest's opinion, continued investment in more user-friendly, sophisticated tools will reap significant dividends for the FPGA supplier.

Patricia Galligan

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Research Newsletter

TIME TO MARKET: THE ASIC ADVANTAGE

TOP BILLING: TIME TO MARKET

ASICs provide a way to get to market sooner with a differentiated product. Regardless of whether an ASIC is defined as a classic ASIC, a single-user IC, or a so-called application-specific standard product (ASSP), the entire ASIC concept involves shrinking time to market. Some may contend that other factors such as development cost and reduced risk are equally important, but these factors are just the supporting cast to the main attraction, the time to market.

CPLDS: WHAT'S THE ATTRACTION?

Complex programmable logic devices (CPLDs) are sufficient proof of this theory; for instance, what exactly do CPLDs have going for them? They are slower than gate arrays, their tools are not as sophisticated as gate array tools, fewer alternate sources are available, and CPLDs cost an order of magnitude more than gate arrays on a price-per-gate basis. Yet they continue to win new designs. In 1990, the annual number of CPLD designs will exceed that of gate arrays, and Dataquest expects CPLD revenue to grow at a compound annual growth rate (CAGR) of 65 percent through 1994.

THE CPLD PHENOMENON

The spectacular growth of CPLDs is due to no nonrecurring engineering (NRE) costs, low risk, and fast time to market. However, closer scrutiny is required to learn anything from the CPLD phenomenon, which can be applied to the rest of the ASIC community. Let us first examine the NRE issue. Gate arrays and cell-based ICs (CBICs) come fully loaded with one-time NRE charges, but CPLDs bear no such burden. Consequently, if the gate array unit volume over which the NRE must be amortized is low enough, a CPLD solution could compete on a price-per-gate basis. As shown in Table 1, a gate array selling for one-tenth the price of a CPLD would have to ship under 1,100 units for the life of the design before a CPLD could compete on a price-per-gate basis. Clearly, CPLDs are the obvious choice for such low-volume applications. Preliminary data indicate that approximately one-half of all CPLD revenue falls into this category.

The striking corollary of this situation is that approximately one-half of CPLD revenue is derived from applications that have sufficient volume to justify using a gate array solution. Therefore, if price per gate is not the driving criterion for these applications, just what is the justification for

TABLE 1
Gate Arrays versus CPLDs

	Gate Array	CPLD
Gate Density	1,500	1,500
ASP	\$1.50	\$15.00
NRE	\$15,000	NA
Break-Even Volume	≥1,100 units	≤1,100 units

NA = Not applicable
Source: Dataquest (December 1990)

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choosing the CPLD solution? Reduced risk is a commonly cited reason, but what exactly is meant by risk? Risk can be boiled down to achieving working silicon on schedule, which directly impacts time to market. If a low-risk CPLD solution offered no time-to-market advantage over a gate array, there would be no reason to use the CPLD; time to market is the chief reason CPLDs are experiencing such rapid growth. This explanation holds significant implications for gate array vendors because gate arrays will have to compete on a time-to-market basis with CPLDs or risk giving up a large portion of revenue.

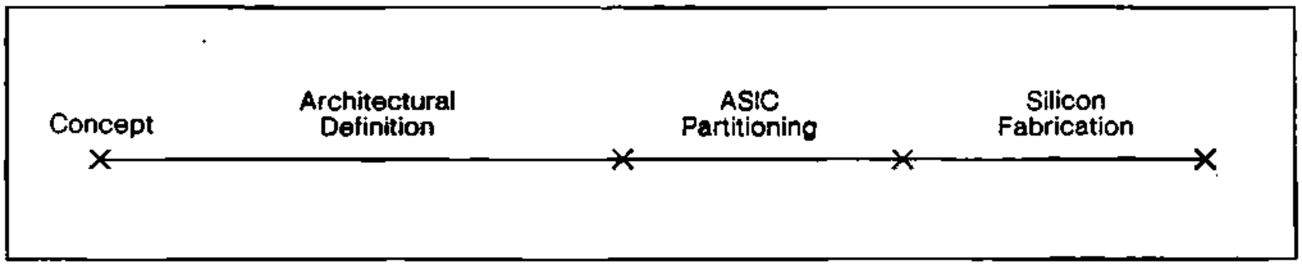
TOTAL TIME TO MARKET

How can gate arrays compete with CPLDs on time to market? After all, CPLDs are field programmable and require no fab cycles to be factored into their sample and production schedules. Seeing how gate arrays can compete requires an expanded view of the time-to-market cycle. CPLDs currently compete on a silicon turnaround basis, which is but one part of the time-to-market issue. As shown in Figure 1, time to market is measured more accurately from concept to production.

ASIC PARTITIONING

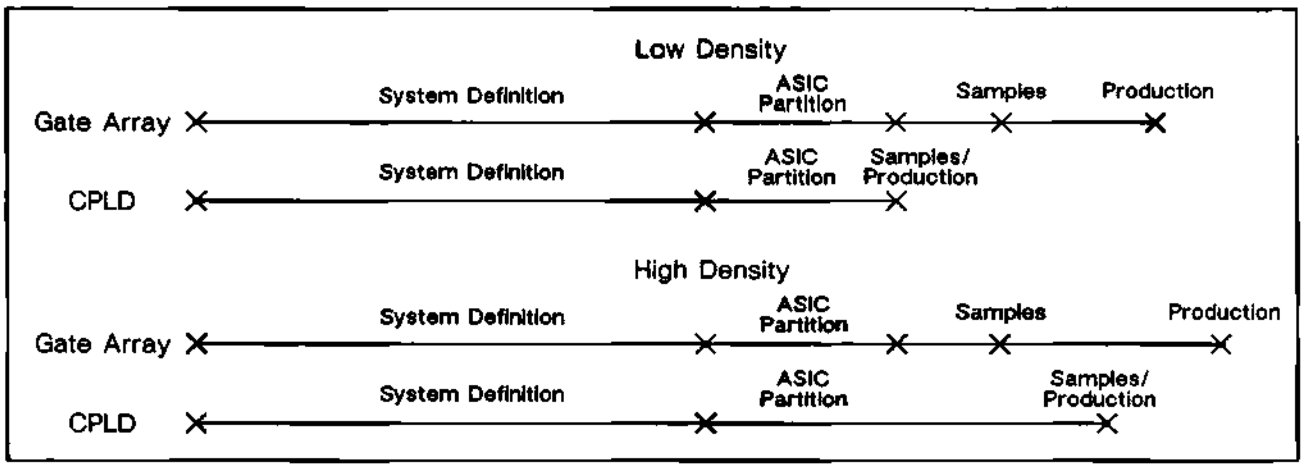
CPLDs have eliminated the silicon manufacturer cycle, and CPLD manufacturers are working on the ASIC partitioning cycle. Gate array and CBIC manufacturers currently are ahead of CPLD vendors regarding shortening the ASIC partitioning cycle; they currently are expending their time-to-market efforts on the never-ending task of shortening fab cycle times. In low-density applications, the ASIC partitioning cycle is not the major bottleneck in the time-to-market contest; consequently, in such low-density applications, the off-the-shelf availability of CPLDs gives them a distinct advantage. As higher-density applications are required, the ASIC partitioning cycle increases disproportionately to the other elements that make up the time-to-market cycle. As a result, gate arrays and CBICs are more competitive on a time-to-market basis with CPLDs at higher densities. This concept is illustrated in Figure 2.

FIGURE 1
Time-To-Market Cycle



Source: Dataquest (December 1990)

FIGURE 2
Time to Market by Product



Source: Dataquest (December 1990)

To date, the architectural definition portion of this cycle has largely been ignored by most ASIC manufacturers. This segment can have the most dramatic impact on time to market, as well as the best opportunity to provide added value (the profit generator). Impacting this segment of the cycle requires focusing on specific end markets, then on specific applications within those markets, and finally, on establishing alliances with major users in those chosen application-focused markets.

DATAQUEST CONCLUSIONS

Dataquest believes that as CPLDs achieve higher densities, their development tools will have to improve substantially if they are to maintain their time-to-market lead over other ASIC solutions. If other ASIC solutions, such as gate arrays and CBICs, maintain their lead in development tool sophistication, they will be more competitive in higher-density applications because the CPLD time-to-market advantage will diminish as ASIC densities rise.

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Research Newsletter

DIGITAL CELL-BASED ICs—VLSI TECHNOLOGY IS STILL NUMBER ONE

INTRODUCTION

Dataquest's European application-specific integrated circuit (ASIC) research has highlighted the significance of mixed-signal cell-based ICs (CBICs) in Europe due to the European applications base (see ESIS newsletter 1989-22 entitled "Mixed Analog/Digital ASIC—An Embryonic Market"). For the first time, Dataquest has published separate rankings and analysis for pure digital CBICs and mixed-signal CBICs.

This newsletter presents Dataquest's European cell-based ASIC rankings for 1989 and highlights the key market trends present at the moment.

SUMMARY

The European market for digital cell-based ICs in 1989 grew by 26 percent. VLSI Technology kept the lead over Austria Mikro Systeme (AMS) as the number one supplier of digital CBICs, while Texas Instruments increased market share and moved up to the number three position. US companies have a strong presence in digital CBICs; five of the ten top CBIC suppliers are US-based companies. Of the total European market, 43 percent was supplied by US companies.

In mixed-signal CBICs, there is a greater European presence. This is due to the strength of European OEMs in telecoms, industrial, and automotive applications. Mietec takes the number one position when digital and mixed-signal CBIC revenue is combined, due to its high revenue from mixed-signal CBICs, although a large portion of this is from its parent company, Alcatel.

Trends in 1989

We have noted an increasing trend for vendors with in-house design capability to customize individual cells to meet customers' needs. This trend has allowed vendors to command higher nonrecurring engineering (NRE) charges and higher unit prices for these CBICs.

The mixed-signal market is still limited by the ability to design the CBICs, as the design tools used are still not capable of complete mixed-signal simulation, although they are improving. The trend to migrate CBICs to application-specific standard products, seen strongly in the United States, is not having as much impact in Europe. This migration has occurred mostly in personal computers, with PC chip sets replacing CBICs. In Europe, PC manufacturers have tended to use PC chip sets from the outset, thus minimizing this factor. However, with the advent of European standards such as Groupe Speciale Mobile (GSM), we expect to see an increase in the use of chip sets in Europe.

DIGITAL CELL-BASED ICs

Market Shares

Table 1 shows the top 10 vendors of digital cell-based ICs in Europe for 1989 and their growth from 1988. There were 18 manufacturers of cell-based ASICs in 1989, the same as in 1988. The CBIC supplier list in Europe has seen a number of changes. GE Solid State was acquired by Harris Semiconductor in 1988, and its revenue is now included in Harris Semiconductor for 1989. Dataquest has for the first time recorded significant European revenue for Fujitsu and NEC.

The total market for digital cell-based ICs grew 26 percent in 1989 to $215 million, as shown in Table 1. This total compares with a growth of 94 percent in 1988, to $171 million. The high 1988 growth rate was from a small base, because

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TABLE 1
Estimated European 1989 Digital Cell-Based IC Market Share Rankings (Millions of US Dollars)

Rank 1988	Rank 1989	Company	Sales 1988	Sales 1989	CAGR (%) 1988/1989
1	1	VLSI Technology	22	29	32
2	2	Austria Mikro Systeme	16	24	50
4	3	Texas Instruments	12	22	83
5	4	European Silicon Structures	12	17	42
6	5	Marconi Electronic Devices	11	17	55
3	6	Siemens	15	17	13
14	7	SGS-Thomson	3	11	267
-	8	Harris Semiconductor	-	10	NA
9	9	LSI Logic	7	9	29
-	10	AT&T	-	8	NA
		Total All Companies Digital CBICs	171	215	26

NA = Not applicable
Source: Dataquest (October 1990)

the market was establishing itself. We expect the future growth rate to settle down to between 20 and 30 percent.

Austria Mikro Systeme grew by $8 million in 1989 to $24 million, which enabled AMS to challenge VLSI Technology for the number one position in digital CBICs. VLSI Technology grew by $7 million in 1989, a growth of 32 percent. This compares with AMS' 50 percent growth, which came from its strength in telecoms, and to a lesser extent, from its automotive designs—two strong areas for European CBICs.

Texas Instruments enjoyed 83 percent growth, which took its 1989 digital CBIC revenue to $22 million. Its main strength came from consumer applications and the success of its new cell-based family. Siemens had a disappointing year in CBICs, partly due to the company focusing on its domestic market rather than expanding into Europe as a whole. However, Siemens has recently announced a cell library targeted at automotive designers in an attempt to move to the automotive sector of the CBIC market. SGS-Thomson showed very high percentage growth—but from a very low base—as some of its design wins went into volume production.

Current Trends in Digital CBICs

Price pressure on digital CBIC vendors remains strong in spite of the high growth supported by the market. This is due to the immaturity of the market, with too many suppliers chasing too little business. A high-growth market should allow higher prices, but the CBIC users have a price expectation level set by their use of gate arrays, where the prices and costs are much lower. They bring this expectation to the CBIC vendor, and because of the number of vendors chasing business, the user is able to command lower prices.

There are signs of a merging of the cell-based and full-custom markets, because many cell-based designs now have some customized cells in them to give added functionality. As price pressure grows on the CBIC suppliers, they are adding value to their designs by using their design resource to customize some of the standard cells in their library for specific customers. This allows suppliers to charge higher NRE prices and higher unit prices for the customized cells in the design.

MIXED-SIGNAL CBICs

Market Shares

The mixed-signal market has shown similar growth to the digital CBIC market. Revenue for mixed-signal CBICs in 1988 totaled $73 million and grew 26 percent to $92 million in 1989.

Table 2 shows the top 10 vendors for mixed-signal cell-based ICs. One of the limiting factors in the growth of mixed-signal CBICs is the number of engineers who are able to design mixed-signal devices. The design tools available to the engineer do not fully address all of the requirements of mixed-signal design, and problems such as cross-talk and cross-coupling capacitors are not simulated at design time. As a result, more than one iteration of a design is normally required.

TABLE 2
Estimated European 1989 Mixed-Signal CBIC Market Share Rankings (Millions of US Dollars)

Rank 1989	Company	Sales 1989
1	Mietec	27
2	Plessey	16
3	IMP Europe	11
4	Telefunken	10
5	National Semiconductor	6
6	Philips	5
7	Sierra Semiconductor	5
8	Austria Mikro Systeme	3
9	LSI Logic	2
10	Marconi Electronic Devices	2
	Total All Companies Mixed-Signal CBIC	92

Source: Dataquest (October 1990)

Combining mixed-signal and digital revenue alters the total cell-based market significantly. Table 3 shows the top 10 suppliers of digital and mixed-signal CBICs. Mietec takes the number one position due to its high mixed-signal revenue and pushes VLSI Technology to the number two position. VLSI Technology has a simple mixed-signal capability, but these are peripheral analog cells and they fall outside the Dataquest definition of mixed-signal, as defined in ESIS newsletter number 1989-22 entitled "Mixed Analog/Digital ASIC—An Embryonic Market." AMS, with its relatively weak position in mixed-signal devices, is ranked third.

The greatest percentage growth in mixed-signal revenue has come from mixed-signal specialists such as Mietec and IMP, which have concentrated their expertise in this market, resulting in a near doubling of their revenue. Some of the other suppliers of CBICs have not grown their mixed-signal revenue as much because of the additional investment needed in support, CAD tools, design centers, and design staff.

TABLE 3
Estimated European 1989 Digital and Mixed-Signal CBIC Market Share Rankings (Millions of US Dollars)

Rank 1989	Company	Sales 1989
1	Mietec	34
2	VLSI Technology	29
3	Austria Mikro Systeme	27
4	Texas Instruments	24
5	Marconi Electronic Devices	19
6	European Silicon Structures	17
7	Siemens	17
8	Plessey	16
9	SGS-Thomson	13
10	IMP Europe	11
	Total All Companies Digital + Mixed-Signal CBIC	307

Note: The market for digital and mixed-signal cell-based ICs in 1988 was $244 million.
Source: Dataquest (October 1990)

Current Trends in Mixed-Signal CBICs

Many of the smaller suppliers of mixed signal CBICs have had large percentage growths in revenue during 1989, with some companies growing as much as 300 percent, although from a very small base, and 1990 looks set again to show big increases in revenue. Average NREs and unit prices for mixed-signal CBICs are higher than for digital CBICs for several reasons. The need to design many of the devices in-house due to their complexity increases design revenue. Price pressure is lower than for digital CBICs, so average unit prices tend to be higher. Finally, more than one iteration of the design is usually required, so again, NREs tend to be higher to cover this additional cost.

DATAQUEST CONCLUSIONS

The European digital and mixed-signal cell-based IC market is growing at an above-average rate, and is still set to overtake the gate array market. However, mixed-signal revenue is now needed to achieve this. In the past, CBICs were used to achieve lower unit cost at higher volumes when compared with gate arrays, but this is no longer the case. Falling gate array prices have meant that it is cost-effective to make large volumes in gate arrays, lessening the economic pressure to move to a CBIC design. Today, CBICs are used for the complex and special designs that gate arrays are not able to meet, rather than for lower cost, as indicated by the growth of mixed-signal CBICs. The driver for future growth of the cell-based market will come from the need to integrate higher-performance analog into the CBIC, and the need for higher levels of integration.

The mixed-mode market will grow significantly as customers recognize the benefits of combining digital and analog on the same chip. Design tools are not yet capable of designing mixed-signal devices, but they are developing fast, and should be able to give a level of design support similar to digital design tools within the next five years. The improvements in these tools will open up the mixed-signal market by allowing nonspecialist designers to develop mixed-signal designs and will remove the bottleneck of in-house expert designers.

In addition to the growth in the mixed-signal market, the CBIC and custom markets are starting to merge, with the customizing of some of the standard cells in the cell library. This customizing of cells addresses the problems that arise because of the limitations of some cell libraries and can be used to differentiate CBIC suppliers that have in-house design capabilities.

VLSI Technology is being challenged by AMS and TI for the number one position in digital CBIC, but it already has been overtaken by Mietec when mixed-signal CBIC revenue is included. VLSI, AMS, and TI have all reported low revenue for mixed-signal CBICs and will need to address this section of the market to be sure of maintaining their top positions in the CBIC market. The European mixed-signal market is set for high growth in the future, and suppliers who are weak here may be caught out.

Jerry Banks
Mike Glennon

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Research Newsletter

PLDs—CMOS COMES OF AGE

SUMMARY

The total European programmable logic device (PLD) market grew by 5 percent in 1989, but emphasis is moving away from bipolar to CMOS PLDs. The bipolar PLD market is shrinking, and this is just balanced by high growth in CMOS PLDs. We believe that the total number of units of bipolar PLDs is increasing, but price erosion is causing the fall in the total bipolar revenue.

AMD retained the number one position in spite of falling revenue, with 42 percent of the total European PLD market. Texas Instruments (TI) kept the number two position, and Philips fell to the number eight position from number three. This fall is because Philips main market focus for its older bipolar devices is in the consumer market, and its new PLDs are targeted toward data processing. The company is therefore going through a product transition.

There is an increase in the use of complex CMOS PLDs, which are driven by new technology from companies such as Altera, Actel, and Xilinx. So far these suppliers have only a small revenue base, but 1990 should show explosive growth for the suppliers of complex PLDs. Their main market at the moment is the replacement of low-end (less than 3,000 gates) gate arrays, but the introduction of higher complexity CMOS PLDs will allow them to address the midrange gate array market.

The PLD market is currently dominated by US suppliers (see Table 1) with only Philips as a major Europe-based supplier of PLDs. However, some European companies are starting to challenge this US dominance, with SGS-Thomson and Plessey introducing CMOS PLDs into the market.

TABLE 1
Estimated European 1989 Total PLD Market Share Rankings

Rank 1988	Rank 1989	Company	Sales ($M) 1988	Sales ($M) 1989	CAGR (%) 1988-1989
1	1	AMD/MMI	58	52	(10)
2	2	Texas Instruments	18	18	0
5	3	Altera	7	12	71
6	4	Xilinx	5	8	60
4	5	National Semiconductor	8	8	0
7	6	Cypress	4	7	75
8	7	Intel	4	7	75
3	8	Philips	10	6	(40)
9	9	Lattice Semiconductor	3	4	33
	10	Actel	-	2	NA
		Total All Companies Bipolar and MOS PLDs	119	125	5

NA = Not applicable
Source: Dataquest (October 1990)

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BIPOLAR PLDs

Market Shares

The only difference in the ranking for 1989 over the previous year was Philips and Texas Instruments changing places. AMD maintained its leadership with 62 percent of the European bipolar PLD market. The major suppliers in Europe are shown in Table 2. The European market saw a fall of 14 percent for 1989, to $79 million. This is due to price erosion on the medium-performance products, although unit shipments of lower-performance products are still increasing. Prices are being driven down as other suppliers try to take market share from AMD. AMD has suffered falling revenue, but has been able to slightly increase its market share from 61 percent in 1988, despite the lower unit prices.

TI has managed to match its 1988 revenue by concentrating more on high-performance PLDs with speeds as low as 5ns. Price pressure on the suppliers is much less for high-performance PLDs, and TI's strategy has paid off, as it is the only bipolar PLD supplier not to have shown a reduction in revenue for 1989.

National Semiconductor has suffered the same price erosion that hit AMD and has also been able to compensate with an increase in unit sales. National is just introducing the faster 7ns and 5ns devices, as it attempts to increase PLD revenue from these high-performance PLDs. National also has the Aspect ECL process and is able to supply very fast ECL PLDs with 2ns propagation delays for very high speed applications such as supercomputers. Price pressure for National will be negligible here, as it will have very little competition from the other PLD suppliers in the very high performance segment.

Philips has a proprietary architecture, which is mainly used for internal consumer applications and also has a range of industry-standard programmable array logic (PAL) devices sold in the merchant market. Most of its PLD revenue comes from the sale of these PALs, which are targeted at the higher-performance user. Signetics manufactures PALs, and the company has been weak in Europe. Philips traditionally concentrates on the consumer market, whereas Signetics has targeted the data processing market with these higher-performance devices. Philips has fared worse than the other bipolar PLD suppliers in the fight to gain revenue in a shrinking market because of this mismatch between the different product lines.

Market Trends

Bipolar PLDs are a well-established technology, and revenue will suffer as CMOS PLDs take a larger percentage of the mainstream market. The real benefit in using bipolar for new designs is speed. The introduction of 10ns, 7ns, and now 5ns PLDs provides higher performance that CMOS PLDs cannot yet achieve, and this will stimulate the bipolar PLD market. The suppliers that have been successful have concentrated on this part of the market. CMOS PLDs are now matching the speeds offered by mainstream (25ns) bipolar PLDs, and have lower power. Most sales of bipolar PLDs will come from products already designed in or from the high-speed options offered by the high-performance bipolar PLDs. Good examples are the 386- and 486-based PCs, which use many high-speed bipolar PLDs.

TABLE 2
Estimated European 1989 Bipolar PLD Market Share Rankings

Rank 1988	Rank 1989	Company	Sales ($M) 1988	Sales ($M) 1989	CAGR (%) 1988-1989
1	1	AMD/MMI	56	49	(12)
3	2	Texas Instruments	18	18	0
2	3	Philips	10	6	(40)
4	4	National Semiconductor	7	6	(14)
		Total All Companies Bipolar PLDs	92	79	(14)

NA = Not applicable
Source: Dataquest (October 1990)

CMOS PLDs

Market Shares

CMOS PLDs are the major growth area for PLDs, and 1989 showed 77 percent growth to $46 million. CMOS now accounts for more than one-third of the total PLD market, an increase from 22 percent in 1988. The rankings of the major suppliers of CMOS PLDs in Europe are shown in Table 3.

Much of the European CMOS PLD growth for 1989 came from new CMOS PLD vendors such as Altera, Actel, and Xilinx. Altera has the number one position in European MOS PLDs with $12 million revenue, growing by 71 percent in 1988. Xilinx is ranked at number two with $8 million, up from 1988's figure of $5 million. These are both relatively young companies that have concentrated on a niche product area. Altera has the highest revenue in CMOS because it was the first company into the market with its CMOS PLDs, and it has a much larger installed base of PLD development systems.

New entrants such as Actel are achieving high growth but from a low revenue base. Actel's main objective is to achieve sales of development systems so that it can ship volume silicon to its customers for future designs. Much of the revenue achieved by the new entrants to the CMOS PLD market is from sales of these development systems rather than from sales of the PLDs themselves. This is set to change in 1990, as the growing installed base of development systems starts to mature.

Plessey introduced its electronically reconfigurable array (ERA) late in 1989 and has not recorded significant revenue yet. Although it is too early to gauge market reaction to its product, we expect this business to grow substantially. Plessey has the same challenge as Actel in that the company is fighting to establish an installed base of development systems prior to shipping volume silicon.

Plessey and SGS-Thomson are the only Europe-based suppliers of MOS PLDs, and together they have less than 3 percent of the European market. SGS-Thomson has only recently started shipping PLDs under a second-source agreement with Lattice Semiconductor. Plessey is still mainly shipping development systems. The high market growth rate and its local knowledge of European needs should enable its market penetration to grow in the future, but the company will have to fight hard to gain market share against US vendors.

Market Trends

Much of the MOS PLD growth has come from customers' demand for complex PLDs. These PLDs are addressing the low gate count segment of the gate array market, where designs are digital only and gate counts are less than 3,000 gates. Most suppliers of complex PLDs have products out or soon to be released, with gate counts up to 10,000 gates, and this should put the medium-complexity gate array market under threat. In addition, the clock speeds of typical systems are quite

TABLE 3
Estimated European 1989 MOS PLD Market Share Rankings

Rank 1988	Rank 1989	Company	Sales ($M) 1988	Sales ($M) 1989	CAGR (%) 1988-1989
1	1	Altera	7	12	71
2	2	Xilinx	5	8	60
3	3	Cypress	4	7	75
4	4	Intel	4	7	75
5	5	Lattice Semiconductor	3	4	33
6	6	AMD/MMI	2	3	50
	7	Actel	-	2	NA
7	8	National Semiconductor	1	2	100
	9	SGS-Thomson	-	1	NA
		Total All Companies MOS PLDs	26	46	77

NA = Not applicable
Source: Dataquest (October 1990)

low, well within the capabilities of the 50- to 70-MHz clock rates achieved by complex PLDs. PLD development systems make prototyping fast and easy, and there is no nonrecurring engineering (NRE) charge for PLDs. This cost-effectiveness for low-volume production runs makes the decision to use a gate array for low-volume equipment a difficult one for designers.

One of the key issues with complex PLDs is the number of gates that can be incorporated into the device. Two factors affect this: the total number of gates available in the device and the efficient use of these gates. Early devices had low gate counts, and utilization of these gates was also poor. Typical gate counts were less than 2,000, and the utilization of these gates could be as low as 30 percent. The newer-generation devices have addressed both of these problems, resulting in high gate count devices of up to 10,000 gates and better utilization—up to 90 percent.

ESIS newsletter 1989-29, entitled "European MOS Gate Array and CBIC Design Starts Analysis" showed that 70 percent of gate array design starts in 1989 were 5,000 gates or less. This means the high-density, complex PLDs can now address a large proportion of the digital gate array market because of their ability to incorporate the higher gate counts. Price has now become the deciding factor over whether to use complex PLDs or gate arrays. The less efficient area usage of the complex PLD makes the unit price higher, but for lower volumes, this higher price can be offset against the saving of not having to pay an NRE charge.

DATAQUEST CONCLUSIONS

Clearly, CMOS PLD has become the major driver for growth in the total PLD market. The mainstream bipolar PLDs with propogation delays of 25ns or more are suffering from severe price erosion as vendors try to retain market share. The competition from CMOS PLDs is also becoming significant, but 25ns CMOS PLDs are still priced much higher than their bipolar equivalents. The higher-performance bipolar PLDs still have reasonable margins and provide a niche for PLD suppliers. The development of ECL cores for bipolar PLDs should ensure that the speed for these devices will continue to improve, thus ensuring that high unit prices can be maintained. MOS PLDs are currently the domain of the newer companies such as Altera and Xilinx with their complex PLDs and field programmable gate arrays. Existing bipolar suppliers need to move to MOS to maintain their revenue or concentrate on high-performance PLDs. The European MOS PLD market should overtake the bipolar PLD market in size in 1990 if the trends set in 1989 continue. In 1989, MOS PLDs represented 36 percent of the total market, an increase from 22 percent in 1988.

All of the bipolar suppliers have MOS PLD devices available. Until recently, however, these have all come from other suppliers and are made under license as part of a technology or second-source agreement. AMD was supplying the Logic Cell Array from Xilinx as part of an agreement made in 1985, but has now developed its own CMOS architecture similar to the Lattice Semiconductor GALs and dropped the Xilinx product. National Semiconductor supplies the Lattice Semiconductor GAL architecture, and Texas Instruments has a second-source agreement with Altera for its PLDs. TI also has a technology agreement with Actel for its antifuse prgrammable gate arrays; TI makes these devices for Actel as part of this agreement.

AMD is in the strongest position to dominate the MOS PLD market, despite the lead attained by Altera. AMD will have the greatest installed base of users because of its strength in the bipolar PLD market, and will be able to leverage this position to supply its MOS PLDs. AMD's position is not unassailable, however, and the linkup between TI and Altera will provide tough competition for AMD, mainly because of the strength of Altera's installed base of design systems. The main battle in the market in the short term will be to install a base of development systems, to provide a channel down which future silicon can flow.

The PLD market is dominated by US-based vendors, with Philips, Plessey, and SGS-Thomson the only European suppliers. The European vendors' share of the total European PLD market is 5 percent. This should grow as Plessey and SGS-Thomson establish themselves as PLD suppliers. Entry costs to the complex PLD market are high because most complex PLDs are protected by patent rights. This means that entry must be either by licensing technology from existing suppliers or by independent research and development to create a new architecture. The current suppliers have demonstrated that they are prepared to resort to the courts to protect their technology, so the risks are considerable in developing new architectures and design systems.

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Jerry Banks
Mike Glennon

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Research Newsletter

DATAQUEST SLASHES GATE ARRAY DESIGN START FORECAST

SUMMARY

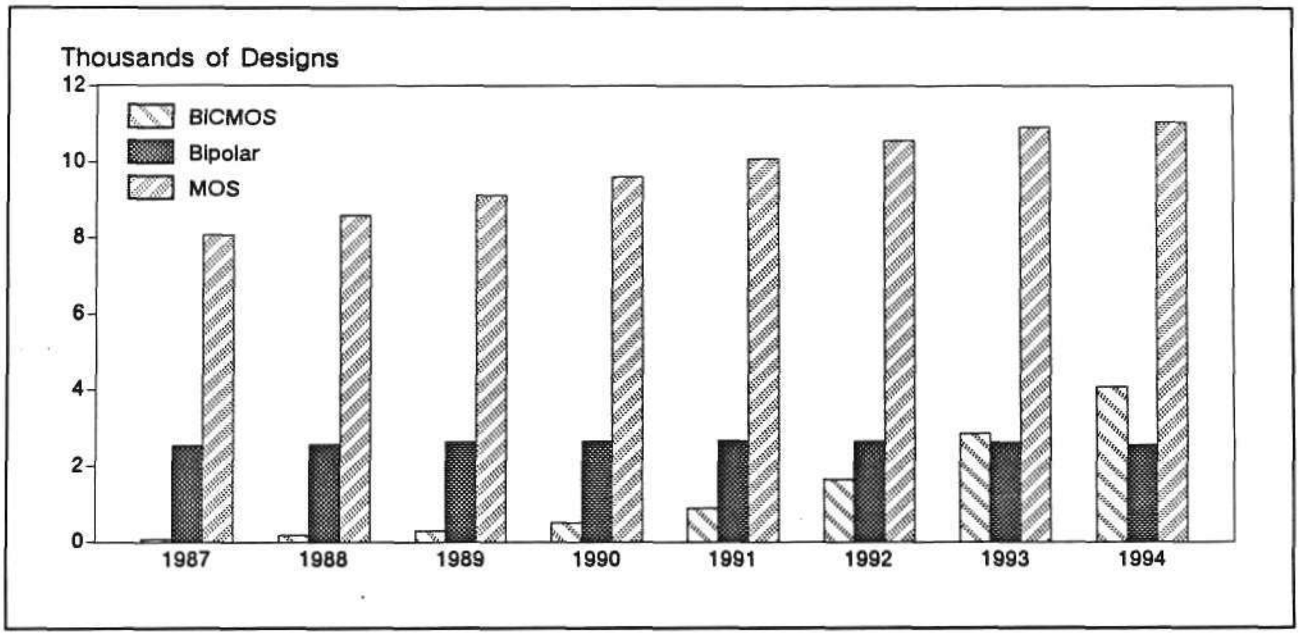
Dataquest has made a major change to its gate array design start forecast: We have decreased the five-year projection by 10,000 designs! After extensive analysis of both gate array suppliers and users, we concluded that there will be far fewer gate array design starts in the future than originally projected, primarily due to increasing chip complexity, field-programmable gate arrays (FPGAs), and chip sets/standard products.

As Figure 1 illustrates, we forecast that MOS gate array designs will have modest growth, bipolar (ECL) will be flat, and the real growth will be in BiCMOS.

INCREASING COMPLEXITY

System designers now are replacing two to three low-complexity gate arrays with one high-complexity array, which is slowing the overall growth of gate array design starts. Although complexity is increasing in all technologies, we will discuss increasing complexity in terms of MOS gate arrays in North America. During 1986, the average number of utilized gates per MOS gate array design was 5,100; in 1987, it was 6,300; in 1988, 7,700; and in 1989, it is estimated to be 9,900.

FIGURE 1
Estimated Worldwide Gate Array Design Starts by Technology



Source: Dataquest (September 1990)

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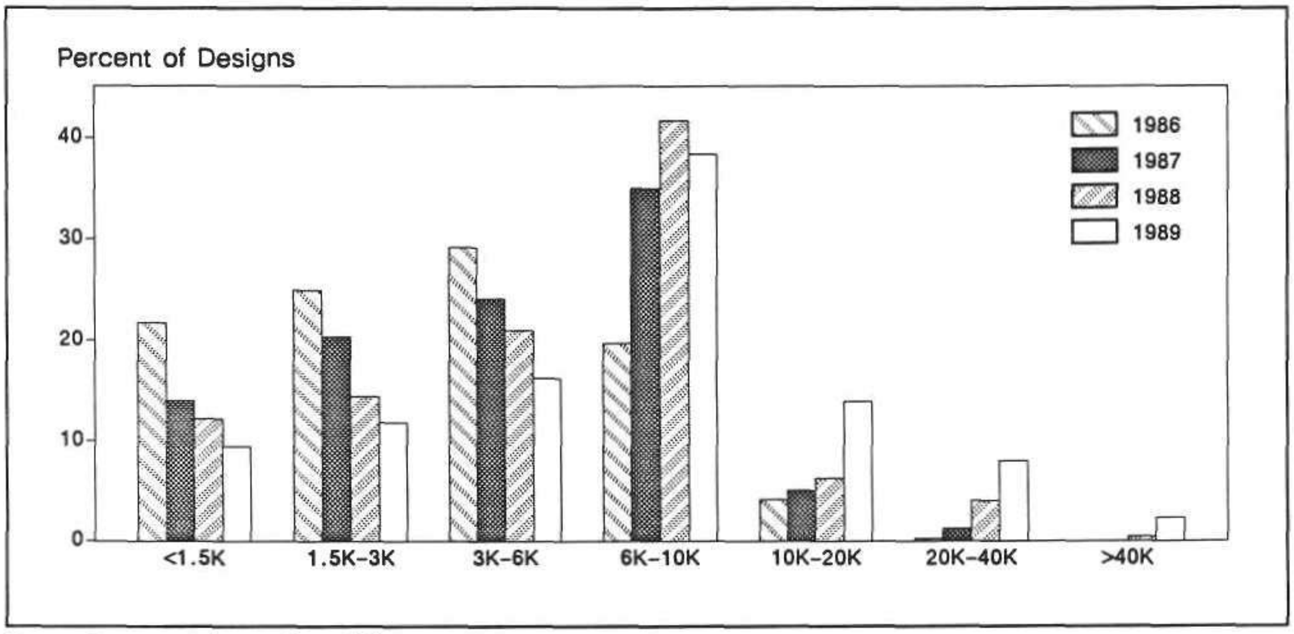
FIGURE 2
Estimated North American MOS Gate Array Design Starts by Gate Count

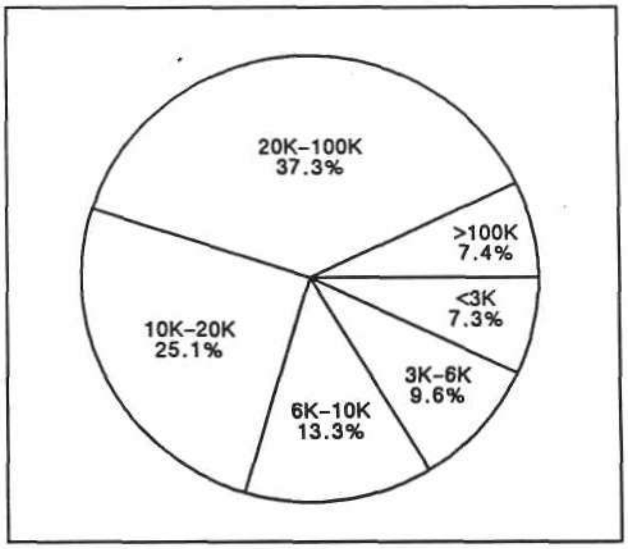


Source: Dataquest (September 1990)

Figure 2 illustrates the percentage of MOS gate array designs captured in North America by utilized gates from 1986 through 1989.

Furthermore, most of the 1992 MOS gate array designs will have 20,000 to 100,000 available gates, as shown in Figure 3. Fujitsu, LSI Logic, Motorola, NEC, Toshiba, and VLSI Technology are some of the leading suppliers of high-complexity arrays.

FIGURE 3
Estimated 1992 North American MOS Gate Array Design Starts by Gate Count (Percentage of Designs)



Source: Dataquest (September 1990)

ENCROACHING TECHNOLOGY

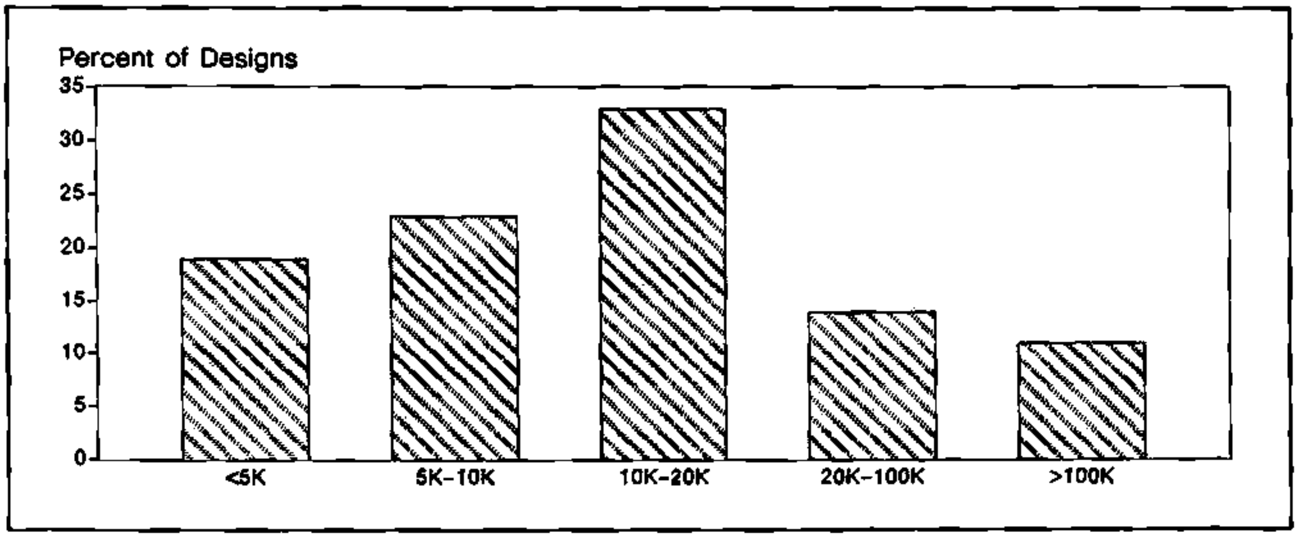
Field-Programmable Gate Arrays

FPGAs also are having an impact on the growth of gate array design starts. FPGAs are affecting low-density/low-volume gate array designs today; they also have the potential to impact medium-density/medium-volume gate array designs in the future.

Dataquest estimates that more than 4,000 cumulative FPGA development systems were installed through mid-1989. If each system was used for only 2 designs a year, that would equal 8,000 FPGA designs total. Most of the FPGA designs that have been captured to date have less than 2,500 gates.

Today, most FPGAs are used for prototyping or for applications that require less than 5,000 units for the life cycle of the design. In the past, gate arrays were used for breadboarding, which tests the logic of the system for problems. System designers now use FPGAs for this application, which saves them both development time and NRE fees.

Figure 4
Estimated 1989 North American MOS Gate Array Units per Design



Source: Dataquest (September 1990)

Table 1
Worldwide Logic Chip Set Forecast (Millions of Units)

	1987	1988	1989	1990	1991	1992	1993	CAGR 1987-1993
DOS PC Shipments	9.6	12.3	13.8	15.4	17.1	18.7	20.6	13.6%
Chip Set Shipments	3.1	8.0	12.7	15.1	16.9	18.5	20.4	36.8%
Saturation	33%	65%	92%	98%	99%	99%	99%	

Source: Dataquest
November 1989

Because the current price per gate for FPGAs is approximately 0.60 to 0.80 cents per gate and a gate array costs approximately 0.15 to 0.20 cents a gate, it is reasonable to assume that most FPGA designs have less than 5,000 units. Gate arrays are not as cost effective in low volumes because the NRE fee is only amortized over a low number of devices.

It is interesting to note that only 18 percent of the 1989 North American gate array design starts in production have unit volumes of less than 5,000 units for the life cycle of the design. If future FPGA pricing falls to less than 0.30 cents per gate during the next two years, FPGAs will affect gate array designs with unit volumes in the 5,000 to 10,000 range, which accounts for an additional 23 percent of the 1989 designs.

Figure 4 illustrates the percentage of 1989 MOS gate array designs in production by unit volumes for the life cycle of the design.

Chip Sets/Standard Products

While FPGAs are attacking low-volume applications, chip sets or standard products are attacking high-volume applications. The personal computer (PC) clone market is a prime example. The goal of a PC clone designer is to make the lowest-cost compatible system. With the use of chip sets and standard products, the system designer can get the same features as in a gate array to make the system compatible without paying the $15,000 to $75,000 NRE fees associated with each gate array.

Dataquest believes that more high-volume gate array applications will be recognized over the next five years and will be lost to chip sets. ASIC suppliers must counter this trend by also offering chip sets and standard products.

Table 1 illustrates the forecast saturation of logic chip sets in personal computers over time.

DATAQUEST CONCLUSIONS

Although Dataquest still believes that gate arrays will remain the dominant ASIC technology over the next decade, we expect overall gate array design start growth to be modest. Key products encroaching on gate arrays include FPGAs, cell-based ICs (CBICs), and chip sets/standard products. Gate array design start growth is slowing not only because of encroaching products but also because of increasing integration per chip.

What does all of this mean for the future ASIC suppliers? They must form close relationships with the end users so they can determine what standard products to offer and what cell libraries to build. We believe that suppliers and users will look toward embedded arrays for increasing integration (i.e., megacells such as RAM and RISC microprocessors embedded in gate array base wafers). BiCMOS will be the new frontier for future ASIC suppliers. Hard times may be ahead for many gate array suppliers as a result of low or negative margins. Service will rise in importance as gate array designs become more scarce.

Bryan Lewis

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Research Newsletter

SUBMICRON PROCESS GEOMETRIES POSE NEW CHALLENGES FOR EDA VENDORS

SUMMARY

For electronic design automation (EDA) tool vendors, providing a full range of ASIC design kits is a key element to winning in the electronic systems design marketplace. It is a competitive weapon. The more ASIC libraries that an EDA vendor supports, the greater the choice of ASIC foundries the EDA vendor can offer its customer base. Indeed, ASIC libraries often are a critical benchmark used by the market when comparing EDA vendors. But as process geometries routinely fall below 1 micron, the support issues become more challenging for both EDA and ASIC vendors. Remaining competitive in the ASIC design market demands that EDA suppliers provide highly accurate models in their submicron ASIC design kits. This newsletter explores the following:

- The number of ASIC libraries supported by EDA vendors
- Third-party ASIC vendor library support
- The impact of submicron process geometries on EDA vendors
- The challenges facing EDA vendors in the ASIC library wars

ASIC DESIGN KIT WARS

Tables 1 and 2 provide a snapshot of the current ASIC library wars. Table 1 summarizes the number of ASIC libraries available to customers that use the EDA tools from these companies.

Table 2 lists the ASIC vendors with libraries supported on EDA tools from Cadence, Dazix, Mentor Graphics, Racal-Redac, Synopsys, Valid Logic, and Viewlogic.

Since the beginning of the ASIC revolution in the early 1980s, much of the success of the leading CAE vendors can be attributed to providing tool suites that support ASIC design for a myriad of ASIC foundries. In fact, this support was the primary force behind the rapid growth of Dazix, Mentor, and Valid in their early days. The EDA systems from these companies became the de facto standards for ASIC design, to the exclusion of most other competitors. Similarly, in the early days ASIC vendors recorded tremendous competitive advantage when they provided the customer with advanced EDA tools developed internally. However, over time, the market trends shifted in favor of standards, open systems, and nonproprietary tools.

The challenge for EDA vendors has always been to entice ASIC manufacturers to support their

TABLE 1
Number of ASIC Libraries Supported

Company	Number of ASIC Libraries
Cadence*	76
Dazix	169
Mentor Graphics*	200
Racal-Redac	53
Synopsys*	53
Valid Logic Systems*	139
Viewlogic Systems	50

*A small fraction of the company's library count is designated as being under development and becoming available during 1990.
Notes: PLD devices not included in these data. Approximately 40 percent of Mentor's library count comprises libraries that the company classifies as "Others." These kits have not been formally submitted to Mentor.
Source: Company Literature, Dataquest (September 1990)

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Table 2
Third-Party ASIC Vendor Library Support

	Cadence*	Dazix	Mentor Graphics*	Racal-Redac	Synopsys*	Valid Logic*	Viewlogic
ABB Hafo		X					
AEG			X				
AMCC	X	X	X			X	
Atmel					X		
AT&T	X		X		X	X	X
Austria Mikro Systeme			X				
California Micro Devices			X				
Custom Silicon			X				
DOD MOSIS					X		
Ericsson Components		X					
ES2			X				
Exar			X				
Fujitsu	X	X	X	X	X	X	X
GigaBit Logic		X	X				
Goldstar		X	X				
Gould Semiconductor		X	X	X		X	X
Harris		X	X	X		X	
Hitachi	X	X	X	X	X	X	X
Honeywell		X					
Hughes			X				
Intel		X	X				
International Microcircuits		X	X				
LSI Logic	X	X	X	X	X	X	X
Marconi Electronic Devices		X	X				
Matra Harris		X	X			X	
Micro Linear		X					X
Mietec		X					
Mikron			X				
Mitsubishi	X	X	X		X	X	X
Motorola	X	X	X	X	X	X	
National Semiconductor	X	X	X	X	X	X	X
NCR	X	X	X	X	X	X	X

(Continued)

TABLE 2 (Continued)
Third-Party ASIC Vendor Library Support

	Cadence*	Dazix	Mentor Graphics*	Racal-Redac	Synopsys*	Valid Logic*	Viewlogic
NEC	X	X	X	X	X	X	X
Oki Semiconductor	X	X	X	X	X	X	X
Panasonic		X	X				
Philips/Signetics			X	X	X	X	
Plessey		X	X			X	X
Qudos			X				
Raytheon Semiconductor			X				
Ricoh		X	X				
Rockwell			X				
Samsung		X	X		X		X
Sanyo		X					
Seiko Epson/SMOS	X	X			X	X	X
SGS-Thomson	X	X	X	X	X	X	X
Siemens	X	X	X		X	X	
Sierra Semiconductor		X	X				
Silicon Systems			X				
Sipex		X					
Sony		X	X				
Standard Microsystems (SMC)		X		X			X
Texas Instruments	X	X	X	X	X	X	
Toshiba	X	X	X	X	X	X	X
TriQuint Semiconductor		X	X				
United Microelectronics Corp.		X					
United Silicon Structures (US2)			X				
USC/Information Sciences Institute			X				
UTMC	X	X	X		X	X	
Vertex Semiconductors			X		X		
Vitesse	X	X	X		X	X	
VLSI Technology	X	X	X	X	X	X	X
VTC			X				

*A small fraction of the company's library count is designated as being under development and will become available during 1990.
Notes: PLD devices are not included in these data. Approximately 40 percent of Mentor's library count comprises libraries that the company classifies as "Others." These kits have not been formally submitted to Mentor.
Source: Company Literature, Dataquest (September 1990)

tools (e.g., porting the library to the EDA vendor's design entry system and simulator and updating the software when either the fabrication process changes or the EDA tools change). But ASIC manufacturers will support only those third-party EDA vendor tools that either have gained acceptance in the marketplace or show tremendous promise toward gaining such acceptance. In short, ASIC vendors view merchant EDA tools as vehicles for leveraging and selling their silicon to the marketplace. EDA vendors, on the other hand, view ASIC libraries as value-added technology for their EDA product line, to be used as leverage in the sale of their EDA tools. In the absence of ASIC vendor support, EDA vendors are forced to absorb the development and support costs associated with offering ASIC libraries.

Although developing ASIC design kits has not required much technological innovation, it nonetheless demands attention to detail and continuous maintenance by trained engineers. Thus, for both EDA tool suppliers and ASIC vendors, the issue over whether or not to support each other's tools and processes, respectively, depends on the development and support costs versus the return on investment. In the past, the data needed to develop an ASIC library have been modest. Moreover, third-party models have not had to match the ASIC's characteristics perfectly because enough margin existed within the ASIC's timing performance to rely on good approximations of parameters. For example, piecewise linear modeling could be used to approximate the timing delays across a broad fanout range. (Of course, the ASIC foundry's internal verification tools and models, which are used to simulate a design just prior to layout, exactly match the characteristics of the devices produced by the fabrication process.)

Yet as fabrication process geometries shrink to the submicron range, what once were insignificant delays that could be ignored by third-party models become critical. Examples of parameters that potentially have a far greater impact on the design of submicron ASICs include fanout loading, slew rate, and pin-to-pin interconnect delays. In order for designers to be able to rely on ASIC design kits, the models must closely mimic characteristics of the electronic devices being produced by the fabrication process.

DATAQUEST CONCLUSIONS

Dataquest believes that a major challenge for EDA vendors over the next two years will be to provide simulation and modeling technology that enables ASIC manufacturers to easily incorporate process-specific information into the simulation models. EDA vendors also must be mindful of the fact that although ASIC vendors will clearly gravitate toward supporting the most popular third-party EDA systems, they also will favor porting their libraries first to those popular EDA systems that require the least effort. For EDA vendors, being among the first to offer a particular ASIC library can yield a significant competitive edge.

ASIC vendors that market proprietary tool sets may be tempted to delay offering updated simulation models to third-party EDA suppliers in an effort to promote their own tool sales. However, such a strategy would be shortsighted. Dataquest believes that, in the long term, it would behoove ASIC vendors to support third-party EDA suppliers with updated libraries as soon as they become available. As ASIC densities increase, the ability of ASIC vendors to develop and support leading-edge tools becomes increasingly difficult. Instead of devoting massive resources to such development in the face of focused third-party EDA suppliers, ASIC vendors are likely to realize greater success if they concentrate on more specialized software tools that continue to provide value-added benefits that are unavailable through other sources.

Patricia Galligan
Ron Collett

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Research Newsletter

EMBEDDED GATE ARRAYS: THE BEST OF BOTH WORLDS

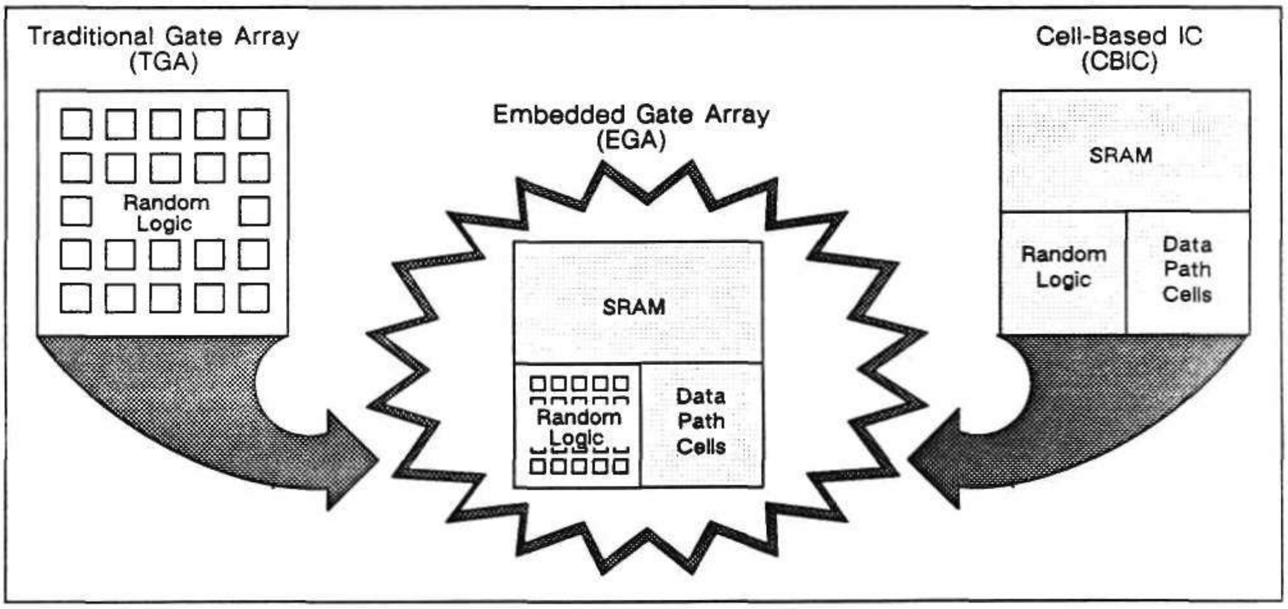
SUMMARY

In 1985, ASIC visionary and president of LSI Logic Wilf Corrigan stated, "We will make available several exciting new ASIC offerings in 1985, including structured arrays. Structured arrays are application-specific integrated circuits with metal-configurable memory and large dedicated building blocks called 'megacells' added to a logic array." The product was five years ahead of its time.

Today, ASIC suppliers throughout the world are developing and introducing the same concept with new technology and a new name—it is now called an "embedded gate array" (EGA). EGAs incorporate the best features of both traditional gate arrays (TGAs) and cell-based ICs (CBICs). EGAs offer reduced risk and turnaround time associated with gate arrays along with increased functionality and performance associated with CBICs.

Figure 1 illustrates the EGA concept. EGAs are a crossbreed of a gate array and a CBIC. Large, compact functional blocks such as SRAMs and data path elements (i.e., ALUs, multipliers, barrel shifters, etc.) can be embedded in the base wafer of

FIGURE 1
Embedded Gate Array—The New ASIC Crossbreed



Source: Dataquest (October 1990)

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TABLE 1
Worldwide MOS Gate Array Ranking versus Leading Products

1989 Rank	Company	Process (Drawn)	Maximum Gates (Gross)	Metal	Maximum Gates (Usable)	Embedded Cells
1	LSI Logic	1.0	250K	2	100K	Yes
2	NEC	1.0	178K	3	88K	Yes
3	Toshiba	1.0	172K	3	100K	?
4	Fujitsu	0.8	160K	3	80K	?
5	Hitachi	0.8	250K	3	100K	?
6	Oki	0.8	231K	2	100K	Yes
7	Seiko	0.8	255K	2	102K	?
8	National	1.0	250K	3	125K	?
9	Matsushita	1.2	35K	2	30K	?
10	VLSI Tech.	1.0	172K	2	69K	?
—	IBM	0.8	300K	4	270K	Yes

Source: Dataquest (October 1990)

a gate array; then control logic, for example, can be added to it by configuring random logic with the final layers of interconnect. Dataquest classifies EGAs under the gate array category because the random logic portion of EGAs is customized with the final layers of interconnect.

POTENTIAL SUPPLIERS

Dataquest believes that by the end of the decade, most of the gate array suppliers, as well as a healthy portion of the CBIC suppliers, will offer some form of EGA product. Today, the top two worldwide merchant MOS gate array suppliers, LSI Logic and NEC, are actively marketing EGAs. IBM, the world's largest captive gate array supplier, also has announced EGA capabilities.

Table 1 contrasts the top ten worldwide MOS gate array suppliers and their respective products. We believe that most of the suppliers with question marks in the embedded cell column have programs in the development stage.

INCREASING COMPLEXITY AND FUNCTIONALITY

The days when gate arrays were only used to sweep up glue logic (standard logic) are gone. Gate arrays are playing a more significant role in system designs with multiple functional blocks now being integrated on-chip. Past gate array research has shown that the average gate array complexity is increasing at a higher rate every year. During 1986, the average number of utilized gates per MOS gate array design in North America was 5,100; in 1987, it was 6,300; in 1988, 7,700; and in 1989, it was estimated at 9,700.

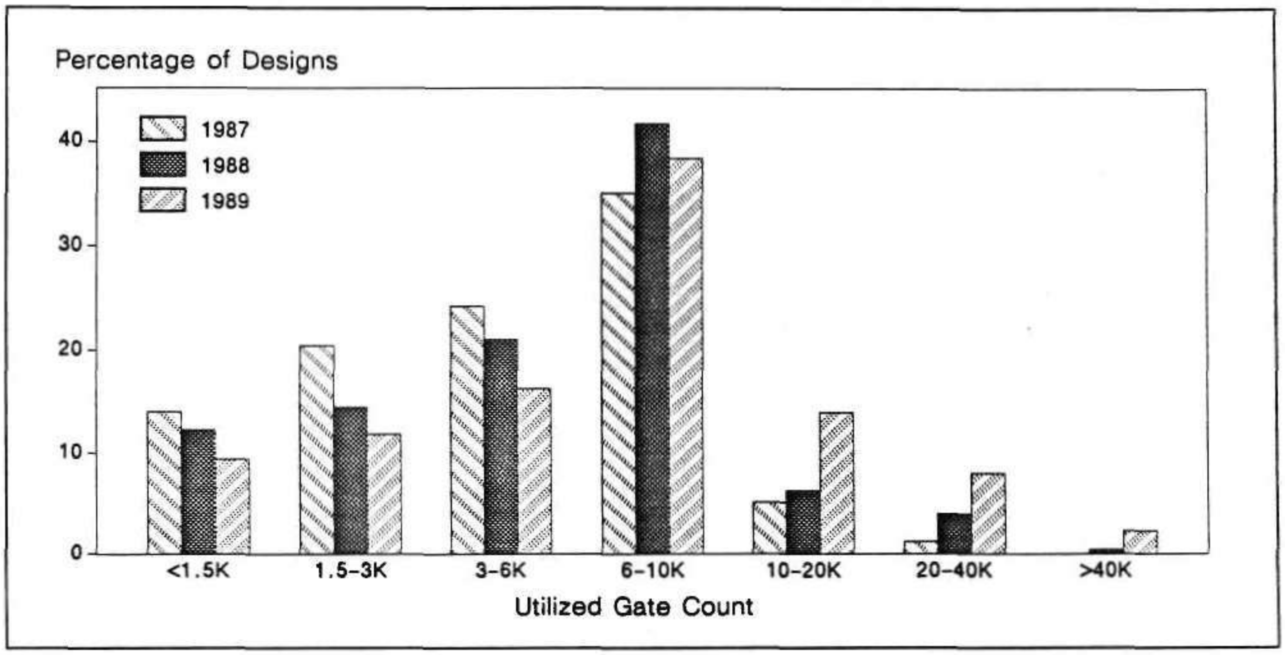
Figure 2 illustrates how gate array complexity is increasing over time.

As complexities rise, it becomes more important to work on the functional block level rather than on a gate level. System designers now partition their systems in functional blocks that can then be combined and implemented with ASICs.

Initial findings from two major ongoing Dataquest studies on gate arrays and CBICs are incorporated in Figure 3. The figure illustrates the preliminary relative percentage of CBIC and gate array designs that had on-chip RAM, microperipherals, and analog.

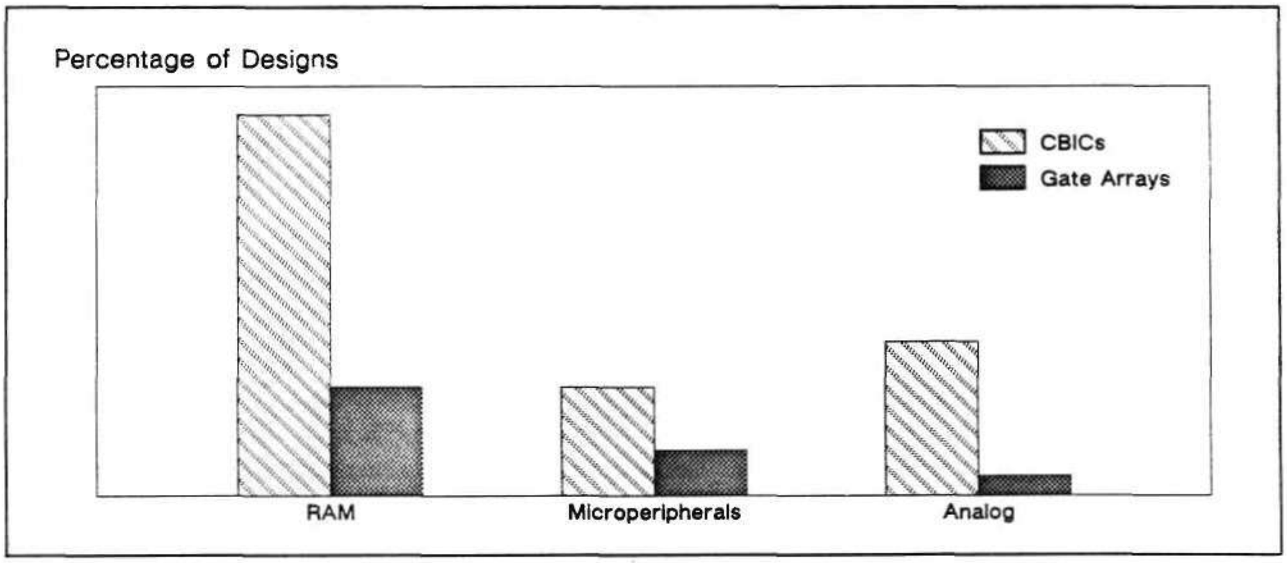
As Figure 3 shows, RAM is a key function block being incorporated in ASIC designs. CBICs traditionally have been the ASIC product of choice for implementing RAM because it was a more efficient implementation. Our studies show that an SRAM block implemented in a CBIC can be two

FIGURE 2
Estimated North American MOS Gate Design Starts by Utilized Gate Count



Source: Dataquest (October 1990)

FIGURE 3
Estimated 1990 North American ASIC On-Chip Functions



Source: Dataquest (October 1990)

TABLE 2
ASIC Feature Trade-Off Matrix

Feature	Traditional Gate Array	Embedded Gate Array	CBIC
Memory Efficiency	Low	High	High
Die Size	Large	Medium	Small
Device Cost	Highest	Low	Lowest
NRE Cost	Low	High	High
Retooling Cost	Low	Low	High
Retooling Time	Short	Short	Long
Performance	Medium	Medium-High	High
Risk	Lowest	Low	Highest

Source: Dataquest (October 1990)

to three times denser than the same function done with random logic gates in a TGA. However, if this same SRAM were implemented in the base wafer of an embedded gate array, it would be just as dense as the CBIC solution. Our research indicates that as a general rule of thumb, most large functional blocks in an EGA or CBIC are, on average, at least 20 percent denser and achieve an increase in performance of least 10 to 15 percent over a TGA.

ASIC COMPARISON

Table 2 shows the ASIC feature trade-off matrix.

As previously mentioned, EGAs and CBICs are the most efficient products for implementing memory and other large functional blocks. EGAs still retain a portion of the chip available for random logic gates, so the die size and device cost will not be quite as good as with CBICs but far better than with TGAs.

Although the first EGA NRE charge is the same as for a CBIC, the big savings occur when the design is retooled. Most gate array designs are retooled two to three times because they do not meet the system requirements. With an EGA, only the random logic will need to be reconfigured with the final layers of interconnect; therefore, the retooling turnaround time and cost are far less than for a CBIC. With this reduced turnaround time and cost comes EGA's reduced risk.

DATAQUEST CONCLUSIONS

Dataquest believes that EGAs will have a major impact on the ASIC market. We believe that the CBIC market will be the hardest hit because of the fact that EGAs will increasingly be able to match the functionality and performance of CBICs with reduced cost and risk.

Furthermore, we believe that there will be four initial waves of types of cells that will be embedded in base wafers of EGAs. The first wave will be memory, followed by data path, microperipherals, and analog. SRAMs will go on-chip first for quick caching. Data path cells such as ALUs, multipliers, and barrel shifters then will be embedded to increase performance and save chip real estate. Analog will be the last to come on-chip because it will be harder to test; also, there are fewer suppliers with analog cells and analog expertise.

What does all of this mean for ASIC users and suppliers? ASIC users should be evaluating their suppliers for their embedded cell capabilities. The depth, breadth, and performance of cell libraries is critical. Embedded RAM cells are a given; data path, microperipherals, and analog cells will be good measurements of supplier commitment. Suppliers should be making major investments in this technology now, or they will be left behind.

Bryan Lewis

Dataquest
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Research *Bulletin*

SYNOPSYS AND SIEMENS EXPAND THEIR EDA OFFERINGS WHILE HP CONTRACTS

SUMMARY

Merger and acquisition activity, which has been the hallmark of the electronic design automation (EDA) industry over the past few years, appears to continue apace as evidenced by the latest developments. Synopsys Inc. recently agreed to acquire Zycad's VHDL software simulation business, and Siemens announced its purchase of Calay Systems GmbH. Under terms of the agreement between Synopsys and Zycad, Synopsys will pay $5 million in cash, an undisclosed amount in Synopsys securities, and future royalties for full rights to Zycad's System VHDL. Siemens has disclosed plans to form a new EDA business unit by combining its in-house CAD capability with the PCB layout expertise of Calay Systems.

Meanwhile, Hewlett-Packard has decided to phase out development of the company's proprietary EDA software. Over the next two years, HP's Electronic Design Division (EDD) will make the transition away from its proprietary EDA software, but HP will continue to support the EDD products for five years thereafter.

DATAQUEST ANALYSIS

One of the clear implications arising from the merger and acquisition activity over the past few years is that the EDA market of the 1990s will be quite different from that of the 1980s. Success in the early 1990s demands that vendors provide open systems and support standards. The myriad of standards that vendors will be forced to support continued to grow in 1989, with VHDL topping the list.

Synopsys' acquisition clearly is part of the company's strategy to establish a strong foothold in the emerging VHDL-based top-down design market. Indeed, Dataquest believes that the acquisition marks a turning point in Synopsys' evolution where "Synopsys the synthesis company" is now "Synopsys the CAE company." Synopsys, which specializes in logic synthesis tools, experienced tremendous growth in 1989, with company revenue reaching approximately $10 million. The company expects to record revenue of between $20 million and $30 million in 1990. Although not immediately imminent, the company is likely to attempt further expansion into the broader EDA market if it successfully penetrates the simulation market.

Synopsys maintains that the company's commitment to being an integratable technology with a range of CAE vendors will not be adversely impacted by this deal. Zycad assessed its stance vis-à-vis the sale as a move that will allow the company to concentrate on its core hardware accelerator business. Also, the financial compensation received for the business presumably represents a welcome infusion of cash.

Meanwhile in West Germany, Siemens apparently took aim at the US-dominated EDA industry. According to Dataquest's market share estimates, Calay Systems' PCB layout software revenue of $14.2 million in 1989 made it the seventh largest company in its field, with its competition coming from such major EDA vendors as Mentor Graphics, Racal-Redac, and Valid Logic. If Siemens plans to set itself up as a major European full-line EDA supplier, it faces several major challenges, including the development of framework technology, further expansion of its product portfolio, and establishment of a robust EDA distribution channel. It also must position itself more aggressively as an EDA supplier in the marketplace.

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HP rationalized its move by citing the momentum of the open systems movement in the industry, as well as the company's belief that this decision will allow it to focus on its workstation and mechanical CAD businesses. Dataquest believes that the company questioned a strategy of continuing to commit the substantial R&D resources needed to maintain a competitive and viable product in the EDA marketplace. In 1987, 1988, and 1989, HP's EDA software revenue remained constant at approximately $20 million, but its market share dropped from 2.6 percent to 1.8 percent during this time period. Furthermore, the company may have recognized an inherent conflict between its workstation business and its tools business. The company's orderly retreat from the EDA application software market provides its strong Japanese client base (approximately 1,000 licenses) with adequate notice to migrate smoothly from HP's EDA products to those of other vendors. It appears unlikely at this point that HP would sell the EDD unit to another EDA vendor.

Table 1
EDA Industry Concentration

Year	Market Share
1986	50.0 percent
1987	50.0 percent
1988	55.2 percent
1989	60.9 percent

Source: Dataquest (September 1990)

DATAQUEST CONCLUSIONS

Dataquest believes that the recent events in the EDA industry exemplify the continuing turmoil and volatility in the EDA industry. Table 1 shows the market share captured by the top ten EDA vendors over the past four years.

The consolidation and shakeout that has been occurring this year is likely to further increase the industry's concentration.

Patricia Galligan
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Research Newsletter

DESIGNING FOR DOLLARS: WIN WITH FPGAs

OVERVIEW

With the introduction of high-density devices, Dataquest expects manufacturers of field programmable gate arrays (FPGAs) to challenge low-density masked gate array suppliers for design starts. Just as gate arrays have affected the market for custom ASICs, FPGAs currently are impacting the gate array market at the lower densities. Dataquest believes that an FPGA product with a 6,000-gate density should allow the ASIC manufacturer to address one-half of today's worldwide MOS gate array design starts.

Although FPGAs now can compete with masked gate arrays on the basis of density, they are far from being price competitive with their gate array counterparts. However, FPGA solutions do offer systems manufacturers the benefit of faster time to market than a gate array solution. In the context of a system life cycle, this time-to-market advantage should translate into a healthy increase in profitability for systems suppliers. Dataquest believes that the choice of an FPGA solution may, in fact, increase margin dollars by more than 25 percent over those attainable with a masked gate array solution.

ASSUMPTIONS

Our analysis of the time-to-market advantage attained through the use of FPGAs is based on a number of assumptions, as summarized in Table 1. First, we assume a system product lifetime of 12 months and a system cost of $1,200 for the product utilizing the gate array solution. In addition, we assume a selling price of $2,000 (at introduction) for the complete system and a fixed quantity of 5,000 units sold per month for each logic array solution. Also, we assume a time-to-market advantage of 3.3 months for the FPGA over a masked gate array. This final assumption is based on the fact that a gate array will take 3.3 months to reach production status once final design is completed, compared with immediate production of the FPGA. Dataquest considers 3.3 months the best-case scenario for gate array production, based on fully functional first silicon.

Our example is based on an ASIC requirement of 6,000 gates and a volume of 5,000 units per month. We assume a price of $6 for a 6,000-gate masked gate array. The price for a 6,000-gate FPGA is assumed to be $60. Because of the price difference between the solutions, the cost of the system using an FPGA solution will be $1,254. A final assumption is that systems vendors using gate array solutions capture a 40 percent margin at the time of product introduction, declining linearly to 20 percent by the end of the twelfth month. The price level, then, drops from $2,000 at product introduction to $1,500 at the end of the product's life.

THE MODEL

Figure 1 illustrates the margin dollars available in the lifetime of a typical system product in a competitive market. The straight line plots margin dollars per month with respect to time. In this model, the product is introduced at month 0, where the margin is at its maximum level. Assuming a constant rate of monthly unit sales, margin dollars per month will decline throughout the product's life until, at month 12, the product is discontinued.

Figure 2 compares the margin dollars earned by a system product with a gate array solution with a system product using an FPGA solution. If we begin with a 12-month product lifetime, the use of an FPGA solution gives us an early introduction by 3.3 months. Effectively, then, FPGA use allows us to shift the Y axis of Figure 1 to the left by

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TABLE 1
Assumptions for FPGA Time-to-Market Model

Logic Array Density	6,000 gates
Monthly System Shipments	5,000 units
Market Window	12.0 months
Gate Array Solution	
Time to Market	3.3 months
System Life Cycle	12.0 months
System Cost without Array	$1,194
Gate Array ASP (Includes NRE)	$6
Total System Cost	$1,200
At System Introduction	
Margin per System ($)	800
Margin per System (%)	40
At System Life End	
Margin per System ($)	300
Margin per System (%)	20
FPGA Solution	
Time to Market	0 months
System Life Cycle	15.3 months
System Cost without Array	$1,194
FPGA ASP	$60
Total System Cost	$1,254
At System Introduction	
Margin per System ($)	746
Margin per System (%)	37.3
At System Life End	
Margin per System ($)	246
Margin per System (%)	16.4

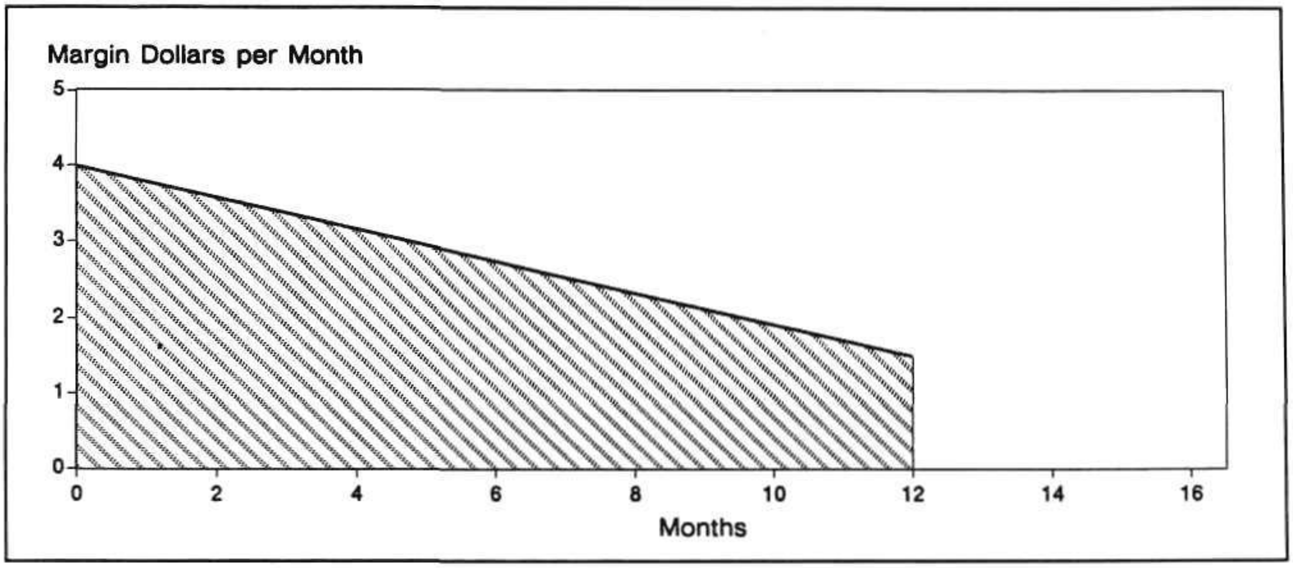
Source: Dataquest (September 1990)

3.3 months. So, the system utilizing the FPGA solution is introduced at month 0, while that using the masked gate array solution enters the market at month 3.3. Each product is discontinued at month 15.3.

Because the FPGA-based product is introduced 3.3 months ahead of the rest of the market, the manufacturer of this system may be able to hold prices and margins high prior to the introduction of competitive products (shown by the horizontal segment of the line). As the second manufacturer, using the gate array solution, enters the market, however, the margins for each manufacturer begin to decline and continue to decline throughout the life of the product.

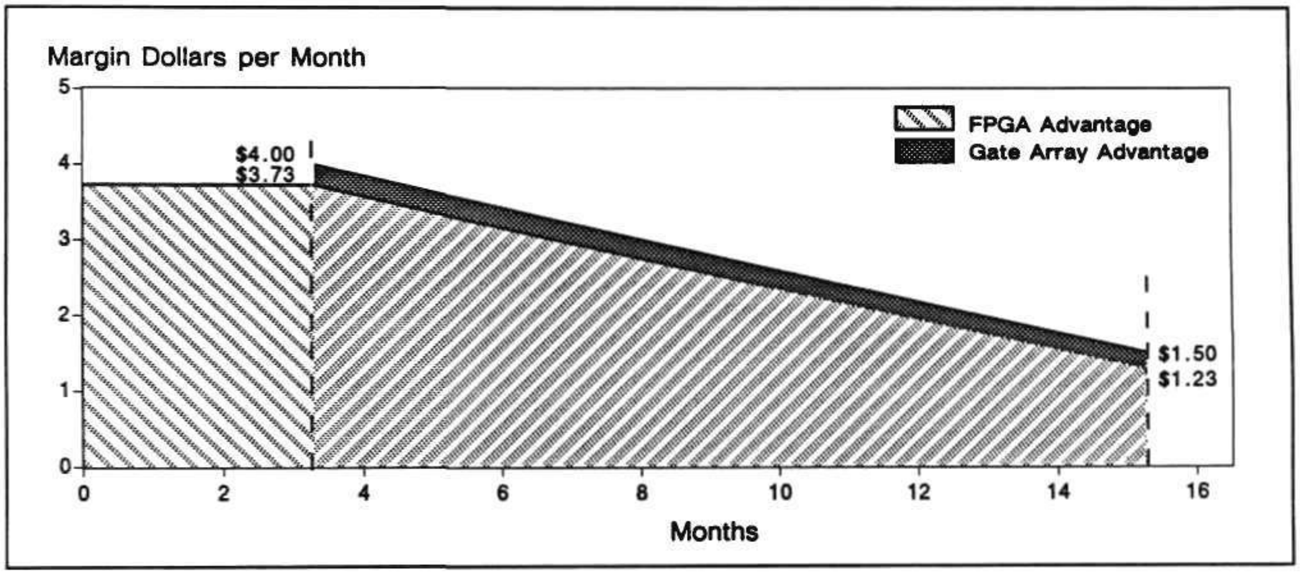
The line representing the margin dollars of the gate array solution is higher than that of the FPGA solution, because of the lower cost per unit of the system with the gate array solution. So, the area between the two lines represents an advantage in margin dollars of the gate array solution over the FPGA solution. However, because the system with the gate array solution is not introduced until month 3.3, the FPGA solution captures high margin dollars for a full 3.3 months before the second product is introduced.

FIGURE 1
Margin Dollars Earned—Typical System Product



Source: Dataquest (September 1990)

FIGURE 2
Margin Dollars Earned—FPGA Compared with Gate Array Solution (Millions of Dollars)



Source: Dataquest (September 1990)

It is easy to see from the graph that the FPGA solution captures more margin dollars than the gate array solution. This time-to-market advantage can be evaluated quantitatively by computing the area under each line. The area under the FPGA line equals $42.1 million, while the area under the gate array line equals $33.0 million. This calculation shows that the product with the FPGA solution has a $9.1 million advantage, in terms of margin dollars, over the system with the gate array solution.

DATAQUEST ANALYSIS

The results of our model show that a time-to-market advantage may offer significant benefits to systems manufacturers. A 27.5 percent increase in total margin dollars was realized over the lifetime of the system product used in our model.

The FPGA lead-time advantage is absolutely dependent on the production lead time for the gate array. For our example, we chose a conservative product lead time, assuming working first silicon in the gate array production. In reality, this period could be much longer than the 3.3 months we used for the purposes of our model. The manufacturer that achieves early introduction can expect to earn high margins throughout the early introduction period and thus earn more margin dollars over the lifetime of the product than can other manufacturers.

A number of other benefits existing outside the framework of this model could provide further advantages to users of FPGAs. For example, early introduction could result in a market leadership position in terms of market share, which translates into higher unit sales for the vendor that uses an FPGA solution, thus leading to an even greater advantage in margin dollars. In addition, a manufacturer able to gain a time-to-market advantage in several generations of systems will be in position to gain high margins at the beginning of a product life cycle and then exit to a new product with higher margins as the margins in the first generation deteriorate.

Obviously, there are many possible scenarios with differing margin levels, product lifetimes, and early introduction periods. The values we chose for these factors are ones that Dataquest believes to be quite typical in the current industry environment. We believe that this model provides a useful framework for the evaluation of the FPGA alternative.

DATAQUEST CONCLUSIONS

Dataquest expects FPGAs to increasingly challenge masked gate arrays for design starts as FPGA products continue to increase in density. Despite the large cost differential between FPGA and gate array solutions, FPGAs may offer substantial returns because of the inherent time-to-market advantage of these products. We have shown that this advantage can be quite attractive to the system manufacturer. As system designers begin to explore the FPGA solution more thoroughly, Dataquest expects more semiconductor vendors to address this growing market, which currently is dominated by two players, Actel and Xilinx.

To our systems clients, we recommend evaluating the use of FPGAs in systems products, especially where time to market is a crucial issue. To our semiconductor clients, Dataquest recommends a hard look at this rapidly growing market segment.

Phil Mosakowski
Jerry Banks

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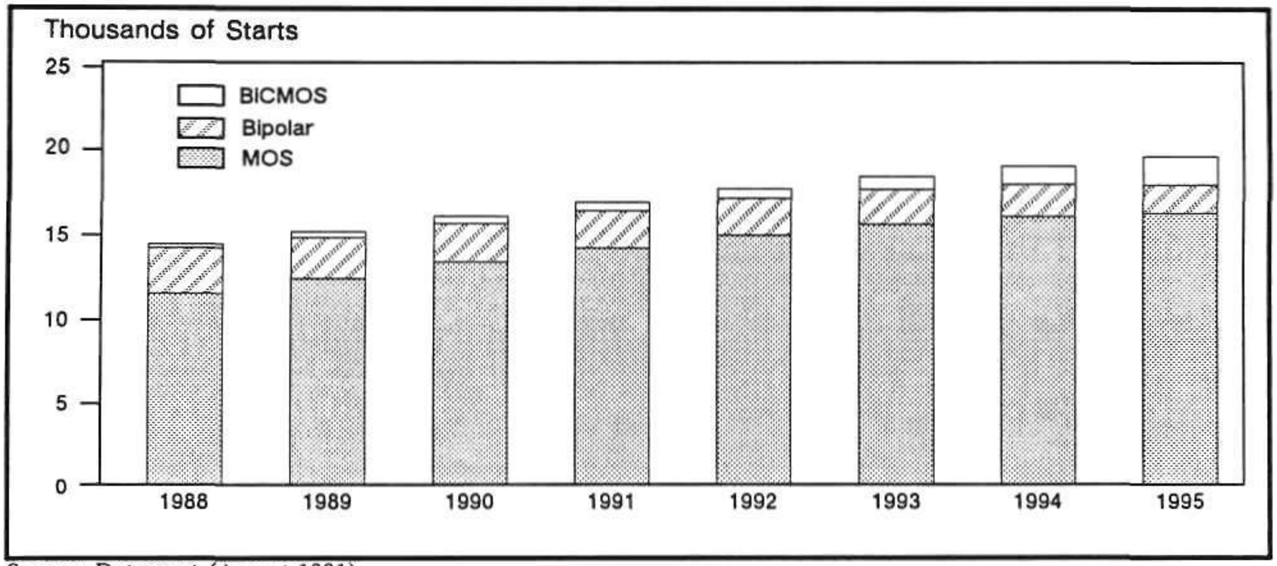
Research Newsletter

SEARCHING FOR ADDED-VALUE OPPORTUNITY AS ASIC MARKET DYNAMICS SHIFT

The ASIC market has begun to stall. Primary indicators of the ASIC business are profitability and design starts—both are slowing (see Figure 1). The ASIC market appears to be going through a stage of metamorphosis. Dataquest believes that the market is waiting for ASIC vendors to transform from chip suppliers to what we call "system solution" suppliers. Becoming a system solution supplier demands that chip vendors be capable of delivering (but not necessarily creating) a more diversified portfolio of products and services to the customer. In short, ASIC suppliers of the future must share in the burden of the entire system development.

To meet this challenge, it will be crucial for ASIC suppliers to gain a far better understanding of the system manufacturers' complete design requirements. These include design flow, functional elements of the system, interaction among functional elements, system interconnect requirements and constraints, system packaging, and system testing. The days when ASIC suppliers could simply maintain an arm's length relationship with the system design market are finished. ASIC suppliers must add value on the system level if they are to be profitable in the future. To do so, they must put in place organizations that can quickly respond to the changing dynamics of the electronic design market.

FIGURE 1
Estimated Worldwide Gate Array and CBIC Design Starts by Technology



Source: Dataquest (August 1991)

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SIS Newsletters 1991 ASIC

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This newsletter examines the following:

- ASIC design start activity
- Future impact of ASSPs and FPGAs on the ASIC business
- Future directions ASIC suppliers should take

WHERE HAVE ALL THE DESIGN STARTS GONE?

Today, profit margins are razor thin for low-complexity ASICs because of the vast number of suppliers and the continuous encroachment of substitute products, namely, field-programmable gate arrays (FPGAs) and application-specific standard products (ASSPs) or chip sets. Not only have these products impacted profit margins, they have also worked to slow the ASIC design start growth. Dataquest's preliminary estimates show that there were over of 20,000 FPGA designs captured during 1990 compared with only 16,000 total gate array and CBIC designs. The FPGA market alone grew 92 percent from $61 million during 1989 to $117 million in 1990. Logic and graphic chip sets combined have reached an astounding $1 billion in just five years. These products have and will continue to impact the ASIC market.

Increasing chip density is another source acting to slow design start activity. For example, five 20,000-gate chips are rapidly becoming one 100,000-gate chip. Thus, five design starts are becoming one.

Figure 1 illustrates the projected growth of worldwide gate array and CBIC design starts.

DESIGN STARTS BY TECHNOLOGY, REGION, AND PRODUCT

The growth in design starts varies by process technology, by region of the world, and by product.

Figure 1 shows that bipolar design starts will continue to decline, CMOS design start growth is flattening out, and BiCMOS designs are growing, with strong growth expected in the mid- to late 1990s.

Although design start activity throughout the world is slowing, Japan has the highest growth rate followed by Rest of World countries, Europe, and North America, which has close to flat growth. FPGAs and chip sets are having the most pervasive impact on ASIC design starts in North America, hence the low growth rate.

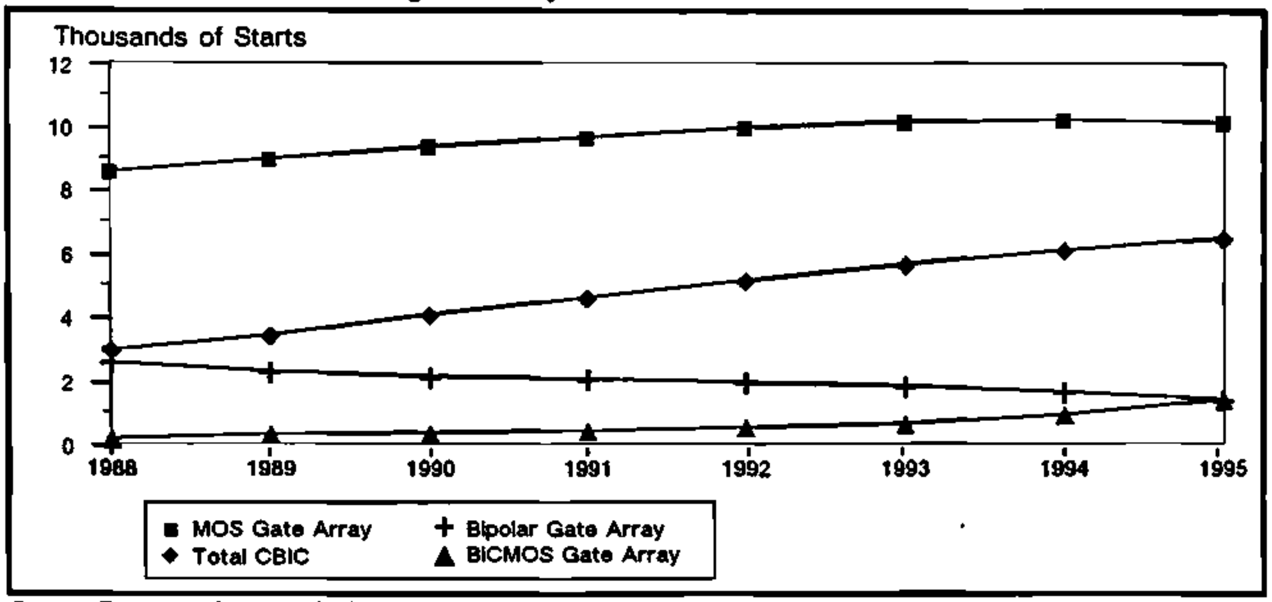
Figure 2 illustrates gate array and CBIC design starts. Table 1 shows Dataquest's worldwide design start forecast by technology and product.

Assumptions

Key assumptions incorporated in the design start forecast include the following:

- A design start is counted when a prototype is delivered. On average, approximately 50 percent of the designs go to volume production.
- Captive design activity from pure captives that do not sell ASICs to the merchant market (e.g., IBM, DEC, and Unisys) are excluded from this forecast (Dataquest estimates the total 1990 captive ASIC designs to be 2,000 to 3,000).
- Bipolar design start growth (ECL) will continue declining because of its high cost and high power consumption and will be replaced by BiCMOS, CMOS, and GaAs ASICs.
- BiCMOS growth will increase in the mid- to late 1990s as large, vertically integrated semiconductor manufacturers such as Fujitsu, NEC, and AT&T begin incorporating them into their system products, which, in turn, will drive the product down the price learning curve.
- ASIC chip density will rise at an increasing rate because of increasing on-chip functions such as SRAM and the increasing reuse of soft megacells based on hardware description languages (HDLs) such as Verilog HDL and VHDL.
- Embedded gate arrays (i.e., megacells such as static SRAM that are diffused in the array base wafer) are included in the gate array category and are expected to experience a high growth rate by the mid-1990s.
- CBIC design start growth will be higher than gate array growth over the next few years because of increasing demand for CBICs in telecom, mixed-analog/digital devices, high-performance circuits, and high-volume applications.
- FPGAs and ASSPs will continue to experience rapid proliferation and will further reduce the growth of gate array and CBIC design starts.

Figure 2
Estimated Worldwide ASIC Design Starts by Product



Source: Dataquest (August 1991)

Table 1
Estimated Worldwide Gate Array and CBIC Design Starts

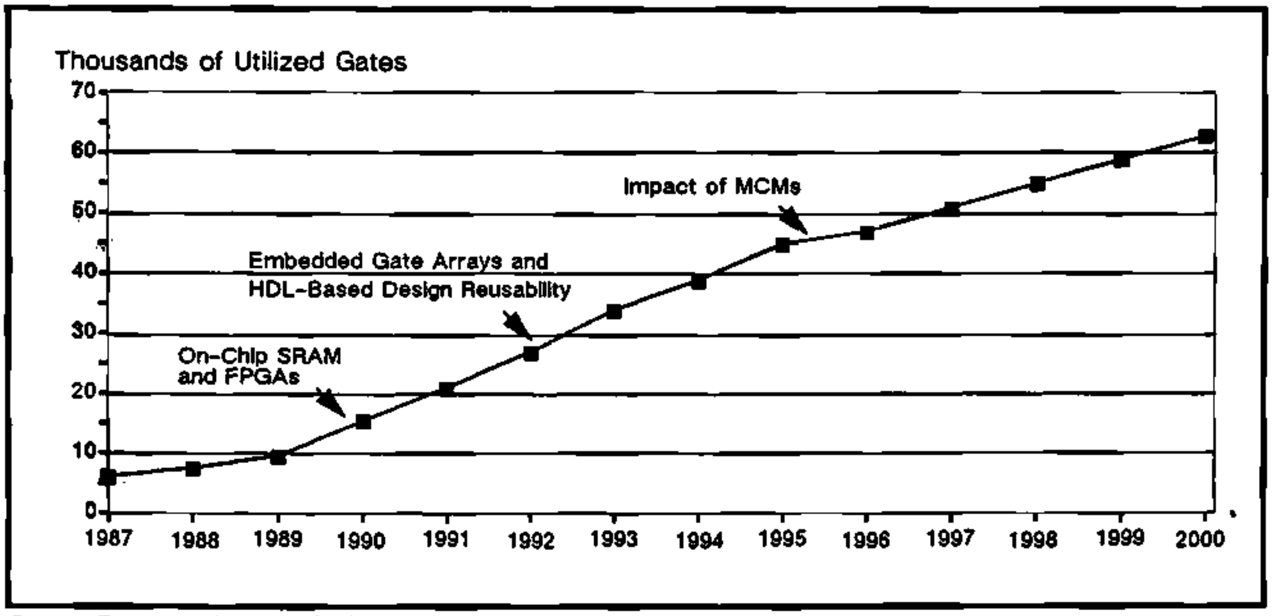
	1987	1988	1989	1990	1991	1992	1993	1994	1995
Total Gate Array and CBIC	13,229	14,335	15,066	15,970	16,811	17,622	18,320	18,945	19,489
MOS Gate Array and CBIC	10,506	11,448	12,294	13,297	14,123	14,897	15,523	15,963	16,179
Bipolar Gate Array and CBIC	2,637	2,694	2,432	2,279	2,215	2,138	2,050	1,890	1,657
BiCMOS Gate Array and CBIC	86	193	340	394	473	587	747	1,092	1,653
Total Gate Array	10,689	11,355	11,614	11,877	12,174	12,456	12,655	12,830	12,993
MOS Gate Array	8,078	8,601	8,998	9,390	8,708	9,996	10,181	10,247	10,178
Bipolar Gate Array	2,539	2,583	2,307	2,135	2,047	1,943	1,825	1,643	1,405
BiCMOS Gate Array	72	171	309	352	419	517	649	940	1,410
Total CBIC	2,540	2,980	3,452	4,093	4,637	5,166	5,665	6,115	6,496
MOS CBIC	2,428	2,847	3,296	3,907	4,415	4,901	5,342	5,716	6,001
Bipolar CBIC	98	111	125	144	167	195	225	247	252
BiCMOS CBIC	14	22	31	42	55	70	98	152	243

Source: Dataquest (August 1991)

Increasing Density

As mentioned earlier, a key reason behind the slowing of worldwide ASIC design start growth is that ASIC chip density is climbing at an increasing rate. As Figure 3 illustrates, the average number of utilized gates per MOS gate array design in North America during 1988 was 7,700, in 1989 it was 9,900 and in 1990 it was estimated to be 15,500. The primary reason for the big jump in 1990 gate counts was due to increasing use of on-chip SRAM. During 1989, 13 percent of MOS gate array design starts had on-chip SRAM compared with 21 percent in 1990. Furthermore, the average size of on-chip gate array SRAM increased from 2Kb in 1989 to 4Kb in 1990. An increasing number of gate array designs also had on-chip microperipherals and SCAN path logic, which also increased the average 1990 gate count.

FIGURE 3
Estimated North American Average MOS Gate Array Design Starts by Gate Count



Source: Dataquest (August 1991)

Looking forward, Dataquest believes that larger SRAMs (128Kb and 256Kb) will be diffused in the gate array base wafers and used for cache memory. Other functions such as SCSI, ALU, multiplier, multiplier-accumulator, FIFO, DMA controller, cache controller, and 82XX microperipherals will also be diffused in the gate array and drive average gate counts upward.

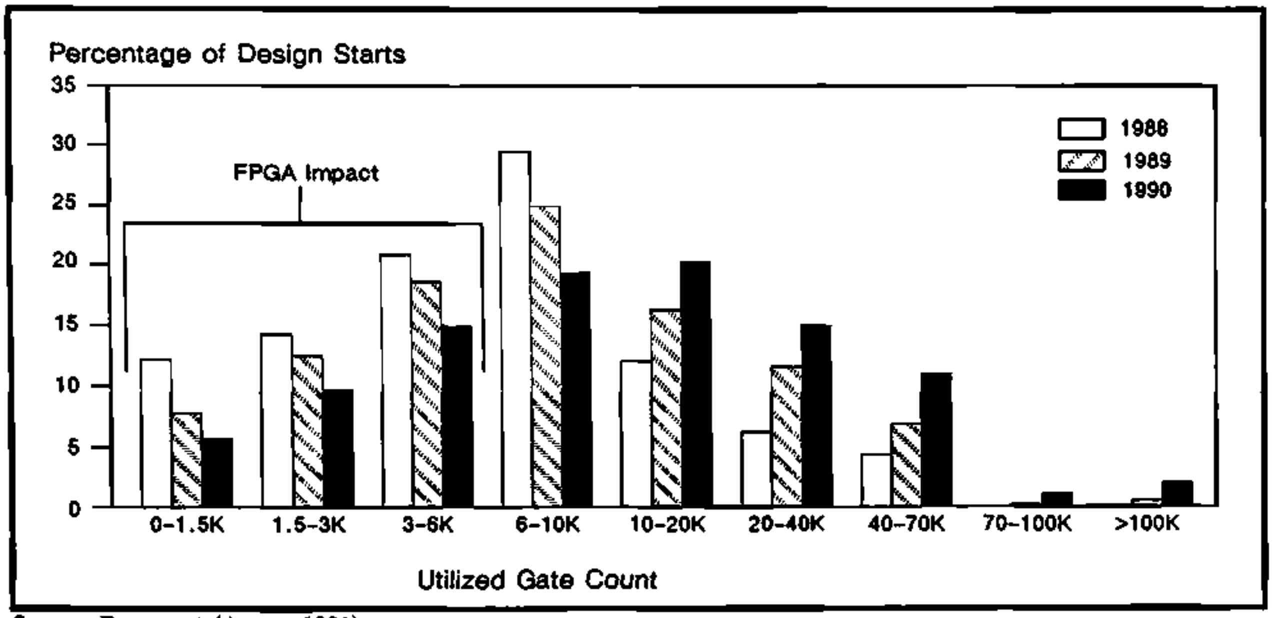
Dataquest also believes that there will be an increasing trend toward design reusability, which will push gate counts significantly higher than they have been in the past. ASIC designers will describe logic functions in VHDL or Verilog HDL, and the HDL functions then will be archived. Designers will retrieve these functions and reuse them on subsequent designs. We believe that functions will include both LSI and VLSI functions.

Dataquest expects multichip modules (MCMs) to temporarily stall average gate counts in the 1995 time frame. In Dataquest's view, MCMs will be moving quickly down the price learning curve by 1995 and, thus, are expected to become attractive for a wide range of applications. For many applications, it will more cost effective, for example, to put four 50,000-gate chips in an MCM compared with one 200,000-gate chip without losing much system performance. MCMs also offer a solution to the problem of high-gate-count ASICs having a limited number on bonding pads. With an MCM, a high-gate-count ASIC can be divided into multiple ASICs to more closely match individual device gate counts to I/O requirements. We expect the I/O problem to intensify over the next five years. Our belief stems from the fact that fabrication process technology developments (e.g., feature size reductions) are drastically outpacing corresponding reductions in pad pitch.

Encroaching Products

FPGAs are also having a dramatic impact on the growth of gate array design starts. Dataquest estimates that the installed base of FPGA development systems surpassed 10,000 units by the end of 1990. If each system were used for two designs per year (a conservative estimate), that would equal 20,000 total FPGA designs. This is not to suggest that either gate arrays would have been used for all of these designs or that the dollar market for FPGAs is larger than the gate array market; of course, it is not. The gate array market was $3.9 billion in 1990 compared with a $117 million market for FPGAs. Rather, it is clear that FPGAs are capturing many sockets that at one time would have been exclusively reserved for gate arrays. FPGAs are affecting low-density/low-volume gate array designs today; they will impact

FIGURE 4
Estimated North American MOS Gate Array Design Starts by Gate Count



Source: Dataquest (August 1991)

medium-density/medium-volume gate array designs in the future.

Today, most FPGAs are used for prototyping or applications that require less than 5,000 units for the life of the design. Furthermore, most of the FPGAs captured to date have less than 5,000 equivalent gate array gates. Figure 4 illustrates the impact that FPGAs have had on MOS gate array design starts in North America.

While FPGAs are attacking low-volume applications, chip sets and ASSPs are attacking high-volume applications. There have been several waves of application-specific chip sets to date. Among the most recent were logic and graphic chip sets, which in 1990 accounted for close to $700 million and $275 million, respectively. Another wave is well on the way—telecom/local area network chip sets. Other high-volume applications and products that Dataquest expects to be penetrated by application-specific chip sets include memory cards, multimedia including video compression, facsimile machines, laser printers, ISDN, and HDTV.

Dataquest believes that more high-volume gate array and CBIC applications will be recognized over the next five years and will be lost to chip sets. ASIC suppliers must complement their semicustom product lines by identifying ASSP market needs as early as possible and acting quickly to seize the opportunity. Time to market and/or including a high level of unique intellectual property will be the crucial elements necessary to achieve success in this business.

SUPPLIERS CHART NEW COURSES

It is clear that FPGAs will continue their assault on the low-end gate array market. Indeed, FPGAs will experience improvements in gate counts, speed, and price. As a result, FPGAs will gradually shift from the low-density market to today's midrange gate array market. Outflanking FPGAs will be a constant battle for ASIC suppliers. Many ASIC suppliers have resorted to dropping low-end gate array prices and further reducing prototype turnaround times to combat the FPGA onslaught. But this tactic struggles to come to terms with the changes in the paradigm—namely, that the definition of added value must change.

System knowledge is the critical element in offering added-value products. Knowing the entire system design flow and functional elements required for each type of system being targeted is crucial for successful ASIC suppliers of the 1990s.

ASIC suppliers must form close relationships with the systems design market to gain the necessary understanding of added value. Added value can come in many forms. Areas of opportunity include the following:

- Solving the test problem on both the IC and system level
- Offering new packages such as multichip modules
- Offering new high-performance/low-cost manufacturing processes
- Providing high-complexity megacells than can be diffused in gate array base wafers
- Reducing time to market
- Offering standard products that provide targeted system solutions

The ASIC market continues to evolve. The market will reward those suppliers that anticipate the changes and deliver added-value products and services.

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Research Newsletter

LINE GEOMETRIES OF GATE ARRAYS AND DRAMS CONVERGE

INTRODUCTION

Line geometries of DRAMs have long been the benchmark by which the industry has judged its lithography needs. However, in recent years, the line geometries of gate arrays have been shrinking almost as fast as those of DRAMs. For example, in 1984, the line geometry of the average gate array and the leading-edge gate array lagged the line geometry of the average and leading-edge DRAMs by about two years. This lag is much shorter now, and Dataquest expects it to be less than one year by 1995.

MARKET-DRIVEN CONVERGENCE

Different Manufacturing Strategies Lead to the Same End

The reasons for this convergence are market driven on the gate array side. The number of usable gates is a competitive feature of gate arrays. There are several different strategies whereby manufacturers can increase the number of usable gates—one depending on shrinking line geometries.

If the percentage of total gates actually used (gate utilization) is constant, a manufacturer can increase the number of used gates by increasing the number of total gates. On the other hand, if a manufacturer is able to increase the gate utilization rate, the number of gates used can be increased without increasing the number of total gates. Table 1 lists the different strategies open to manufacturers in order to increase usable gates.

Strategies Can Be Mixed

These strategies are not exclusive. Manufacturers differ, however, on the mix of strategies that they adopt. Japanese manufacturers, for example, tend to emphasize increasing the number of available gates by shrinking line geometries and increasing die size. This is a technique that they have used very successfully in the DRAM market.

It is interesting to note that because manufacturers can mix the strategies listed in Table 1, a successful gate array manufacturer does not have to follow "the leading edge" in order to be successful. The important factor is the mix of strategies and how they work in bringing the customer the most usable gates in the fastest time. The smaller line geometries and maximum levels of metal are only means to this end.

FORECAST FOR LINE GEOMETRIES

Our forecast for the line geometries of DRAMs and gate arrays is shown in Figure 1. The forecast for leading-edge gate arrays is the smallest geometry that will be used by those manufacturers that follow the strategy of shrinking line geometries in order to increase the available number of gates. Those manufacturers that opt for the strategy of optimizing routing efficiency can get by with a smaller number of total gates and larger line geometries.

The year in which the leading-edge DRAM generation begins is the year in which that density sells 1 million units. The year that a leading-edge gate array family begins is the year in which that density reaches $1 million in sales.

DATAQUEST CONCLUSIONS

The choice of strategy to increase the number of usable gates has major implications for

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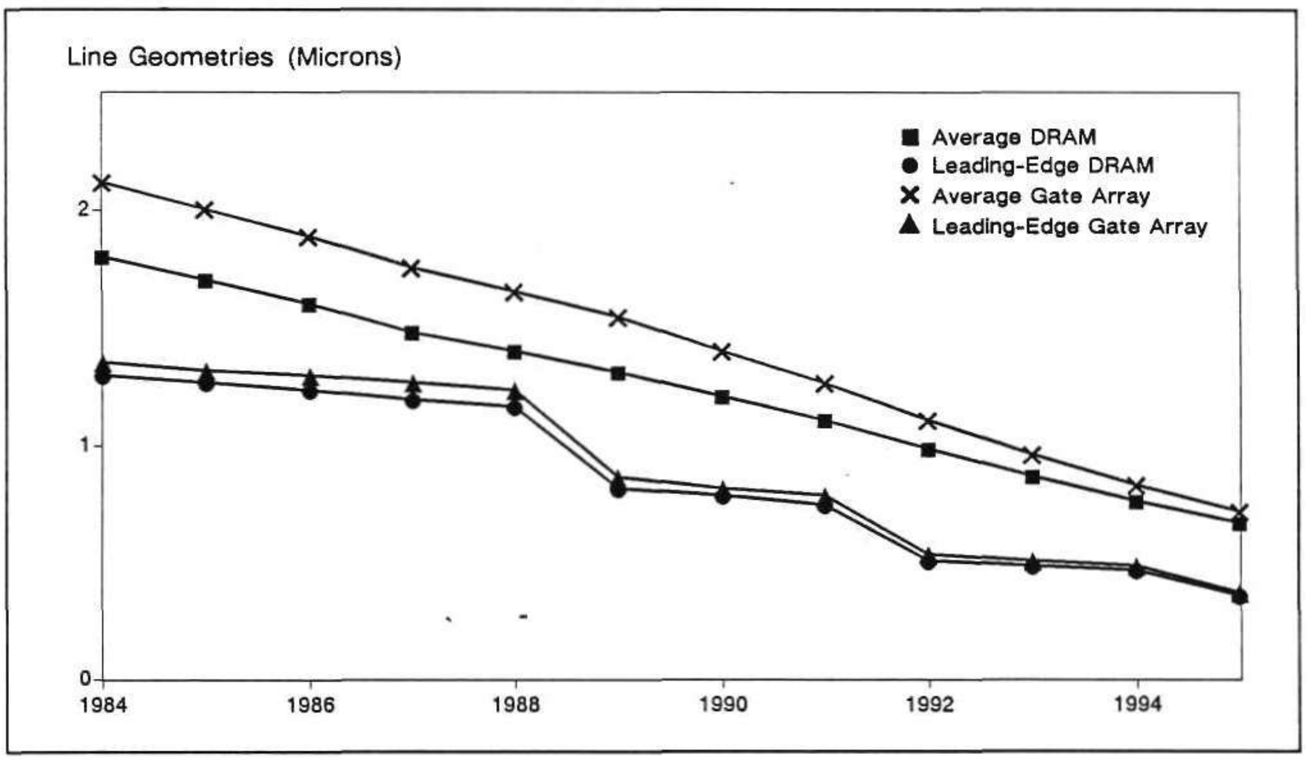
TABLE 1
Strategies of Increasing Usable Gates

Strategy	Characteristics
Decrease line geometry	Increases total available gate count Capital (lithography) intensive Uses base wafers Quick turn
Increase chip size	Increases total available gate count Design intensive Uses base wafers Quick turn
Increase levels of metal	Increases usable gates Capital (deposition/etch) intensive Smaller die Uses base wafers Quick turn
Develop more efficient routing algorithms	Increases usable gates Design intensive Smaller die Uses base wafers Quick turn
Add functional blocks, such as memory and peripherals	Design intensive Does not use base wafers All mask levels unique to functional block Is customer/system specific Circuit is optimized for function Not quick turn

Source: Dataquest (August 1990)

FIGURE 1
Converging Tecnologies—ASICs and DRAMs



Source: Dataquest (August 1990)

manufacturing and for equipment vendors. Shrinking line geometries and increasing levels of metalization are capital-intensive strategies. They are also strategies that rely on the use of base wafers. A manufacturer can mass produce base wafers and thereby drive down the cost. This should be an option only to those manufacturers certain that they can be the low-cost producers.

There are three strategies that are design intensive rather than capital intensive. These strategies increase die size and optimize routing algorithms using base wafers and would therefore have to compete in a mass-produced standard-product market. They, too, would have to be low-cost producers; however, because they are design intensive, they would not have the capital burden that small line geometries and increasing levels of metal would carry.

Finally, there is the strategic option of embedded functions. This option is design and capital intensive. But it does not use base wafers and, hence, is not a commodity product. Using embedded functions allows manufacturers to follow a niche rather than a commodity marketing strategy.

Clearly, no one strategy is head and shoulders above the rest. Dataquest believes that prudent manufacturers will be both design and capital intensive and will demand the maximum of uptime and throughput and the minimum of setup time from their vendors.

George Burns

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Research Newsletter

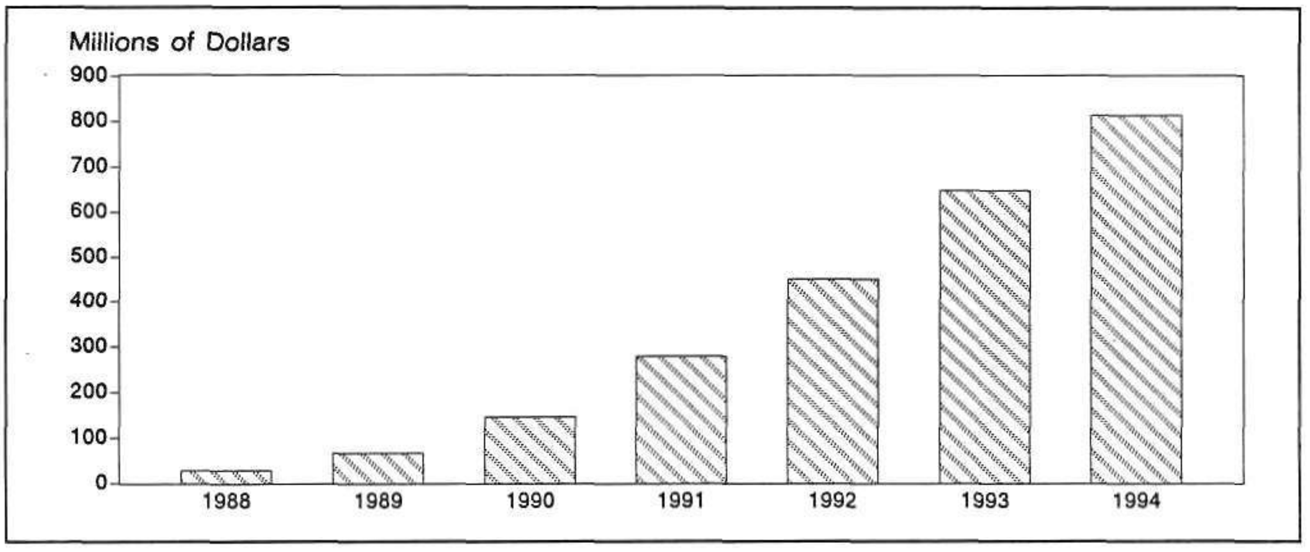
COMPLEX PLDs—WHAT IT TAKES TO WIN!

SUMMARY

A revolution is under way in the land of ASICs. Complex programmable logic devices (CPLDs) have taken the low-density ASIC applications by storm. The CPLD market grew at a 128 percent rate from 1988 to 1989, shooting from $29 million to $66 million. We expect it to continue this meteoric rise in 1990, for which we are projecting a 120 percent growth, closing out 1990 at $145 million! Furthermore, as seen in Figure 1, Dataquest is forecasting CPLDs to maintain a compound annual growth rate (CAGR) of 65 percent through 1994. As one would expect, this phenomenal growth has attracted the attention of many potential suppliers hoping to capture a piece of this lucrative market.

Breaking into this market, although not impossible, requires solid planning and strong alliances. Two leaders in the CPLD arena, Actel and Xilinx, each have solid product families and development tools in addition to having put together strong teams of allies to assist them in their attempts to make their unique products into industry standards. As a result, each has erected sizable market entry barriers. Those companies attempting to "go it alone" will find that overcoming these barriers is a very difficult task.

FIGURE 1
Estimated Worldwide Complex PLD Consumption



Source: Dataquest (July 1990)

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JUST WHAT IS A CPLD?

Dataquest splits the PLD market into two basic categories:

- Simple or standard PLDs (SPLDs), which consist of GAL- and PAL-type devices as well as 22V10 type products
- Complex PLDs (CPLDs), which are PLDs capable of implementing multiple levels of logic (more than two) without exiting the device.

Included in this category are such devices as field programmable gate arrays (FPGAs), which evolved from traditional masked gate arrays. Examples of FPGA vendors are Actel, Xilinx, and their licensed alternate sources. Also included in the CPLD category are programmable multilevel devices (PMDs), which evolved from SPLDs. Examples of PMD vendors are companies such as Altera, AMD, ICT, Plus Logic, Signetics, and their licensed alternate sources.

CPLDs and SPLDs coexist with very little application overlap. The primary applications for SPLDs are well identified, and there is very little new applications growth. The most dynamic event happening to SPLDs is the rapid growth of CMOS within the overall SPLD category. Conversely, the overall number of new applications for CPLDs is growing rapidly. Many CPLDs are dense enough to implement single-chip microperipheral-type functions, which would normally require a gate array or cell-based device or multiple SPLDs.

WHY USE A CPLD?

The benefits of using a CPLD are many: NRE charges are negligible, their "off-the-shelf" availability and field programmability eliminate "quick turn" fab requirements demanded by other ASIC solutions, and there is little risk if the first iteration needs a redesign. Also, once the user has approved the prototype, production may begin immediately, eliminating the need for the lengthy fab cycle that would be required by a gate array or cell-based approach.

The only significant drawback of a CPLD is cost, and this is an issue only in high-volume applications. In most medium-volume applications, the revenue rewards of hitting the market four to nine months faster than a gate array or cell-based approach more than make up for the higher unit cost of a CPLD. In high-volume applications, it is still worthwhile to use a CPLD solution for prototyping and early production and then switch to a gate array or cell-based version when it becomes evident that high volumes will be realized.

CAN THE GROWTH BE SUSTAINED?

As shown in Figure 1, the overall CPLD revenue is growing at a dramatic pace. This growth comprises the following two basic components:

- Development tool sales
- IC or chip sales

The early revenue stream of a CPLD is typically driven by the sale of design and development tools. Significant chip sales typically do not begin until about six to nine months after the sale of a development tool. If one were to look only at the chip sales of CPLDs, the growth rate for 1990 would exceed 150 percent! Also, if one were to consider the fact that CPLDs typically are not used in high-volume applications, it becomes self-evident that in order to achieve such rapid revenue growth, CPLD suppliers have to develop a broad customer base. Because CPLDs are such an embryonic product line, we expect the rapid market penetration to continue as new applications are discovered by the current customer base and new users discover the benefits of designing with CPLDs.

WHAT DOES IT TAKE TO PLAY?

Penetrating this market, as stated earlier, will not be easy. Two small start-ups, Actel and Xilinx, already have begun to establish themselves by introducing innovative, well-supported products and by forming comparatively unique alliances that include major semiconductor suppliers, foundries, and users. What makes these alliances unique is their rarity. Most fabless semiconductor start-ups form a relationship with a wafer foundry and rely solely on their own marketing and sales distribution channels to secure design wins. They believe that this puts them on a somewhat equal manufacturing footing with other semiconductor companies and that by moving more quickly than the large established companies, they will grow fast enough to establish a strong market position before the large companies can react. Actel and Xilinx have each taken their alliances a step further. Each has strong offshore foundries that can provide it with high-quality, low-cost silicon—Xilinx with Seiko-Epson and Actel with Matsushita. Additionally, each has formed alliances with major semiconductor companies that have large sales and applications organizations to help spread the word about their products and thus accelerate the design-in process—Actel with Texas Instruments and Xilinx with AMD. (This relationship has evolved into a 21 percent ownership of Xilinx by AMD.) Also, each company has allied itself with a different major user that has made commitments to use the product as well as act as a foundry and possibly as another competitor—Xilinx with AT&T and Actel with Hewlett-Packard. In the presence of such strong alliances, it is very likely that if any new entrants are to enter the CPLD marketplace successfully, they must form competitive alliances. Penetrating this market with a "go it alone" attitude will be a very difficult proposition.

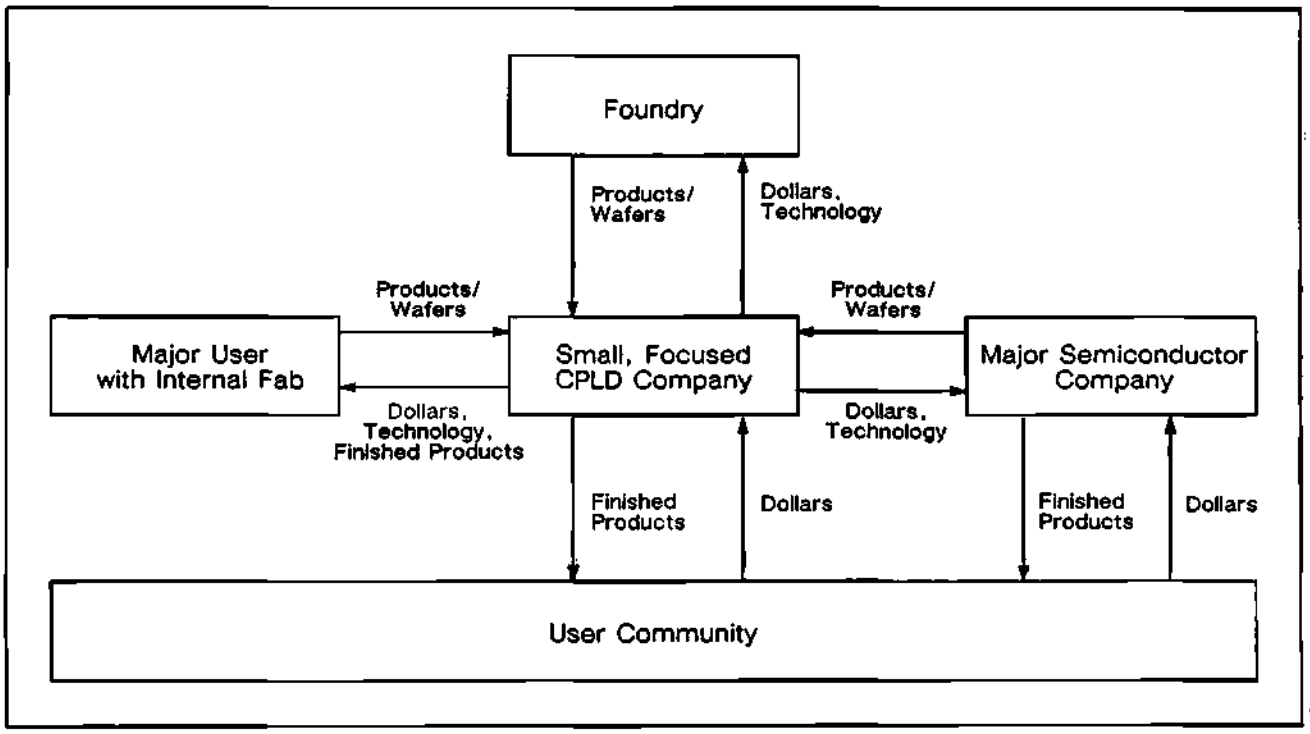
What Roles Do the Allies Play?

The basic core of the alliance (see Figure 2) includes a dedicated CPLD start-up, a major foundry, a major semiconductor supplier, and a major electronic equipment manufacturer.

The small CPLD company is needed to provide the single-minded focus necessary to drive a new concept to the point of being accepted as an industry standard. History indicates that most PLD innovation has come from such small, focused companies. The major semiconductor supplier is necessary for an alternate source for silicon as well as to provide credibility to the product concept. A major supplier with a presence in the PLD marketplace is ideal for this role. The foundry is needed in order to give the start-up some leverage with the semiconductor company, which may also act as a foundry. The major user provides a ready market as well as proof that the product is a competitive alternative to other semiconductor solutions.

If formed properly, this alliance should benefit all parties. Alliances that do not distribute the gain in accordance with the risk and/or effort put into them by the various members may be doomed to failure.

Figure 2
Components of a Successful CPLD Alliance



Source: Dataquest (July 1990)

TABLE 1
CPLD Partnerships

Originator	CPLD Type	Licensee	Agreement
Actel	FPGA	Matsushita	Foundry, marketing (Japan)
Actel	FPGA	Texas Instruments	Foundry, alternate source
Actel	FPGA	Hewlett-Packard	Foundry, technology license
Altera	PMD	Cypress	Foundry, alternate source
Altera	PMD	Texas Instruments	Foundry, possible alternate source
ICT	PMD	Gould/AMI	Foundry, alternate source
Plus Logic	PMD	Ricoh	Foundry
Xilinx	FPGA	Seiko-Epson	Foundry, alternate source (Japan)
Xilinx	FPGA	AMD	Alternate source, 20% ownership
Xilinx	FPGA	AT&T	Foundry, alternate source

Source: Dataquest (July 1990)

Who Are the Players?

As shown in Table 1, Actel and Xilinx have put together strong alliances to support their individual efforts. Advanced Micro Devices, with its strong PLD position, is attempting to go it alone with its family of PMD devices, as is Philips Components/Signetics.

DATAQUEST CONCLUSIONS

The CPLD market is growing at a rapid rate, which Dataquest expects to continue through the mid-1990s. Is it too late to join? No, but it will take careful planning, a unique product line, and strong multifaceted alliances.

This market is unique from other fast-growing IC markets in that the small, focused companies with innovative ideas that helped to create this market have formed strategic alliances with a broad range of large electronics companies. This type of alliance is not your standard fabless start-up buying wafers from a foundry. The CPLD alliances that exist today are using the strengths of each partner to form formidable market-entry barriers. Any company wishing to be successful in the CPLD market must formulate a strategy that will allow it to compete on more than an innovative idea. Success also will require multiple sources of silicon and acceptance by large trend-setting users as well as a competitive price/performance ratio.

Jerry Banks

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Research Newsletter

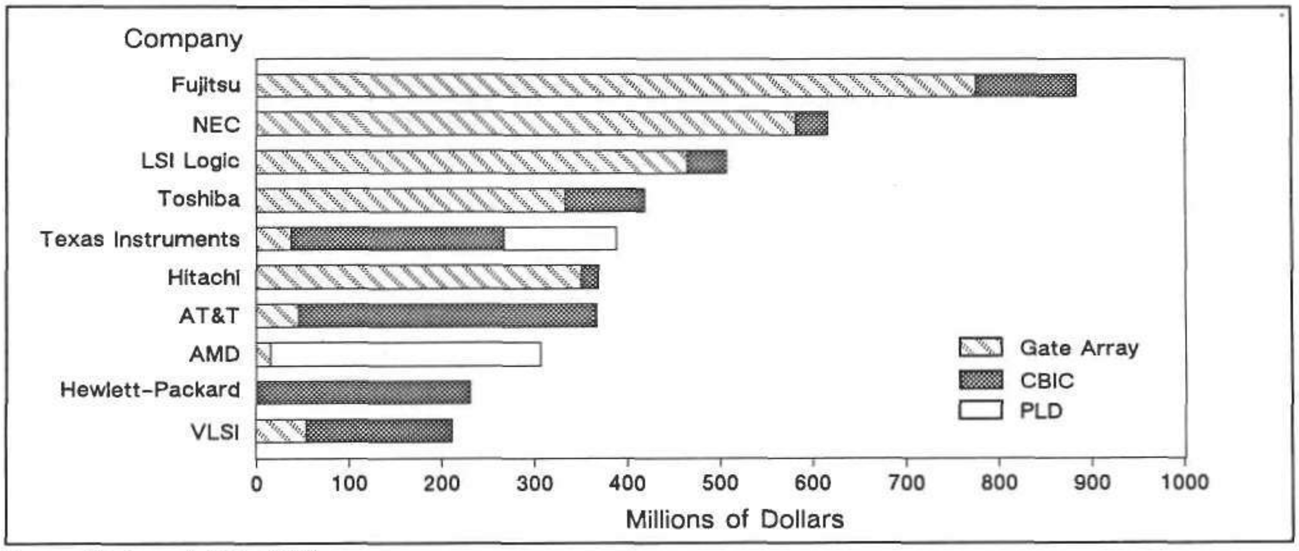
HP RANKS IN ASIC TOP 10 FOR THE FIRST TIME

According to Dataquest's market share data, the top 10 suppliers to the ASIC market in 1990 (excluding full-custom revenue) remained relatively unchanged from 1989 with the exception of Hewlett-Packard, which entered the top 10 rankings for the first time, thereby ousting National Semiconductor. Figure 1 presents the top 10 suppliers to the ASIC market for 1990, showing the composition of their ASIC revenue in terms of gate arrays, CBICs, and PLDs.

As Figure 1 shows, the top 10 ASIC suppliers consist of a healthy balance of U.S.- and Japan-based suppliers. At the same time, the product mix among the top 10 varies considerably. The Japan-based companies, for example, derive the bulk of their revenue from gate arrays. In contrast, U.S.-based suppliers are dominant in the CBIC market. Only one company, AMD, now claims a spot in the top 10 by virtue of its PLD revenue.

Although it may seem that companies such as LSI Logic are not growing as fast as Fujitsu and NEC, it is important to recognize that increasing revenue alone will not be a good enough gauge of success in the 1990s. LSI Logic's slower revenue growth is a reflection of its greater focus on profitability. The challenge facing all suppliers is to increase profit margins, not just increase revenue. Vendors such as LSI Logic and VLSI Technology are trying to focus on high-margin products while decreasing their exposure to low-margin commodity ASIC business.

FIGURE 1
Top 10 ASIC Suppliers—1990



Source: Dataquest (July 1991)

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For example, National Semiconductor fell from the top 10 rankings in 1990 because, in attempting to compete head-on in the low-density, low-margin commodity CMOS gate array business, it was at a competitive disadvantage with vertically integrated ASIC suppliers that could amortize their ASIC costs over both their internal system business and their merchant ASIC business.

PRODUCT OVERVIEW

Gate Arrays

The worldwide ASIC market grew approximately 12 percent over 1989 to $9.27 billion. Figure 2 presents the composition of the ASIC market by product and shows that gate arrays continue to dominate the market.

For gate arrays, 1990 was a year that yielded few surprises. Generally, the year can be characterized as exhibiting modest growth with the strong growing stronger and a significant segment of suppliers experiencing very tough times. Dataquest's final market share data show the gate array market growing by almost 12 percent over 1989. Figure 3 shows the picture in terms of supplier rankings. The market share rankings remained essentially unchanged from the previous year with the exception of the new conglomerate, GEC/Plessey/MEDL, switching places with Oki in the lineup. Fujitsu, the market leader, expanded its revenue by 25 percent over the prior year. Gains in the company's ECL gate array business for use in testers and very high end computer systems contributed significantly to this strong performance.

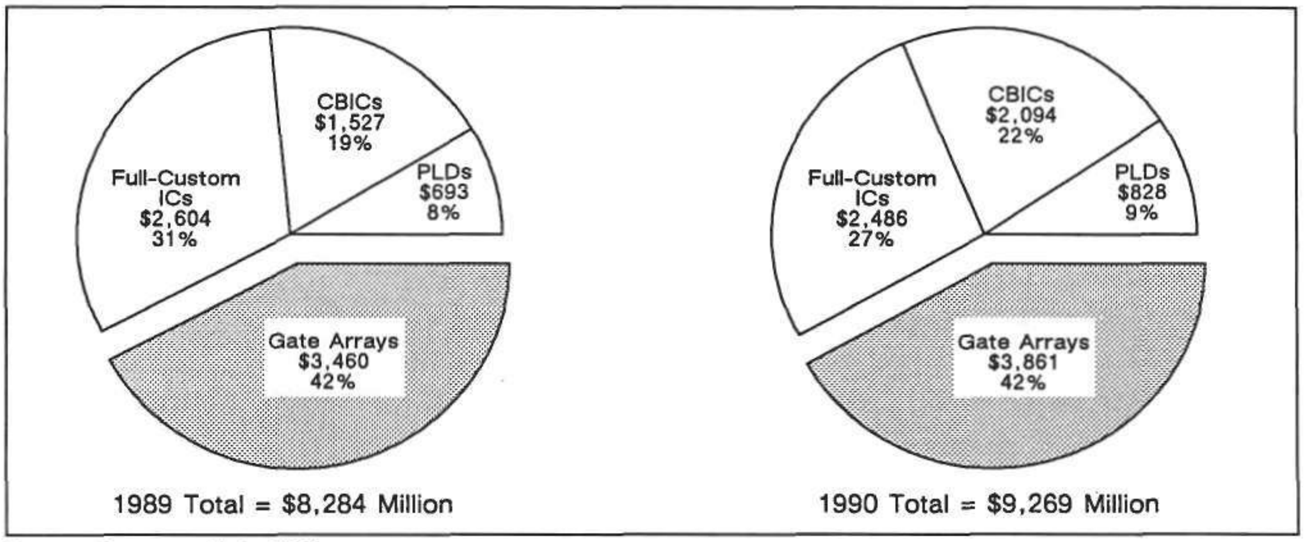
Figure 4 compares worldwide gate array consumption between 1990 and 1989 from a technology perspective. MOS gate arrays grew by 13 percent, whereas bipolar gate arrays grew a mere 6 percent. Meanwhile, growth in the BiCMOS arena significantly picked up. Indeed, the BiCMOS market grew by 40 percent in 1990. NEC, Fujitsu, and Hitachi are the only companies at this time with any significant revenue in this process category.

Cell-Based ICs

Although a 37 percent increase in CBIC revenue in 1990 over 1989 might seem to point to a very rapidly growing market, the jump in revenue stems from Hewlett-Packard's entry into the merchant CBIC market in 1990. For purposes of comparison, if we take out HP's $230 million contribution to the market, the corresponding growth rate of 22 percent is more in keeping with our forecast. Figure 5 represents the top 10 CBIC suppliers in terms of merchant and captive sales.

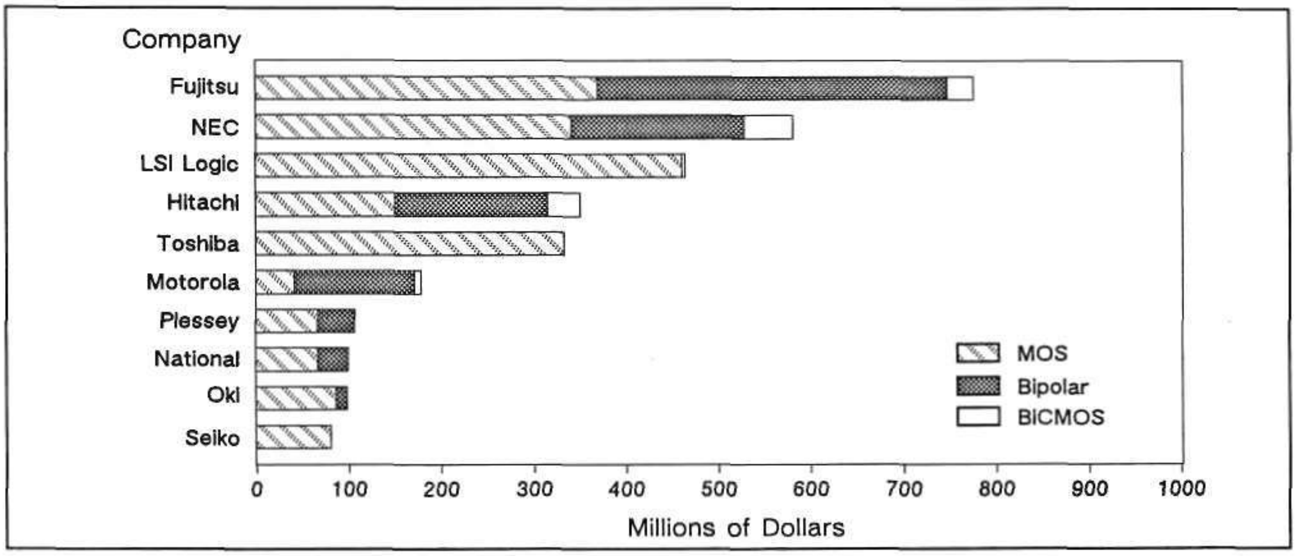
AT&T's combined internal and merchant CBIC business places the company first in the CBIC rankings. AT&T has been attempting to increase its merchant share of CBIC revenue. Indeed, in 1990, the company succeeded

FIGURE 2
Worldwide ASIC Consumption by Product



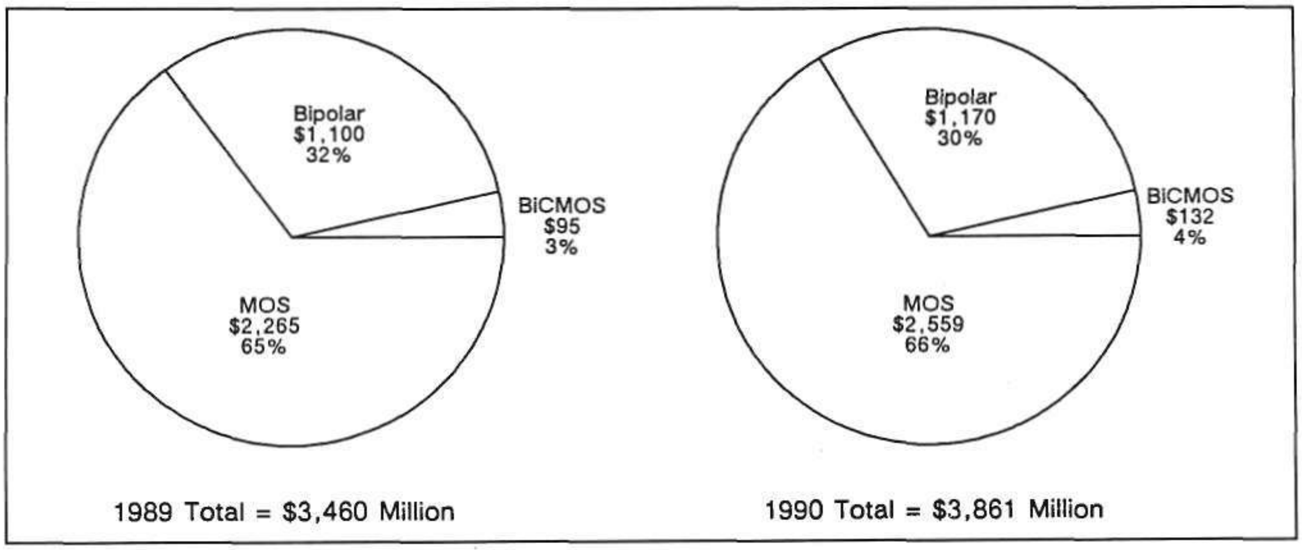
Source: Dataquest (July 1991)

FIGURE 3
Top 10 Worldwide Gate Array Suppliers—1990



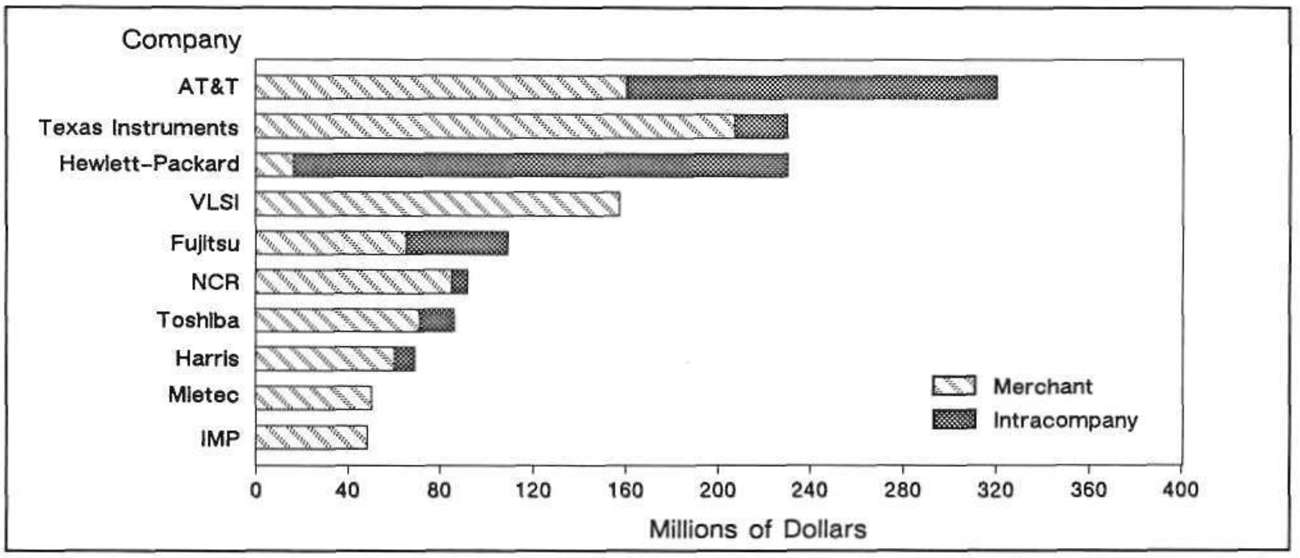
Source: Dataquest (July 1991)

FIGURE 4
Worldwide Gate Array Consumption by Technology



Source: Dataquest (July 1991)

Figure 5
Top 10 CBIC Suppliers Worldwide—1990



Source: Dataquest (July 1991)

in capturing a significant chunk of merchant CBIC revenue by securing business from Western Digital. When AT&T eventually takes over NCR, the addition of that company's merchant CBIC business will make AT&T the number one CBIC supplier in the merchant market. Although suppliers such as Fujitsu, NEC, and Toshiba are not as prominent in the CBIC arena as in the gate array market, Dataquest expects to see them work aggressively to increase their penetration in this market. Already Fujitsu and Toshiba have captured solid business in this arena by focusing on applications including video games, printers, hard disk drives, and instrumentation. Finally, Mietec, a European company, is noteworthy because it is the only supplier with substantial BiCMOS CBIC revenue.

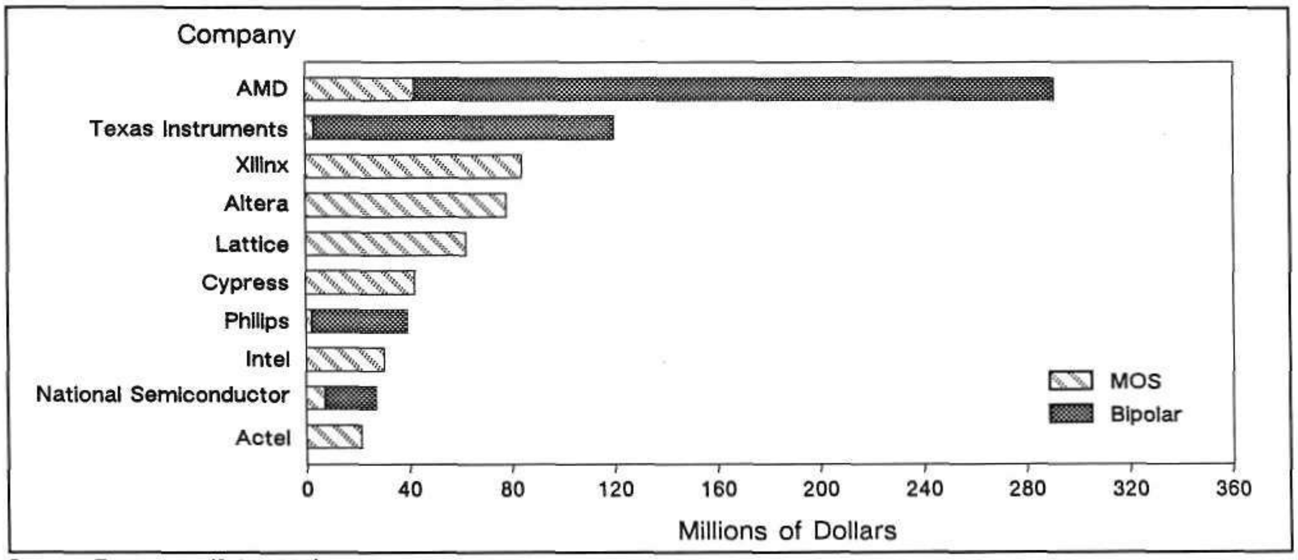
Programmable Logic Devices

Although representing the smallest portion of the ASIC market, the PLD market is receiving much attention. The dynamics of this market are such that the traditional bipolar PLD market continues to decline, whereas CMOS continues to make inroads. This represents an opportunity for a host of small companies to offer replacement CMOS parts and enter the market with new and innovative PLD architectures.

The number one supplier to the CMOS PLD market in 1990 was Xilinx with its FPGA products. Altera and Lattice ranked second and third, respectively, in the CMOS market. They are prominent suppliers of simple CMOS PLDs and are offering (or will be offering) complex PLD products. Although the gate array market is dominated by Japan-based suppliers, which are also strengthening their portfolios to compete more aggressively in CBICs, the PLD market is solidly commanded by U.S.-based companies. This dominance can be seen from Figure 6, which depicts the top 10 suppliers to this market.

In 1990, the CMOS portion of the PLD market grew so rapidly, it almost caught up with the bipolar market. CMOS PLD revenue amounted to $405 million in 1990 compared with bipolar's $423 million. This year, 1991, represents the crossover point when CMOS will overtake bipolar shipments.

FIGURE 6
Top 10 PLD Suppliers Worldwide—1990



Source: Dataquest (July 1991)

DATAQUEST PERSPECTIVE

Low-end gate arrays have been described as the ultimate commodity in terms of silicon availability. Certainly the cutthroat pricing in the CMOS arena is testimony to a commodity pricing profile. Dataquest believes that the area of greatest opportunity in gate arrays will be embedded gate arrays (i.e., megacells such as static RAM and selected microperipherals that are diffused in the array base wafer). We view these devices as representing a future trend that will impact the CBIC arena. We continue to believe that gate arrays will remain the dominant ASIC technology throughout the decade.

Yet the CBIC market will continue to evolve. In applications demanding the highest performance and/or the greatest level of customization flexibility, we believe that CBIC will be the preferred solution over gate arrays. In fact, as the traditional handcrafted, full-custom portion of the ASIC market continues to decline, much of this business will continue to migrate into the CBIC camp. CBIC libraries and tools are infiltrating many standard product groups in large, broad-based IC suppliers so that by the mid-1990s, nearly all standard logic products should be developed using some form of ASIC design methodology.

In the never-ending challenge to meet time-to-market constraints, PLDs are providing the ideal vehicle and thus are eating away at the low end of the gate array market. As complex PLDs such as programmable multilevel logic devices and field programmable gate arrays increase in density, they will capture a greater share of the gate array market, especially as they charge down the learning curve.

Bryan Lewis
Patricia Galligan
Ron Collett

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Research *Bulletin*

CHIP SETS AND AGGRESSIVE PRICING DRIVE NEW ASIC FORECAST

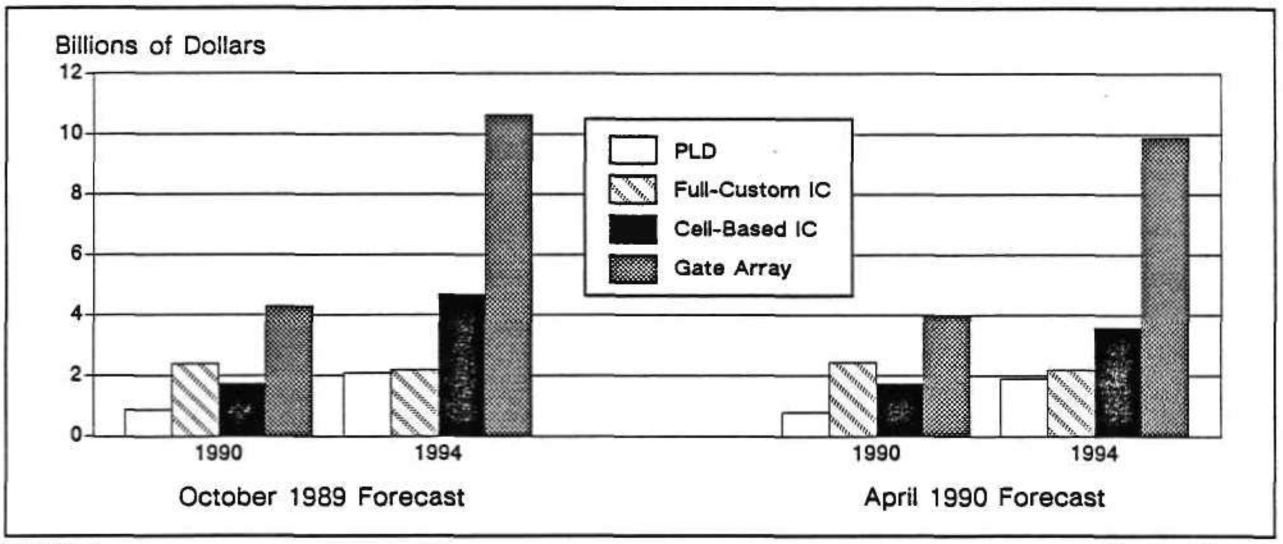
THE ASIC FORECAST

The ASIC market has two strong trends to contend with: rapid ASIC price erosion and the rise in popularity of chip sets and standard products. For example, high-volume CMOS gate array pricing has plummeted close to 30 percent in the last year, and the personal computer logic chip set market is setting record highs at the expense of ASICs—the market broke $490 million in 1989 and had a two-year, 86 percent compound annual growth rate (CAGR). Dataquest believes that the net effects of these two important trends are that gate array annual growth has seen the last of the 30 percent growth years, because of rapid price erosion, and that the cell-based IC (CBIC) market as we know it today will not see the robust growth once expected, because gate arrays and chip sets are replacing CBICs in system applications.

Figure 1 contrasts Dataquest's new worldwide ASIC consumption forecast with our prior forecast. We did not change our 1990 forecast significantly; however, our 1994 gate array and CBIC estimates are adjusted downward. We believe that gate arrays will remain the dominant ASIC technology throughout the decade. Sea-of-gates gate arrays and embedded gate arrays (e.g., megacells such as RAM embedded in base wafers) are expected to be the mainstream ASIC technology of the future. Key gate array advantages compared with CBICs include quicker time to market, lower risk, and lower design cost. Furthermore, we believe that CBIC methodology will take on an additional role to ASICs—becoming the primary design methodology for chip set and standard products.

Table 1 shows Dataquest's new worldwide ASIC technology forecast.

FIGURE 1
Estimated Worldwide ASIC Consumption



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Source: Dataquest April 1990

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TABLE 1
Estimated Worldwide ASIC Consumption by Technology (Millions of Dollars)

	1987	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total ASIC	6,152	7,485	8,302	8,984	10,453	12,468	15,305	17,614	16.2%
MOS	4,323	5,411	6,116	6,680	7,766	9,218	11,211	12,612	15.6%
Bipolar	1,788	1,987	2,045	2,095	2,281	2,482	2,679	2,812	6.6%
BiCMOS	41	87	141	209	406	768	1,415	2,190	72.9%
Gate Array	2,275	2,985	3,465	3,992	4,939	6,272	8,210	9,891	23.3%
MOS	1,409	1,933	2,237	2,595	3,191	4,021	5,207	6,093	22.2%
Bipolar	825	965	1,088	1,193	1,361	1,534	1,713	1,889	11.7%
BiCMOS	41	87	140	204	387	717	1,290	1,909	68.5%
PLD	501	675	718	801	990	1,313	1,713	1,913	21.7%
MOS	79	172	263	386	570	882	1,278	1,521	42.0%
Bipolar	422	503	455	415	420	431	435	392	(2.9%)
Cell-Based IC	910	1,300	1,515	1,748	2,065	2,498	3,092	3,635	19.1%
MOS	873	1,256	1,464	1,676	1,961	2,333	2,823	3,190	16.9%
Bipolar	37	44	50	67	85	114	144	164	26.8%
BiCMOS	0	0	1	5	19	51	125	281	208.9%
Full-Custom IC	2,466	2,525	2,604	2,443	2,459	2,385	2,290	2,175	(3.5%)

Source: Dataquest
April 1990

Key trends incorporated in our new ASIC forecast include the following:

- BiCMOS market projections extended one year
- CBIC growth reduced substantially
- Complex PLDs driving PLD growth
- All ASIC products having a slow year in 1990
- The next industry slowdown expected in 1994

DATAQUEST CONCLUSIONS

Dataquest believes that as gate array prices continue to drop, not only will market growth slow, but, more importantly, most suppliers will experience negative profit margins. High-volume CMOS gate array prices in 1989 rarely went below 100 millicents per usable gate. Now we are hearing about high-volume prices down near 70 millicents. How long can suppliers continue to sacrifice market share for profits? R&D and production equipment costs for submicron gate array products continue to escalate, while the life cycle of each new product generation continues to shrink. Small gate array suppliers must find niche application markets that they can protect and bring unique knowledge to. Deep pockets are required to stay in the mainstream gate array market.

Although we revised our forecast for growth of the CBIC market downward, we are *not* saying that this market is dying. The CBIC market as we know it today will continue to grow but at a modest rate. Traditional CBIC applications are limited to high-performance and high-integration systems, automotive, telecommunications, and mixed analog/digital applications. However, CBIC as a methodology is thriving. Dataquest believes that CBIC tools and libraries will emerge in standard product groups and be used to develop chip sets and standard products. Standard product groups are using system knowledge gained in ASIC groups to better understand system applications; then they develop standard products that satisfy a host of system designers with one product. With the use of CBIC design methodology versus the old full-custom design techniques, standard product groups can dramatically improve their time to market. The trend is clear: Single-user CBICs are becoming multiuser standard products. Standard product profit margins historically have been much higher than ASIC margins. The challenge for ASIC suppliers in the 1990s is to make money.

Bryan Lewis
Jerry Banks

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Research Newsletter

CMOS AND COMPLEX PLDs CONTINUE THEIR METEORIC RISE

SUMMARY

The days of bipolar growth are over; today CMOS is king in terms of growth in dollars as well as percentage. In 1989, CMOS programmable logic device (PLD) revenue increased by 53 percent to $263 million. Complex PLDs jumped to $66 million, representing a 128 percent leap. Both growth rates outstripped the compound annual growth rate (CAGR) of 26.7 percent that PLDs have achieved over the past five years. Only bipolar PLDs experienced negative growth, falling from $503 million in 1988 to $455 million in 1989.

THE PLD MARKET

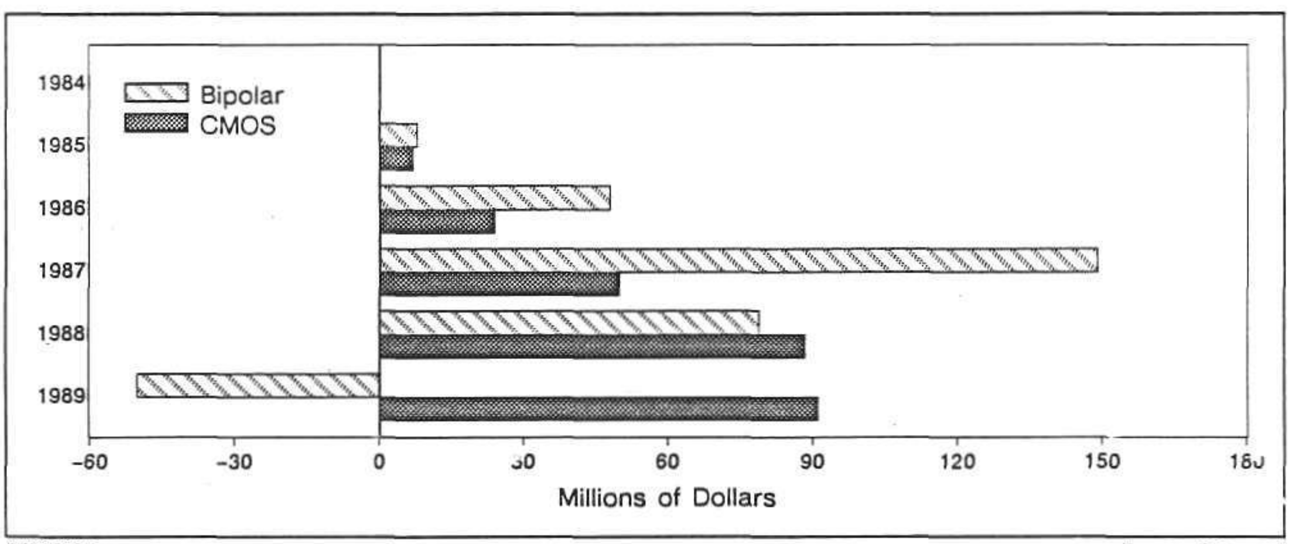
By Technology

Within the total PLD category, the clear winner in terms of technology was CMOS, which grew at a robust 53.1 percent. The PLD technology loser was bipolar, which *shrank* by 10 percent.

Figure 1 illustrates the growth rates of bipolar and CMOS PLDs over the past five years. From this figure, it is clear that CMOS has outpaced bipolar growth not only in terms of growth rates but also in terms of dollars. Over the past five years, CMOS has grown by $260 million compared with $234 million for bipolar. Nearly 69 percent of the CMOS growth has occurred over the past two years. A reasonable expectation would be that CMOS will surpass bipolar in PLD shipments within the next few years.

The rapid growth of CMOS versus bipolar tells us that companies participating in the PLD market without a strong position in CMOS are vulnerable. Based on market share, the top four

FIGURE 1
PLD Growth by Technology



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Source: Dataquest
April 1990

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PLD companies of 1988—Advanced Micro Devices (AMD), Texas Instruments (TI), Philips/Signetics, and National Semiconductor—all have strong positions in bipolar, and all experienced negative growth in 1989, averaging a 6.3 percent decline. As can be seen from Figure 2, these were the only companies to experience negative growth in 1989.

An even more telling indicator of the growth of CMOS-based companies is the fact that the number 3 and number 4 players in 1988—Philips/Signetics and National—have now dropped to number 4 and number 6, respectively. Altera jumped from number 5 in 1988 to number 3 in 1989, becoming the first CMOS-based company to break into the top four. Xilinx has moved impressively from number 7 to a strong number 5, competing hotly for number 4 in total PLD revenue. Xilinx's revenue is based soley on field-programmable gate arrays, which fall into the complex PLD category.

By Complexity

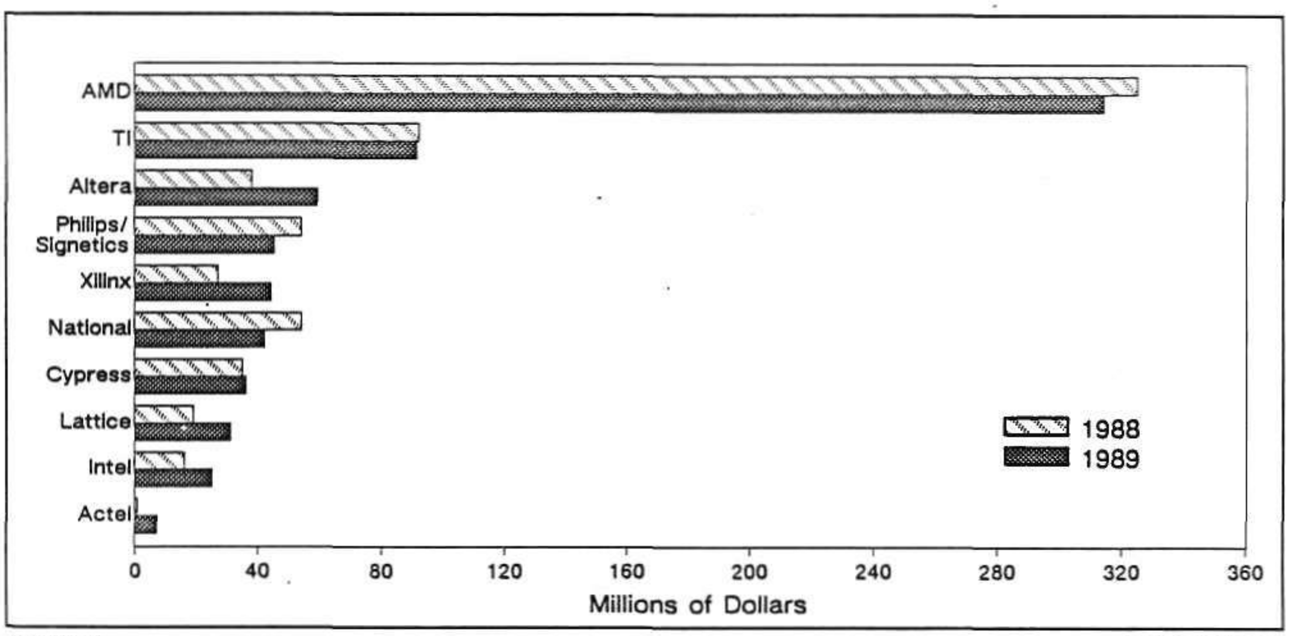
Complex PLDs (CPLDs) grew at a torrid 128 percent to $66 million in 1989. CPLDs are almost exclusively manufactured in CMOS. The market leaders in 1989 were Xilinx, AMD, and Actel.

Standard PLDs (SPLDs) or programmable logic arrays (PLAs) grew only 1 percent in 1989 from $646 million to $652 million. Within this category, CMOS SPLDs grew at a sizzling 38 percent, while bipolar SPLDs slipped by 10 percent. The market leaders in bipolar SPLDs are AMD and TI, while the CMOS SPLD leaders are Altera and Lattice.

Dataquest Conclusions

The signals sent in 1989 may be mixed, but they are extremely clear. Although bipolar PLDs make up approximately 63 percent of the total PLD market, bipolar PLD growth currently is stagnating, while CMOS is coming on strong. In 1984, bipolar PLD revenue was $217 million compared with only $2.8 million for CMOS. Five years later, bipolar had grown by $234 million to $451 million, representing a CAGR of 15.8 percent. In that same time period, CMOS PLD revenue had grown by approximately $260 million to $263 million, for a CAGR of 148 percent! Clearly the competition for

Figure 2
Top 10 PLD Companies Worldwide—1989



0006745-2

Source: Dataquest
April 1990

the remaining bipolar business will become extremely cutthroat, and a strong position in CMOS is a must for success in the PLD marketplace.

So what does all of this mean? Although the CMOS standard PLD market is experiencing rapid growth, it is oversaturated with suppliers at present. Approximately 15 competitors are vying for this low-end portion of the market. Also, the strong basic patent positions of several of these companies provide formidable market-entry barriers. The room for growth and expansion lies in the area of CPLDs. This market is immature but growing quickly. A few standards appear to be forming, but the market is young and there is still room for innovative companies. Dataquest believes that the CPLD market requires the following ingredients for success:

- Development tools and support
- Innovative product architectures
- Aggressive marketing
- A technical sales organization and distribution network

At the same time, these "ingredients for success" are also barriers. They are barriers for your market entry, but they are also barriers that your competitors must overcome to share in your hard-fought design wins. PLDs are not for the timid, but the winners will reap long-term rewards.

Jerry Banks

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Research *Bulletin*

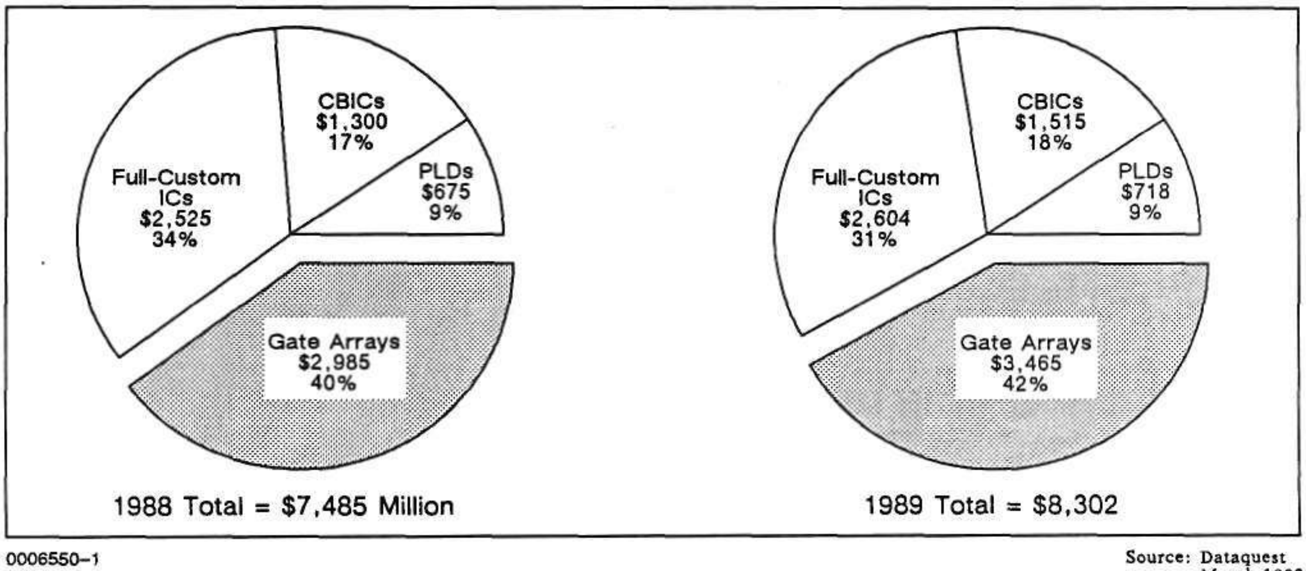
GATE ARRAYS CAPTURE LION'S SHARE OF 1989 ASIC MARKET

Gate arrays, for the second year in a row, dominated the $8.3 billion 1989 worldwide application-specific integrated circuit (ASIC) market. Gate arrays extended their lead over other ASIC products by growing from 40 percent of the 1988 ASIC market to 42 percent in 1989. The next-largest 1989 ASIC market was full-custom ICs with 31 percent, followed by cell-based ICs (CBICs) with 18 percent, and programmable logic devices (PLDs) with 9 percent. Gate arrays offer many advantages over full-custom ICs and CBICs. Key gate array advantages include quicker time to market, lower risk, and lower design cost. Moreover, 1989 gate array pricing was cutthroat as suppliers battled for market share. The spot market for high-volume submicron CMOS gate arrays dipped below 0.08 cents per usable gate. This pricing increased the overall cost effectiveness of gate arrays to the users and severely impacted the suppliers' margins.

Figure 1 illustrates worldwide ASIC consumption during 1988 and 1989 by product type. The worldwide ASIC market grew by $817 million (11 percent) from 1988 to 1989. Gate arrays grew by $480 million (16 percent), CBICs by $215 million (17 percent), full-custom ICs by $79 million (3 percent), and PLDs by $43 million (6 percent).

Fujitsu continues to dominate the ASIC market for the sixth year in a row. NEC maintained second place and was followed by LSI Logic and Toshiba. These top four suppliers derived 90 percent of their revenue from gate arrays. Although AT&T, Texas Instruments, and VLSI Technology derived the majority of their 1989

FIGURE 1
Preliminary Worldwide ASIC Consumption



0006550-1

Source: Dataquest
March 1990

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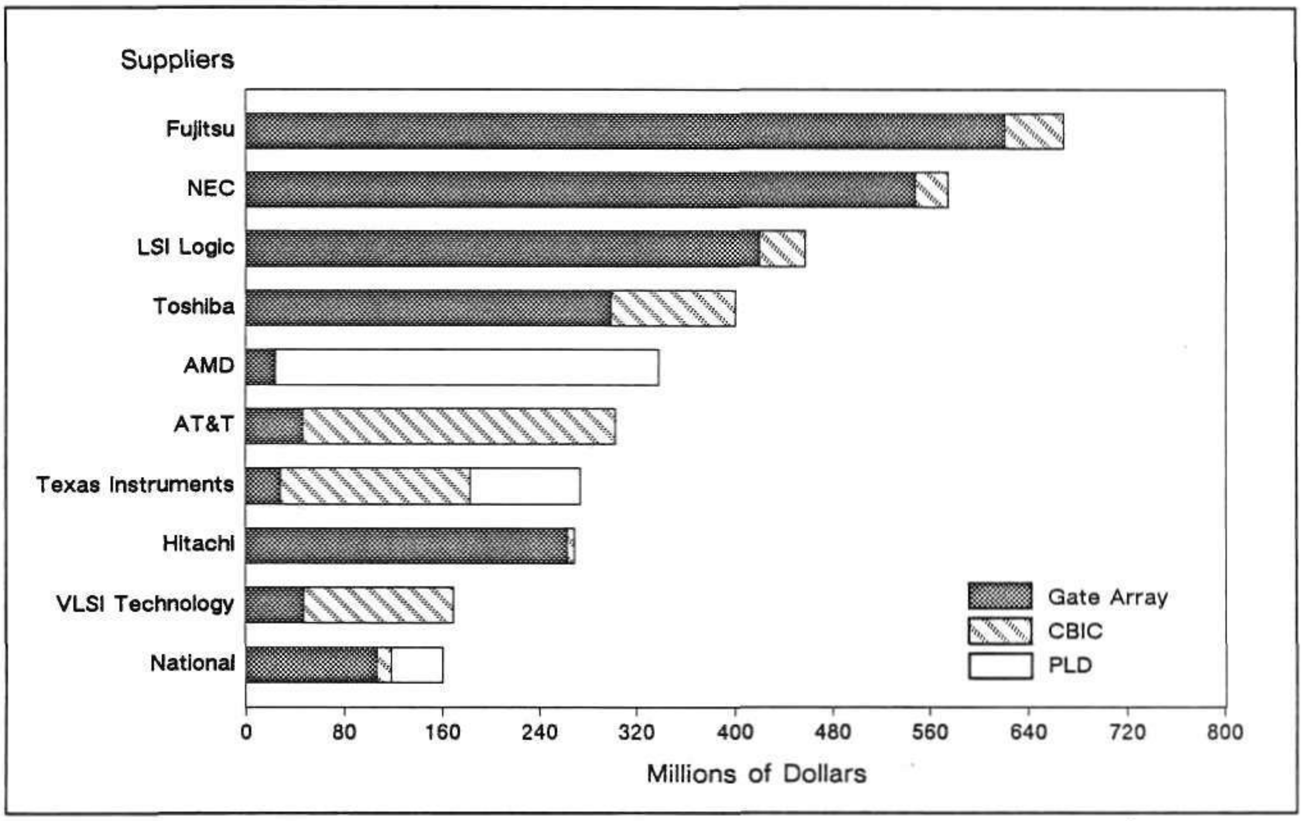
FIGURE 2
Preliminary 1989 Worldwide ASIC Shipments—Top 10 Suppliers



0006550-2

Source: Dataquest
March 1990

ASIC revenue from CBICs, all are pursuing the gate array market with a vengeance. AMD was the only supplier with the majority of its revenue in PLDs to make the top 10 ranking. Figure 2 illustrates the top 10 1989 worldwide ASIC suppliers and their respective product mixes.

DATAQUEST CONCLUSIONS

As we enter the 1990s, Dataquest believes that gate arrays will remain the dominant ASIC technology throughout the decade. Gate arrays are expected to be the mainstream technology for computer, industrial, and military applications. Full-custom ICs eventually will be phased out and replaced primarily by gate arrays and CBICs. Both CBICs and PLDs will earn their place in the ASIC world. We believe that CBICs will continue to dominate gate arrays in automotive, telecommunications, and mixed analog/digital applications. CBICs also will penetrate high-performance applications. Furthermore, Dataquest believes that CBIC tools and libraries will emerge within standard product groups in broad-based IC suppliers and will be used to develop a new CBIC market—altered standard products.

Dataquest believes that MOS PLDs will experience major growth throughout the decade by penetrating bipolar PLD applications, capturing a portion of low-end gate array applications, and creating new markets. Complex PLDs, which include field-programmable gate arrays (FPGAs) and programmable multilevel logic devices (PMDs), are expected to be among the hottest ASIC products of the 1990s.

Emerging gate array products for which we see strong demand in the 1990s include high-density CMOS channelless arrays, high-density ECL arrays, BiCMOS arrays, and embedded gate arrays (e.g., megacells such as RAM embedded in the gate array base wafer).

While the ASICs of the 1980s captured the attention of both suppliers and users with their cost/performance effectiveness in system design, we believe that the ASICs of the 1990s will capture more than just attention—they will penetrate the entire electronics industry.

Bryan Lewis

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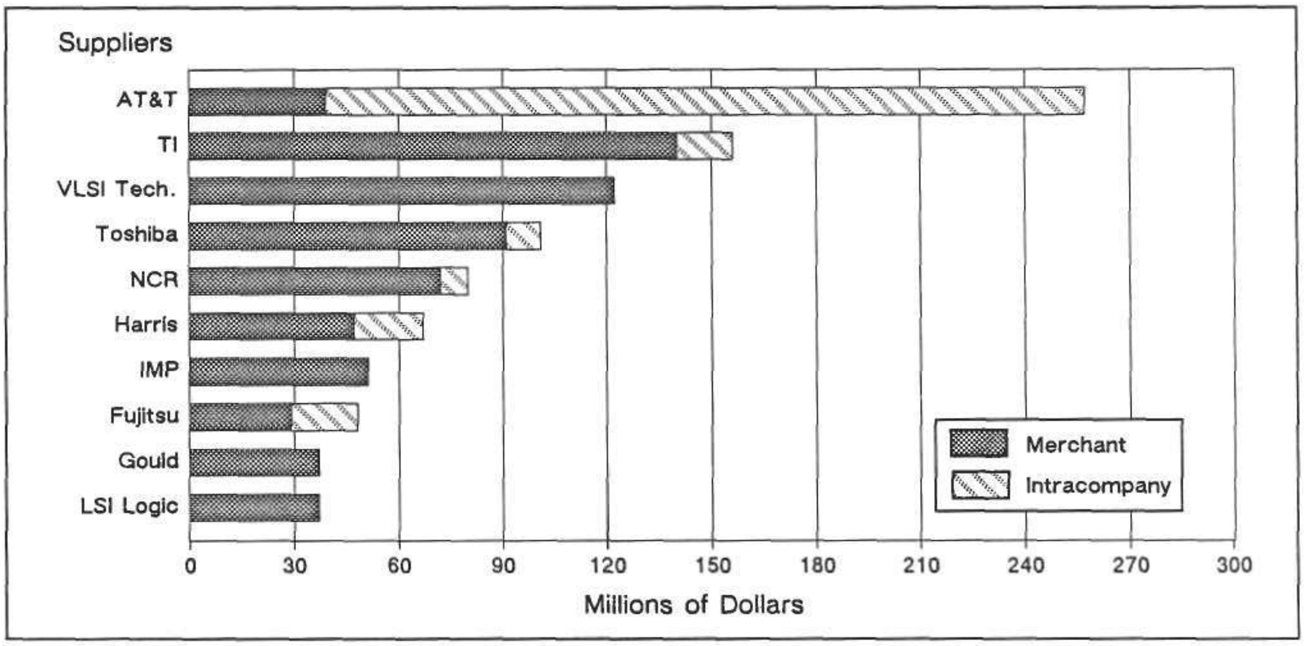
Research *Bulletin*

NORTH AMERICAN SUPPLIERS DOMINATE 1989 CBIC MARKET

During 1989, the worldwide cell-based IC (CBIC) market reached an all-time high of $1.5 billion, growing 17 percent over 1988. North American suppliers owned 67 percent of the market. Of the top 10 1989 worldwide CBIC suppliers, 8 were based in North America and just 2 were based in Japan. This situation is exceptional when compared with the gate array market, where 6 of the top 10 1989 worldwide suppliers were from Japan and only 3 were from North America.

AT&T topped the chart as the number one 1989 worldwide CBIC supplier; however, close to 85 percent of its revenue was generated from sales to internal divisions (intracompany revenue). As Figure 1 illustrates, Texas Instruments clearly was the number one 1989 CBIC supplier to the merchant market, followed by VLSI Technology, Toshiba, and NCR. LSI Logic rocketed into the top 10 1989 ranking after being ranked just 18th in 1988; the company had a healthy 117 percent annual merchant growth.

FIGURE 1
Top 10 Suppliers
Preliminary 1989 Worldwide CBIC Shipments



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Source: Dataquest
March 1990

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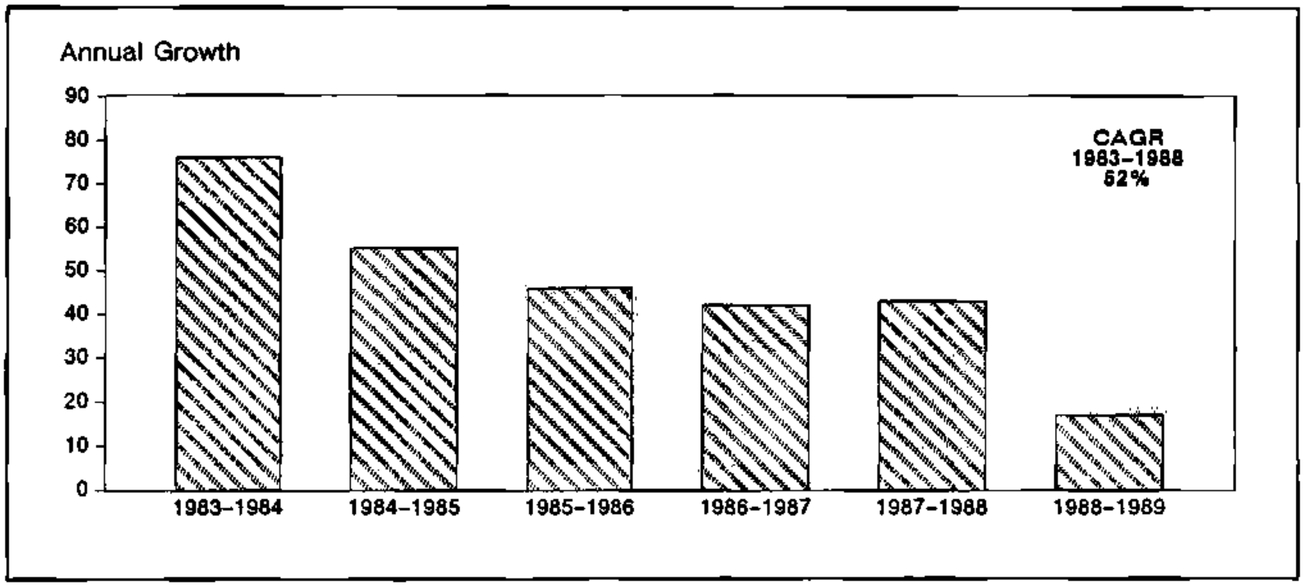
FIGURE 2
Estimated Worldwide CBIC Growth



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Source: Dataquest
March 1990

Figure 2 illustrates the worldwide CBIC market growth during the past seven years. Although the 1989 CBIC growth rate of 17 percent exceeds that of the worldwide semiconductor market at 10 percent, it is quite low in comparison with the growth of the previous five years.

DATAQUEST ANALYSIS

Dataquest believes that there are four primary reasons for the slow growth in 1989: system shipments (primarily computer) were slow; disk drive shipments fell flat in the second and third quarters, hurting mixed analog/digital CBIC suppliers; gate arrays continued to gain ASIC market share (during 1989, gate arrays grew $480 million while CBICs grew $215 million); and chip sets or standard products replaced CBICs in many high-volume applications.

CBIC applications continue to evolve. During the early 1980s, system designers used CBICs over gate arrays when unit volumes were greater than 25,000 to 50,000 a year; by the mid-1980s, gate array pricing plummeted far below CBIC pricing so that the unit crossover point became almost nonexistent. System designers then adopted CBICs over gate arrays when they needed functionality that was not efficient in gate arrays such as memory or analog. Embedded gate arrays (megacells such as memory embedded in the base wafer) now are emerging, and we believe that they will capture a healthy portion of designs that require unique functions.

As we enter the 1990s, Dataquest believes that CBICs will find their place in the ASIC world. We believe that they will continue to dominate gate arrays in automotive, telecommunication, and mixed analog/digital applications. CBICs also are penetrating high-performance applications, primarily computers. Furthermore, Dataquest believes that a new CBIC market is emerging—altered standard products. CBIC libraries and tools are infiltrating many standard product groups in large broad-based IC suppliers. We believe that by the end of the 1990s, most of all standard logic products will be developed using some form of ASIC tools. Many of these standard products will be customized to fit the users' needs through the use of CBICs.

While applications for CBICs continue to evolve, the rewards remain great for those companies that can evolve with the technology.

Bryan Lewis

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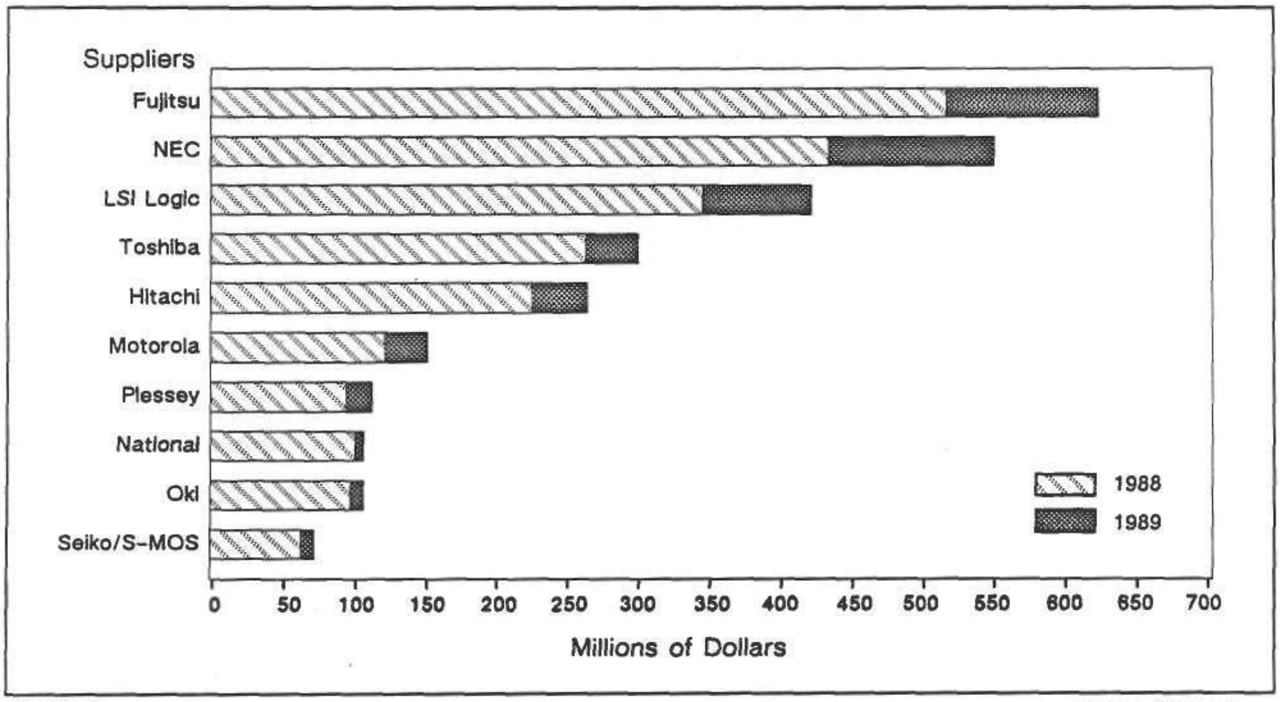
Research Bulletin

GATE ARRAY MARKET SETS RECORDS IN 1989

During 1989, the gate array market reached a record high of $3.5 billion; however, the growth rate for the year also set a record—a record low! Although the gate array market was strong during the first half of 1989, it fell flat in the second half and the year ended with only 16 percent growth—a record low when compared with the previous two years, each of which exhibited growth rates of more than 30 percent. Moreover, during the five years prior to 1989, the compound annual growth rate (CAGR) was a phenomenal 43 percent.

Figure 1 contrasts the growth of the top 10 worldwide gate array suppliers during 1988 and 1989. The average yearly growth for these top 10 suppliers was 20 percent, exceeding the market average by 4 percent.

FIGURE 1
Top 10 Suppliers
Preliminary Worldwide Gate Array Shipments



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Source: Dataquest
February 1990

SIS Newsletters 1990 ASIC

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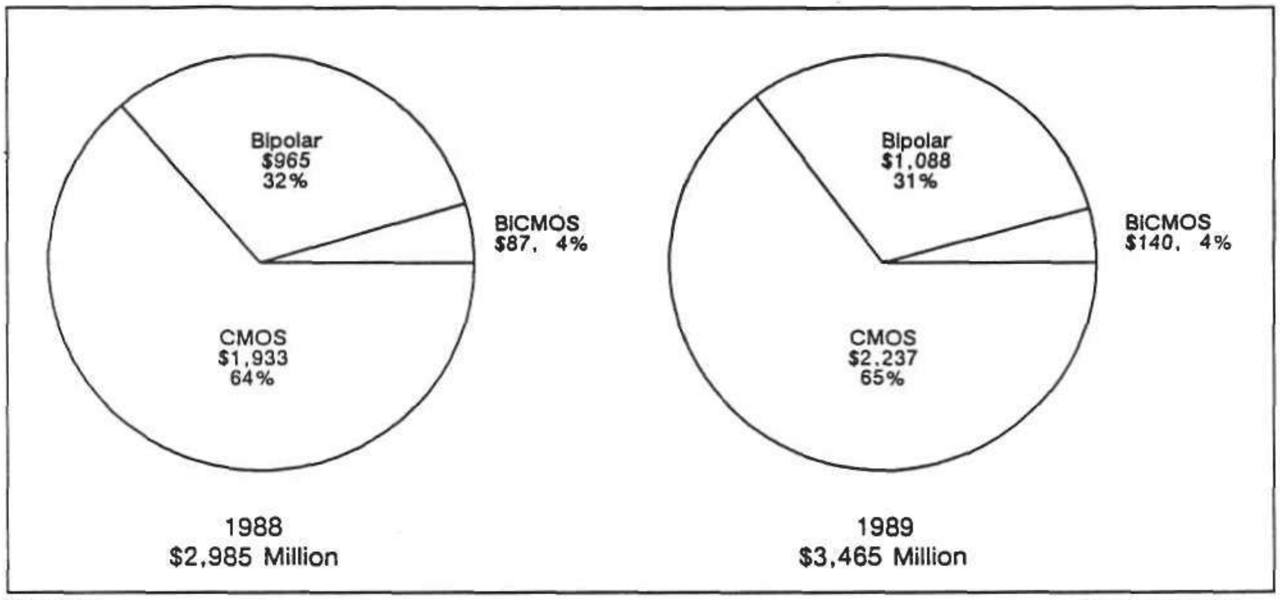
FIGURE 2
Preliminary Worldwide Gate Array Consumption by Technology



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Source: Dataquest
February 1990

Figure 2 illustrates worldwide gate array consumption during 1988 and 1989 by technology. The BiCMOS gate array market grew 62 percent from 1988 to 1989, while the CMOS and bipolar markets grew only 17 and 13 percent, respectively.

DATAQUEST ANALYSIS

Dataquest believes that there are four major reasons for the slow growth in 1989: system shipments (primarily computers) were slow, chip sets replaced gate arrays in many high-volume applications (primarily personal computers), currency fluctuation occurred (yen value compared with the dollar dropped 6 percent), and gate array prices were severely cut.

More than 50 CMOS gate array suppliers are still battling for market share. CMOS gate array pricing is cutthroat. High-volume submicron CMOS gate arrays have started to dip below 0.08 cents per usable gate. We believe that profit margins for most suppliers are negative at this price.

Dataquest believes that 1990 will be another slow year for the gate array market, with only 10 percent growth. During this slow growth period, suppliers need to focus and capitalize on their strengths and steer clear of applications to which they can provide no significant added value. Users need to evaluate their vendors on their strengths and staying power.

During 1989, the top 10 gate array suppliers controlled 78 percent of the total market compared with 75 percent in 1988. The strong are getting stronger. We believe that 1990 will be the year of truth for many gate array suppliers.

Bryan Lewis

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Miles/Feb

6377 2. 1989 ASIAN Activities in GaAs Technology
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Research Newsletter

A GLIMPSE INTO THE WORLD OF ODP

OVERVIEW

Optical data processing (ODP) is a rapidly developing field of applied physics that is relatively untapped by the IC industry. A merging of several disciplines is occurring, the effects of which will continue to be revealed and felt well into the next century. This newsletter offers a brief look at the technologies involved and raises several issues warranting consideration by many of our clients.

WHAT IS IT?

ODP, often referred to as the field of fiber optics, has become an increasing part of our lives in recent years.

Because optical technology uses photons instead of electrons to move data through transmission media (which may include free space), communications are accomplished at much higher speed and lower cost than is physically possible through electronic media such as copper wire. (Electrons are much heavier and therefore more difficult and more costly to manipulate than photons.) The free-space transfer of photons over short distances allows elimination of large numbers of hardware interconnections, enhancing the speed and cost of data processing.

Photonic data buffering, switching, and storage offer the potential to lower computer internal connection costs and communications costs even further. Optical data lends itself to parallel processing, which fits well with the concept of neural networks. Also, optics technology permits efficient implementation of associative (content-addressable) memories, which are very powerful for parallel processing and cache storage.

These realities led to the application of photonic concepts to the data processing within computers and other hardware. Early in 1990, AT&T announced the world's first ODP system, and the company maintains the lead in the race to an all-photonic computer.

All of these factors are spurring interest in ODP, a term coined years ago to describe this emerging field. ODP includes a wide range of disciplines, including holography, liquid-crystal technology, microscopy and telescopy, and others, which will not be discussed herein. This newsletter is confined to ODP as it relates to active devices implemented on or within silicon or compound semiconductor substrates.

TERMINOLOGY

As with any technology, ODP is developing a unique jargon. Several abbreviations relating to this newsletter's discussion are defined as follows:

- BSOC—Bit-serial optical computer
- CAM—Content-addressable memory, a type of memory for which the input is the data and the output is all of the addresses at which the data occurs; also known as associative memory
- CCD—Charge-coupled device, a semiconductor element that stores and moves electron charge packets that are proportional to the photonic energy to which the device is exposed
- CdTe—Cadmium telluride, a compound semiconductor material that has higher photorefractive sensitivity than GaAs, InP, and others
- DSDLM—Digital synchronous delay line memory

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- LCD—Liquid-crystal display
- LCLV—Liquid-crystal light valve
- LED—Light-emitting diode
- $LiNbO_3$—Lithium niobate, a material used in certain photonic couplers
- OEIC—Optoelectronic integrated circuit
- OELE—Optoelectronic logic element
- PIC—Photonic integrated circuit
- PMMA—Polymethylmethacrylate, a material proposed for integrating three-dimensional structures containing lenses and PICs
- SEED—Self-electro-optic effect device
- SESQW—Surface-emitting strained-layer quantum well, a type of laser developed by AT&T
- SSL—Symbolic substitution logic

WHO IS DOING WHAT IN ODP?

Devices that convert photonic energy to electronic energy and vice versa are in mass production in many forms, including CCDs, lasers, LCDs, LEDs and LED arrays, optocouplers, photodetectors, and OEICs. These devices use silicon, GaAs, InP, or other semi-insulating or semiconducting substrates in the manufacturing process. All major, broad-line IC manufacturers have developed considerable expertise in one or more of these products, particularly in those devices that use silicon as the substrate. However, many of these suppliers have little or no R&D activity under way that is directed toward more advanced forms of ODP IC, such as optical (photonic) adders, multipliers, neural network chips, or read-write memories. The usual reason given is the focus on the near term, or next quarter's and this fiscal year's results at the expense of developing long-term survival capability.

Table 1 is a representative listing of organizations and projects involved in the field of ODP. It is by no means exhaustive and will be updated as necessary.

OPEN ISSUES

ODP and photonics-based designs offer many opportunities to make great strides in computing speed and efficiency. However, many issues must be dealt with before the full potential can be realized. The following are some examples of significant problems to be solved:

- Relatively little can be gained by adding photonic interconnections to electronic digital hardware implemented with electronic ICs compared with the approach of all-photonic computing. Thus, system architecture and software requires new approaches.
- Although optical storage systems can hold an order of magnitude more data per unit area than can magnetic disks, access time is relatively slow.
- Using multibeam reading can speed optical storage access by at least two orders of magnitude, which would overload almost all CPUs in existence today.
- No coherent infrastructure supports ODP; a variety of disciplines such as applied physics and applied optics are supporting fragments. Often, little or no dialog exists between ODP and EDP practitioners at any level, from basic materials through IC components to systems hardware and software.
- The first ODP ICs are still in the R&D stage at a few large companies. Very little venture capital has been entered into the race to support start-ups; much will be needed.
- Most CPU-based system architects are bound by thought processes developed around the constraints of electronic ICs. Few corporate management teams are even aware that this may present a long-term survival problem and fewer still really care.

Perhaps the most important issue facing both GaAs and silicon IC houses is this: Is it sufficient to maintain the status quo in electronic devices for EDP systems, or should the horizon be expanded to include all-photonic ICs for the emerging ODP equipment market?

TABLE 1
Representative ODP Activities

Organization	Location	ODP Activity
APA Optics	Blaine, MN	GaAs intensity modulators
AT&T Bell Labs	Holmdel, NJ Naperville, IL Murray Hill, NJ	Developing SEED arrays, photonic cross-bar switches, all-photonic computers, and arrays containing the world's smallest galium arsenide SLSQW lasers
Call/Recall Corp.		3-D memory based on two-photon effect
Carnegie-Mellon University	Pittsburgh, PA	Fast algorithms for optical filter design
City College	New York, NY	CAM-based and other ODP hardware using symbol substitution algorithms
DARPA, USAFOSR, Honeywell, Boeing	Washington, D.C.	Massively parallel optical computer architecture studies
Delft University	Delft, Holland	Application of OELEs to multiprocessing
DSM Research	Geleen, Holland	Implementing OELEs in multiprocessors
Hamamatsu Photonics KK	Hamamatsu, Japan	Learning capability studies of photonic CAMs
Heriot-Watt University, RSRE, ECC; Boeing Aerospace; four other Scottish universities	Edinburgh, UK	Optically bistable filters using GaAs lasers and ZnSe nonlinear photon filters; optical computer storage
Kyushu University	Fukuoka, Japan	Design of laser diode modules with spherical and other lense types
Micracor, Inc.	Boston, MA	Developing the world's first 10¢ laser
MIT Lincoln Labs	Lexington, MA	Gbps board-to-board photonic interconnections
Nestor, Inc.	Providence, RI	Application of optical neural networks to pattern recognition
NTT Labs	Kanagawa and Tokyo, Japan	Developing ODP ICs; implementation of ODP hardware using SLMs in electronic host computer
Opticomp Corp.	Santa Fe, NM	16-bit optical computer architecture

Source: Aztek Associates

TABLE 1 (Continued)
Representative ODP Activities

Organization	Location	ODP Activity
Osaka University	Osaka, Japan	Optoelectronic parallel processing logic
PA State University	ARL State Coll., PA	Optical tunnel applications in computing
Shanghai Institute	Shanghai, PRC	Optoelectronic implementation of cellular logic with polarization coding
Sony, CAL Tech	Tokyo, Japan; Pasadena, CA	ODP hardware development using WORM disk and GaAs neurons
UCLA	Los Angeles, CA	IR neurons implemented in CdTe
University of California/United States Navy Office of Naval Research (USNONR)	La Jolla, CA	3-D memory based on two-photon effect
University of Colorado	Boulder, CO	Building GHz-rate BSOC using $LiNbO_3$ gates and DSDLM storage technologies
University of Neuchatel	Switzerland	ODP hardware R&D using LCLVs and SLMs
USSR Academy of Science	Novosibirsk, USSR	Integrated optical digital computer R&D
University Phys. Institute	Erlangen, FRG	H^+ proton-beam formation of PMMA structures
USAFOSR, Carnegie-Mellon University	Washington, D.C.	Optical computing architectures and algorithms
United States National Science Foundation (USNSF), University of Arizona	Washington, D.C.	SSL algorithm development
USNONR, University of Alabama, Georgia Institute of Technology	Washington, D.C.	Development of ODP algorithms for CAM storage applications
Yonsei University	Seoul, South Korea	R&D of coding algorithms for logic operations in photorefractive crystals

Source: Aztek Associates

DATAQUEST CONCLUSIONS

Dataquest believes that optical data processing is on its way to the marketplace, as exhibited by AT&T's commitment to this technology. The promise of ODP is that it offers major improvements in computing, storage speed, and efficiency, and lower-cost massively parallel data processing systems. As with any technology that has the potential for huge financial rewards for its practitioners, there appears to be a worldwide movement toward accomplishing the R&D needed to generate marketable products. Many significant problems are posed to the eventual participants in this infant industry; the next century will arrive before some of these are solved.

Gene Miles

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Research Newsletter

COMMERCIALIZATION EVIDENT AT 1990 GaAs IC SYMPOSIUM

SUMMARY

The 1990 IEEE-sponsored GaAs IC Symposium, held October 7 through 10 in New Orleans, Louisiana, provided some of the best examples to date of the practical applications of GaAs IC technology. Authors from numerous companies discussed multimillion-dollar programs that are capitalizing on the advantages of GaAs rather than silicon, which now include raw cost in both analog/linear and digital hardware. This newsletter reviews many of the developments presented at the symposium.

EUROPEANS COMMERCIALIZE GaAs ICs

Many GaAs manufacturing projects and programs are now under way in Europe, at the company, country, and European Community (EC) levels. The ESPRIT program, established in 1984, accomplished the feasibility demonstration of such GaAs ICs as 1K and 4K SRAMs (Philips LEP), 4-Gbps MUX/DEMUX (Plessey), and eight-stage multiplication (STL). ESPRIT II is oriented toward high-volume applications such as 20- to 80-GHz communications and automotive hardware and L, X, and Ku-band receivers. The ESPRIT III program is planned for 1991 through 1994. It is likely to include advanced packaging, high-volume material growth, CAD technology, and sub-0.5 micron IC developments.

Individual country programs are under way in Germany, Greece, Italy, the United Kingdom, and others. The programs are supported by GaAs foundry facilities at Daimler Benz, Philips, Plessey, Selenia, Siemens, Telettra, and Thomson, as well as by US and Japanese companies. The largest-volume commercial application of GaAs ICs in Europe to date is the direct broadcast satellite (DBS) receiver. More than 200,000 X-band receivers are manufactured in the United Kingdom each month.

The national program in France is sponsored by several agencies and is believed to be of a similar magnitude as that of Germany. Spain has plans for a future national foundry. Table 1 delineates most of the country programs and EEC programs for GaAs and related development and applications and includes current funding levels.

JAPANESE GaAs ICs GO COMMERCIAL

Japan's GaAs IC developments have been coordinated by MITI since 1981. The careful focus has resulted in a functional GaAs supercomputer and broad applications of GaAs ICs in the communications, industrial, data processing, automotive, and consumer electronics segments. Last month, Dataquest reported that Mitsubishi's GaAs shipments now exceed $3 million per month.

Other GaAs IC suppliers in Japan include Fujitsu, Hitachi, Matsushita, NEC, Sony, Sumitomo, and Toshiba. Since 1989, Fujitsu has had a technology exchange agreement with Vitesse that gives it access to 0.6-micron E/D MESFET arrays of up to 1 million transistors per chip. Sumitomo, Japan's largest GaAs wafer supplier, has a working relationship with GigaBit Logic that is expected to lead to volume GaAs IC production capability at Sumitomo.

End-equipment applications supported by Japanese GaAs IC suppliers include the following:

- Instrumentation—Anritsu and Avantest
- EDP systems—Fujitsu, Hitachi, and others
- Satellite broadcast transmitters and receivers (including 30-GHz transceivers)—Hitachi and NTT

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- TV/VCR front ends—Hitachi and others
- Fiber-optic transceivers, microwave data links—NEC
- Cellular radio transceivers—Fujitsu, Matsushita, NEC, and others
- DSP—Fujitsu and Oki

Other applications include GPS receiver hardware and radar detection, engine speed sensing, and collision avoidance hardware for automobiles. Suppliers of GaAs ICs to Anritsu and Avantest include NEC, Oki, and Toshiba. NEC expects GaAs ICs to compete favorably against silicon in many computer and engineering workstation applications.

TABLE 1
Currently Funded GaAs IC Programs in Europe

Country	Nature of Program	Participating Companies	Funding ($M)
Germany	GaAs and related R&D and applications	Daimler, Siemens, others	90
France	GaAs and related R&D and applications	Alcatel, Thomson, CNET, LEP (Philips), others	(Approx. 90)
Italy	Development of GaAs ICs and discretes	Telettra, Selenia, Italtel, and Elettronica	28
United Kingdom	14 programs in materials and processes; HBT, HEMT, and MESFET applications	Plessey and 15 others	24
Spain	ALE and other materials growth, MMIC design, modeling, and testing	Telettra, Telefonica, University of Barcelona, University of Madrid, National Microelectronic Center	10
Greece	GaAs materials, MMICs, MBE wafers, HBTs, GaAs on silicon wafers	FORTH, Intracom, MITOS, University of Thrace, University of Patras	8
EC	"COSMIC" (MMICs to 23 GHz)	Siemens, Plessey, Telettra, Telefonica, FORTH, Jansen, ArguMens, University of Madrid, University of Rome, PT Torino	70 (Approx. total funding for 6 EC programs)
	"GIANTS" (GaInAs R&D)	Plessey, Thomson, LEP, STL, Picogiga, FORTH, Farran, University of Madrid, University of Lille	
	"PLANET" (MOCVD reactor)	Philips, Aixtron, Polyflow, Telefonica, University of Madrid	
	"MORSE" (MBE growth of HBT and HEMT layers)	Thomson, Riber, RSRE, CNET, FORTH, several universities	
	"AIMS" (20- to 80-GHz receiver front end)	Thomson, Daimler Benz, Alcatel, Electronik Centralen, University of Lille	
	"MONOFAST" (mm-wave design and fabrication techniques)	Alcatel, GaAsCode, Farran Technology, NMRC, others	

Source: Dataquest (November 1990)

GaAs FUELS MEMORIES AND VLSI ARRAYS

GigaBit Logic described two of its GaAs memory ICs now in volume production, a 4Kb SRAM and an 8Kb masked ROM. The SRAM is a pin-for-pin replacement for the silicon ECL 100474, with worst-case cycle time of 2.3ns compared with 5ns for the silicon part. The ROM is a pipelined architecture with on-board translation logic, which allows functioning as a 650-MHz 4Kx8 sine lookup table. Sandia Laboratories funded the ROM chip development.

Other evidence of GaAs VLSI commercialization was provided by Mitsubishi and Rockwell, each reporting 16Kb SRAM availability, and by Sony, with engineers that have developed a 10,000-gate JFET sea-of-gates chip.

Although Vitesse did not make a formal presentation of its Fury gate array series, the company announced a 64x64 cross-point switch based on Fury technology, in parallel with the conference. At one of the panel sessions, a Vitesse representative stated that during the last six months, the company's die sort yields have averaged 55 percent for 5,000-gate E/D MESFET arrays, 35 percent for 15,000-gate chips, and 18 percent for 30,000-gate chips. (Author's note: On November 5, 1990, Vitesse announced availability of VGFX100K and 200K arrays offering 102,000 and 195,000 raw gates for immediate availability and VGFX350K arrays with 353,000 raw gates per chip for second quarter 1991 designs. A VGFX350K chip will contain more than 1,000,000 transistors).

HBT TECHNOLOGY PRODUCES COMBO ICs

Heterojunction bipolar transistor (HBT) AlGaAs/GaAs technology offers many advantages over its silicon counterpart. These advantages include higher cutoff frequency (f_t), higher speed, more efficient speed-power product, reduced base resistance, and semi-insulating substrate. Rockwell has developed a high-yield GaAs HBT process, which satisfies the requirements of Table 2. The potential of the process has been demonstrated in 27-GHz frequency dividers, 10.3-ps/stage ring oscillators, and 98-GHz common emitter transistors, all produced on the same wafer. Yield for the transistors, which have f_{max} of 218 GHz, was more than 90 percent. The company has also operated an HBT phase-detector chip containing 134 HBTs. Using this technology, Rockwell is developing a single-chip digital PLL with voltage-controlled oscillator.

Other groups represented at the conference reported progress in HBT technology. Those included CNET and Thomson (France), FORTH (Crete), Hughes, Pacific Monolithics, and TRW (United States), Plessey (United Kingdom), and Toshiba (Japan), as well as several universities.

TABLE 2
Requirements for Multifunctional HBT ICs

Parameter	Analog ICs	Digital ICs	Microwave Power ICs
f_t	Very high	High	Very high
f_{max}	Very high	High	Very high
R_b	Low	Low	Very low
C_c	Low	Low	Very low
C_{bc}	Low	Very low	Low
Beta	10-30	20	10-20
BV_{ceo}	>10V	>2V	>10V
BV_{cbo}	>5V	>3V	>20V
V_{be} control	Good	Good	Good
Yield	High	Very high	High
Transistor Size	Moderate	Small	Large
Signal Level	Small	Small	Large

Source: Rockwell

DATAQUEST CONCLUSIONS

The conferees confirmed that GaAs IC technology is gaining momentum throughout the world market and is well past the critical mass requirements for marketability and volume consumption. Although some participants question the viability of Vitesse's 1,000,000-transistor chips in the near term (i.e., mid-1991 production), there was no apparent doubt about the production worthiness of GaAs VLSI. The Fujitsu/Vitesse and Thomson/Vitesse alliances and the reported progress on the Japanese National Supercomputer project are good indicators that the days of United States dominance of the supercomputer marketplace now hinge on a major turnaround in the recent lackluster performance exhibited by the shutdown of Prisma and by CRAY, IBM, and the other US-based supercomputer system houses.

Evidence of the approaching threat of the superior performance of HBT technology to that of E/D MESFET and JFET is mounting. One wonders if the CRAY 4 should stick with the E/D MESFET approach or switch to HBT. However, Dataquest expects E/D MESFET to continue to grow rapidly into the mid-1990s because of its cost/performance advantages over silicon ECL and BiCMOS for mainstream EDP and digital communications designs.

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Research *Bulletin*

GaAs ICs PROPEL JAPAN'S NATIONAL SUPERCOMPUTER

SUMMARY

Hitachi recently described test results for the Japanese National Supercomputer Project. This bulletin reviews highlights of the presentation.

DISCUSSION

In 1981, Dataquest reported that Japan was embarking on a nine-year program to gain national advantage in the computing field. A major ingredient of this program was the Fifth-Generation Computer Project sponsored by Japan's Ministry of International Trade and Industry (MITI). Japanese government funding of approximately $120 million, supplemented with R&D by Fujitsu, Hitachi, Mitsubishi, NEC, Oki, and Toshiba, supported the effort. Objectives included a thousandfold improvement in computing speed and a hundredfold reduction in package volume.

To achieve system performance objectives, device technology requirements were set at 30 picoseconds per gate (ps/gate) at room temperature and 10 ps/gate at 77°K for logic LSI chips and at sub-10ns cycle time for 16K SRAMs at room temperature. The demonstration hardware consisted of a high-speed parallel processor with four processing elements, a distributed parallel processor, and a 4Gb high-speed storage unit. In January 1990, the demonstration unit was operated at 10.9 Gflops (billions of floating-point operations per second). GaAs IC applications in the demonstration system were as follows:

- Bus drivers for HPP—1.1K-gate logic LSI using 0.5-micron-gate AlGaAs/GaAs HEMTs (8 chips, supplied by Fujitsu)
- Pseudorandom number generator—3.3K-gate E/D DCFL HEMT LSIs operated at 77°K (8 chips, supplied by Fujitsu)
- System controller—1.3K-gate HEMT LSIs with 17ps gate delay, operated at 77°K (4 chips, supplied by Fujitsu)
- Data buffer—0.7-micron-gate HEMT-based 4Kb SRAMs with 0.5ns cycle time, operated at 77°K (8 chips, supplied by Hitachi)
- Cellular array processor—16Kb (4Kx4) SRAMs with 4.4ns access time, using buried-p-layer, lightly-doped-drain MESFETs and three-layer metal interconnects (64 chips, supplied by Mitsubishi)
- Variable pipeline processor—3,376-logic-gate and 76-bit dual-port register-file (8-bit bus logic) LSIs using 0.8-micron-gate MESFETs (48 chips, supplied by Toshiba)
- Display processor—100-gate and 700-gate, 0.5-micron inverted-HEMT MSIs, one each per chip set (6 chips)

The aforementioned chips were used to implement a demonstration system that transferred data from storage at 1.6 Gbytes per second (Gbps) and performed color signal processing at 400 MHz. The four-element parallel processor was operated at 10.9 Gflops, placing it near the high end of available supercomputing systems. Based on demonstrations already completed, Hitachi concluded that GaAs LSI is ready for the mainstream EDP marketplace.

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Research Newsletter

GaAs ICs BOOST III-V COMPOUND SEMICONDUCTOR GROWTH RATE

SUMMARY

GaAs IC growth through 1994 is expected to exceed Dataquest's forecast of December 1989, primarily because of aggressive entry of several markets by Japanese suppliers. Optoelectronic semiconductor shipments continued to increase during the first nine months of 1990 and are forecast to grow nearly 5 percent in 1990 over 1989. The outlook through 1994 has improved over last year's forecast. This newsletter examines the updated forecast and includes, for the first time, regional data by major product groups.

DATAQUEST ANALYSIS

GaAs and related III-V compound semiconductor ICs and discretes became a $3 billion market in 1989, with GaAs ICs and microwave/millimeter-wave (mm-wave) discrete shipments constituting 20 percent of the total. The worldwide market compound annual growth rate (CAGR) for these devices is forecast at more than 16 percent through 1994 (see Table 1). The North American market will increase somewhat more slowly, at slightly less than 15 percent (see Table 2). Europe will experience double-digit growth also, at more

TABLE 1
Estimated Worldwide GaAs Semiconductor Merchant Consumption
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1994
Total	2,723	3,012	3,242	3,874	4,661	5,536	6,430	16.4
Analog/Linear ICs	157	187	242	319	407	514	643	28.0
Devices	107	141	194	272	368	472	600	33.6
NRE	50	46	48	47	39	42	43	(1.3)
DigICs	86	117	168	264	425	586	725	44.0
Devices	51	88	140	236	391	545	682	50.6
NRE	35	29	28	28	34	41	43	8.2
Optoelectronics	2,237	2,417	2,535	2,973	3,484	4,060	4,652	14.0
Discretes and CCDs	2,179	2,340	2,434	2,826	3,292	3,795	4,304	13.0
OEICs	58	77	101	147	192	265	348	35.2
Microwave/mm-wave								
Discretes	243	291	297	318	345	376	410	7.1

Source: Dataquest (October 1990)
Note: Data include intracompany consumption for merchant suppliers and exclude intracompany consumption by full captives. Optoelectronics include silicon IR emitters, silicon photodetectors, and laser drivers.

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TABLE 2
Estimated North American GaAs Semiconductor Merchant Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1994
Total	717	788	835	981	1,143	1,337	1,577	14.9
Analog/Linear ICs	137	159	183	218	266	322	389	19.6
Devices	89	116	141	182	240	295	361	25.5
NRE	48	43	42	36	26	27	28	(8.2)
DigICs	69	92	111	166	229	285	365	31.7
Devices	37	66	92	149	208	259	336	38.5
NRE	32	26	19	17	21	26	29	2.2
Optoelectronics	394	406	420	470	516	588	675	10.7
Discretes and CCDs	353	353	353	382	405	439	477	6.2
OEICs	41	53	67	88	111	149	198	30.2
Microwave/mm-wave								
Discretes	117	131	121	127	132	142	148	2.5

Source: Dataquest (October 1990)
Note: Data include intracompany consumption for merchant suppliers and exclude intracompany consumption by full captives. Optoelectronics include silicon IR emitters, silicon photodetectors, and laser drivers.

TABLE 3
Estimated Western European GaAs Semiconductor Merchant Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1994
Total	351	386	415	477	544	650	746	14.1
Analog/Linear ICs	15	17	20	28	37	59	91	39.9
Devices	13	15	17	23	31	52	84	41.1
NRE	2	2	3	5	6	7	7	28.5
DigICs	8	11	13	17	34	59	73	46.0
Devices	6	9	11	14	31	55	69	50.3
NRE	2	2	2	3	3	4	4	14.9
Optoelectronics	309	336	359	409	449	507	557	10.6
Discretes and CCDs	306	331	351	394	428	472	511	9.1
OEICs	3	5	8	15	21	35	46	55.9
Microwave/mm-wave								
Discretes	19	22	23	23	24	25	26	3.4

Source: Dataquest (October 1990)
Note: Data include intracompany consumption for merchant suppliers and exclude intracompany consumption by full captives. Optoelectronics include silicon IR emitters, silicon photodetectors, and laser drivers.

Table 4
Estimated Asia/Pacific GaAs Semiconductor Merchant Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1994
Total	1,655	1,838	1,992	2,416	2,974	3,549	4,106	17.4
Analog/Linear ICs	5	11	39	73	104	133	163	71.5
Devices	5	10	36	67	97	125	155	73.0
NRE	0	1	3	6	7	8	8	51.6
DigICs	9	14	44	81	162	242	287	83.0
Devices	8	13	37	73	152	231	277	84.4
NRE	1	1	7	8	10	11	10	58.5
Optoelectronics	1,534	1,675	1,756	2,094	2,519	2,965	3,420	15.3
Discretes and CCDs	1,520	1,657	1,730	2,050	2,459	2,884	3,316	14.9
OEICs	14	19	26	44	60	81	104	40.5
Microwave/mm-wave								
Discretes	107	138	153	168	189	209	236	11.3

Source: Dataquest (October 1990)
Note: Data include intracompany consumption for merchant suppliers and exclude intracompany consumption by full captives. Optoelectronics include silicon IR emitters, silicon photodetectors, and laser drivers.

than 14 percent (see Table 3). The Asia/Pacific region is forecast to gain market share, growing more than 17 percent through 1994 (see Table 4).

The outlook for digital ICs (digICs) is that they will have a 50 percent growth rate worldwide for the next five years. Asia/Pacific is expected to lead this growth with an increase of more than 80 percent per year (see Table 4). Fujitsu will capture much of the worldwide market share, leveraging from its dominant positions in emitter-coupled logic (ECL) ASICs and ECL RAMs and its acquisition of ICL's computer and Vitesse's submicron E/D MESFET ASIC technologies.

Nonrecurring engineering (NRE) revenue has softened as major programs have moved from the development stage to various levels of volume production. Analog/linear NRE is forecast to decline through 1992, as the US Department of Defense (DOD) MIMIC program insertion activities evolve from R&D to production status.

Although discrete optoelectronic devices and charge-coupled devices (CCDs) will continue to provide the majority of the compound semiconductor market segment's revenue, their percentage of the total will decline from 80 percent in 1989 to less than 70 percent in 1994, at $4.3 billion. Japan's shipments will constitute approximately 80 percent of that total by 1994, up from 70 percent of the 1988 market.

Microwave and mm-wave discrete demand will continue modest growth through the mid-1990s. These devices provide users with the ability to exceed IC performance levels in special situations such as ultralow-noise amplifiers and, as a result, will enjoy ongoing niche markets.

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Research Newsletter

RECENT EVOLUTION IN MMIC TECHNOLOGY

SUMMARY

GaAs microwave monolithic ICs (MMICs) are becoming more pervasive in commercial applications, and military insertions of this and related technologies are on the rise. Large-volume production is under way at several GaAs MMIC facilities, with major expansions either completed or in progress. This multitopic newsletter focuses on recent developments and trends in the increasingly important field of III-V compound MMICs, which are believed to be of significance to many of Dataquest's clients.

TREND TOWARD MULTIFUNCTION CHIPS

As MMIC process refinements continue, more multifunction, multiuse chips are emerging from the GaAs IC laboratories in reproducible form. Examples include MMICs and LSI chips recently built by ITT and NTT. Such ICs are finding their way into avionics hardware and will soon be applied to consumer products.

Radar Applications of Multifunction MMICs

The ITT GaAs Technology Center (GTC) recently reported test results on six types of multiuse GaAs ICs designed for radar and other applications. The chips were fabricated on ITT GTC's 0.4-micron multifunction self-aligned gate (MSAG) process. The chip set includes a redundant switch, broadband amplifiers, A/D converter, buffered prescaler, and sample-and-hold (S/H) circuits. Both low-noise and power MMICs and high-speed LSI-density logic are fabricated on the same chip. The overall RF yield achieved on a lot basis was 19 percent for the buffered prescaler. Chip yield for the sample-and-hold IC was 97 percent.

MMIC Ku-Band PLL Synthesizer

NTT's Radio Communication Systems Laboratory and LSI Laboratories have developed a MMIC and an LSI chip that together perform Ku-band frequency synthesis. The MMIC consists of a voltage-controlled oscillator (VCO), a dual-output buffer amplifier, a balun, and prescalers. The LSI chip contains a dual-modulus prescaler, programmable counters, and a phase/frequency comparator. The two chips are packaged in an 11 x 23mm flatpack. NTT expects this technology to be applied to personal wristwatch telephones, pocket-size satellite videophones, and other radio-communication systems.

JAPAN'S SPACE PROGRAM USES GaAs MMICs

Japan has an aggressive space program under way, which ranges from communications satellites to plans for landing payloads on the moon. A recent report written by engineers of two NTT laboratories, ATR Research Labs and Japan's National Space Development Agency, describes a Ka-band (20 to 30GHz) MMIC receiver module.

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The module uses GaAs MESFET chips to implement trim-free 30-GHz receivers for transponders on the ETS-VI satellite, which Japan will launch in 1993. NTT's LSI Laboratories supplied the chips, which allowed a reduction in the weight of the module to 200 grams, a factor of six lower than the weight of the conventional hybrid approach.

MIMIC PROGRAM PROGRESS

The US Department of Defense (DOD) MIMIC program now is partially through Phase 1, which began in mid-1988. Four teams consisting of a total of 26 companies are participating in the program. By mid-1990, the teams reportedly were responsible for 79 chip types, 23 module assemblies, and 16 system brassboards.

Each of the teams has in place a pilot production facility that is capable of 100 3-inch wafer starts per shift per week. One MIMIC Phase 1 team, led by Hughes and GE, has validation work under way at five foundries: AT&T, GE, Harris, Hughes, and M/A-COM. Another team, led by Texas Instruments and Raytheon, had achieved production costs of less than $3 per square millimeter of chip area.

During the first 18 months of Phase 1, one of the MIMIC manufacturing teams experienced chip production cost reduction of a factor of six on small-signal amplifiers and a factor of 2.5 reduction for higher-output power circuits. Package costs and test costs are being vigorously attacked to improve overall system costs. Early in 1989, the HARM missile program started using 1,200 MIMICs per month, and commercial applications of MIMIC-type devices now are occurring in the automotive industry. Texas Instruments expects to produce about 80,000 MIMICs for the HARM missile program.

A parallel Phase 3 MIMIC program also is under way, with 12 critical technology developments in progress in such areas as GaAs epi growth, multichip ceramic packages, modeling, and testing. MIMIC Phase 2, which will follow Phase 1 completion, remains scheduled to start in September 1991.

FORD MICRO DESIGNS 20 MMICS FOR US NAVY

Ford Microelectronics Inc. (FMI), which has been developing GaAs ICs for more than six years, has completed first-pass designs of 12 custom and 8 ASIC MMIC chips for the US Naval Electronics Center. All of the designs are intended for use in navy system applications. The chips are to be fabricated at FMI's Colorado Springs, Colorado, fab facility.

ADVANCES IN PRODUCIBILITY

In addition to ITT's high yields and TI/Raytheon's joint venture progress described earlier, Sumitomo and others have reported excellent results in advancing the state of the art of GaAs wafer and chip production.

Sumitomo Refines Its Wafer Production

Sumitomo has developed a mass-production back-grinding technology for thinning GaAs wafers containing MMICs to less than 150 microns. The technique incorporates a chemical etch after the grinding operation to reduce wafer bow induced during the grinding operation. The use of this approach caused threshold voltage shift of less than 5mV. The technique was demonstrated on a 16x16 parallel multiplier IC as well as on SSI-density OEICs. Sumitomo now uses this technology in the production of raw wafers as well as in IC manufacture.

TREND TOWARD COMMERCIAL APPLICATIONS

Widespread commercial consumption of GaAs MMICs is now evident, a sure sign that this once-infant technology is growing up. The adoption of GaAs ICs into TV receiver downconverters, GPS receivers, and cellular telephones has accelerated commercial consumption of MMICs. While the US commercial consumer-oriented market for TVRO MMICs was virtually destroyed by the combined lobbying of TV program producers and cable companies, the Asian and European markets have developed very rapidly. ANADIGICS, Hitachi, and Mitsubishi are three major benefactors.

Besides the personal communications applications anticipated by NTT, other markets are emerging. These markets include MMICs for proximity detection devices (as demonstrated by General Motors in 1989), GaAs ICs for industrial and medical instrumentation, and GaAs integrated sensors for a variety of applications. The pocket-sized location devices and radio/telephones are also expected to become high-volume users of GaAs MMICs.

ANADIGICS Producing 1 Million MMICs for British Application

The monolithic down converter, developed initially in GaAs MMIC form by Pacific Monolithics, finally is in mass production for the European marketplace. One of the largest commercial GaAs MMIC orders to date was placed by British Satellite Broadcasting with ANADIGICS, Inc. of Warren, New Jersey. ANADIGICS reportedly has achieved a run rate exceeding 70,000 ICs per month on the device, which is a MMIC downconverter used in home TV receiver antenna circuits. The 2 x 2mm die, which is of MSI complexity, is packaged in a modified TO-5 header. The average selling price (ASP) for the device on the approximately 1-million-piece contract is approximately $8.

Hitachi Plans 200,000 DBS MMICs per Month by Mid-1991

Hitachi began producing its DBS tuner ICs in June 1990. The chips were developed for cost and power reduction rather than performance improvement. The prescaler will sell for approximately $3 and the amplifier for less than $1. Hitachi plans to market the MMICs in the United States and Europe. The company expects production volume to exceed 200,000 per month by July 1991; the percentage committed for internal use was not disclosed.

Mitsubishi's GaAs IC Volume Approaches $3 Million per Month

Mitsubishi Electric Company reportedly has increased its GaAs IC production volume to more than ¥4.5 billion (more than $30 million). The company manufactures MMICs for satellite broadcasting, as well as GaAs ICs for other applications. An unspecified percentage of the production is for internal consumption.

IMPROVEMENTS IN SILICON MMICs CITED BY AVANTEK

Engineers in Avantek's Advanced Bipolar Products Group recently reported a semicustom array approach to silicon MMIC implementation, trademarked "star-CHIP-1" by Avantek. The 40x60 mil die contains 92 low-noise npn transistors, 394 thin-film resistors, and 24 bonding pads. The die can be housed in a 180-mil hermetic package.

Experience on two circuits developed using this approach indicates that the prototyping cycle can be reduced to seven weeks compared with five months or more for full-custom designs. NRE break-even volume of a full-custom design for either function has been estimated to be approximately 10,000 units. The engineers consider this approach to be more cost-effective than a GaAs implementation for devices requiring operation below 5 GHz.

INP ICs FOR MM-WAVE APPLICATIONS

GaAs ICs fabricated to 0.5 micron or greater process rules tend to reach a performance barrier in the neighborhood of 40 GHz. The millimeter-wave (mm-wave) frequency band ranges from 30 to 300 GHz. Thus, mm-wave ICs producible to early to mid-1990s design rules require a higher-mobility substrate such as indium phosphide (InP).

InP wafers have been used for several years to build certain types of optoelectronic chips. There are now several suppliers of high-quality InP wafers, and chip designers have gravitated toward this material for fabrication of mm-wave ICs. Examples of recently designed InP ICs include Rockwell's 62 GHz multistage HEMT amplifier and Varian's 100-GHz high-gain cascode amplifier.

More high-performance mm-wave ICs are expected to result from a recent innovation by Hughes scientists. The team at Hughes has fabricated 250-GHz HEMTs on InP, which is more than 60 percent faster than the reported IBM record for silicon. The Hughes device should lead to even higher frequency operation than reported by Varian.

DESIGN SOFTWARE

Another indication of relative maturation of GaAs MMIC products is the growing availability of software for IC circuit design. Table 1 lists representative software products, approximate costs (to single users), and North American suppliers. There is no apparent relationship between cost and number of circuit models included in the various software packages. More than 50 percent of the sources shown are based in the Silicon Valley, and another 20 percent are in other California locations.

TABLE 1
MMIC Design Software Examples

Program	Approximate Cost	Supplier	Location
Contec Spice	To $10K	Contec Microelectronics	San Jose, CA
HaRPE	To $24K	Optim. Systems Assoc.	Dundas, Ont., Canada
H-Spice	To $90K	Meta-Software Inc.	Campbell, CA
Icap	$1.1K	Intusoft	San Pedro, CA
IC-CAP	To $69K	Hewlett-Packard	Palo Alto, CA
Libra	$24K	EESof Inc.	Westlake Village, CA
Mac Spice	$2K	Deutch Research	Palo Alto, CA
Micro-Cap III	$1.5K	Spectrum Software	Sunnyvale, CA
Microwave Harmonica	To $365K	Compact Software	Paterson, NJ
Microwave Spice	To $12K	EESof Inc.	Westlake Village, CA
MNS/MDS	To $45K	Hewlett-Packard	Palo Alto, CA
NANA/Agile	$2K	Sarnoff Res. Ctr.	Princeton, NJ
P Spice	To $30K	MicroSim Corp.	Irvine, CA
Precise	To $80K	Elec. Engrg. Software	Santa Clara, CA
RoMPE	NA	Compact Software	Paterson, NJ
Scout	$3.5K	Compact Soue ťware	Paterson, NJ
Serenade	To $260K	Compact Software	Paterson, NJ
Spectre	$0.15K	UC Berkeley	Berkeley, CA
Spice	$0.15K	UC Berkeley	Berkeley, CA
Spice w/interactive graphics	$19K	A.B. Associates	Tampa, FL
S Spice	To $25K	Silvaco	Santa Clara, CA
Super Compact	NA	Compact Software	Paterson, NJ
Suxes 20	To $35K	Elec. Engrg. Software	Santa Clara, CA
Toast-TCSB	$25K	Caroline Hablgand	Montreal, Que., Canada
Turbo Spice	$1K	Deutch Research	Palo Alto, CA
Utmost II	To $60K	Silvaco	Santa Clara, CA
Xtract	To $28K	EESof Inc.	Westlake Village, CA

NA = Not applicable
Source: Dataquest (September 1990)

DATAQUEST CONCLUSIONS

Major advancements in the field of GaAs MMICs have occurred in the past several months. These events are not isolated; rather, they emphasize the growing acceptance of MMIC technology in a wide range of applications, similar to the silicon linear IC experience in the 1970s. The large investments of resources during the mid- to late 1980s have started to reward suppliers that had the staying power to continue their contributions to this technology.

Dataquest believes that the successes reported herein are just the "tip of the iceberg" and that consumer GaAs MMICs will become significant revenue generators by the mid-1990s. To date, Japan has taken the lead in high-volume commercial applications while continuing to follow American design expertise. Thus, IC shipment and market penetration history is again repeating itself, with more market position shifts to come. American and European consumer electronic equipment suppliers can expect another onslaught of Japanese hardware in their respective markets, made more competitive by the adoption of GaAs ICs.

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Research Newsletter

UPDATE ON GaAs RAMs

The increasing demand for GaAs RAM* ICs has resulted from the growing use of digital GaAs in high-speed data processing systems. This demand is driving the evolution of more sophisticated GaAs memory chips, including both static and dynamic RAM (SRAM and DRAM) devices. As a result, conventional silicon RAMs are being challenged in certain IC storage applications, such as high-performance cache. This newsletter examines many of the recent developments in this technology.

THE IMPACT OF COST-EFFECTIVE GaAs VLSI

Until the late 1980s, highly reproducible GaAs ICs were confined to gates-per-chip counts below 5,000, limiting GaAs RAMs to low density.

Although one Japanese company proposed a 64K GaAs SRAM in the mid-1980s, the majority of chips produced today are at the level of 1 to 4 Kbits (Kb) per chip. In 1988, GaAs digIC chip complexity surged through the 10,000-gate-per-chip level, and in 1989 GaAs gate array pricing crossed below that of silicon ECL. At least one GaAs digIC supplier now promotes its GaAs gate arrays as performing 50 percent faster than the silicon ECL counterparts while consuming one-fifth of the power. Multisourced 30,000-gate GaAs chips now are offered on a production basis, and 100,000-gate GaAs arrays are expected by early 1991.

Such developments have pushed processing capability sufficiently to support the production of GaAs 16K SRAM and 64K DRAM designs. And, GaAs processing capability is by no means mature. Currently, GaAs VLSI arrays use processes resulting in a minimum FET gate length of 0.8 to 1.0 micron. ITT has developed a manufacturable 0.4-micron process, and almost all of the present GaAs IC fabrication processes are scalable on existing factory tooling. Thus, production of GaAs RAM ICs above 64Kb density should become feasible in the early 1990s.

THE CASE FOR GaAs DRAMs

The majority of silicon IC users and producers alike have disallowed the need for and in many cases the possibility of developing GaAs DRAMs. This bias arises from the fact that DRAMs represent the lowest cost-per-bit form of semiconductor read-write memory, and GaAs is not viewed as being potentially cost-competitive with silicon. Furthermore, some US-based GaAs IC producers have feared an onslaught of Japanese competition once the market for GaAs SRAMs grows into the $100 million range, and they do not wish to develop additional markets that would invite a repetition of the penetration of many of the existing IC memory markets by Japanese suppliers. Now that Fujitsu is constructing a ¥30 billion GaAs fab facility, such fears may become justified.

However, some organizations including the US Navy's Office of Naval Research (ONR) perceive sufficient need and merit to invest resources in this technology. Layered memory designs, such as those in 386- and 486-based personal computers on the low end and supercomputers on the high end, use small, fast caches backed by large (4MB and up) IC main storage and much larger (40MB to multigigabyte) disk storage.

*Note: The term RAM has been used for more than 30 years to denote read-write random access memory. The practice continues in today's jargon, although technically the various types of IC read-only and content-addressable memories also may be randomly accessed. Dataquest uses the same convention as others; thus, this report is confined to read-write RAMs.

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Additionally, a need is evolving for very fast (200ps to 2ns access time) chips in the 16- to 256Kb-per-chip capacity range to support the cache memory requirements of certain types of systems now on the drawing board. Silicon memory design effort is not expected to result in a viable approach to this requirement before the mid-1990s, if ever. GaAs DRAMs producible on existing GaAs fab lines offer a promising near-term solution to this particular problem.

PROGRESS IN GaAs DRAMs

Because GaAs SRAM designs require relatively high power per cell (silicon SRAMs need even more power during the operating state), GaAs DRAM cells have been developed as a possible alternative. To date, one-transistor GaAs DRAM cells have exhibited data retention times on the order of 15 minutes without refresh at room temperature, and acceptable data retention above 125°C has been projected from the test results. Power required to maintain storage was approximately two orders of magnitude below that of GaAs SRAM cells. Both MESFET- and JFET-accessed cell implementations using all-implant (no diffusion) processing have been examined.

Dataquest believes that a new niche market opportunity, which could quickly grow beyond $100 million annually, exists for fast, intermediate-density GaAs DRAMs. And, the availability of such devices would spur market growth for other GaAs and silicon ICs, increasing the IC TAM.

OPTOELECTRONIC RAMs

AT&T and Matsushita each have recently reported development activities involving the incorporation of photonic devices in memory storage arrays. The AT&T approach incorporates 2,048 multiple-quantum-well (MQW) devices called symmetric self electro-optic effect devices (S-SEEDs), each of which can function as an optical switch, a logic gate, or a storage element. The Matsushita design uses InP as the substrate material, which promises higher speeds than achievable on GaAs wafers. Dataquest is following this work and expects to publish a newsletter on these designs and related developments later this year.

GaAs SRAMs IN MID-1990

Several manufacturers including GigaBit Logic, McDonnell Douglas, Rockwell, Texas Instruments, and Vitesse now produce and market GaAs SRAMs at the 1- to 16K-density level. The GigaBit and Vitesse products are aimed primarily at the commercial market, with the other US suppliers supporting military/aerospace needs as top priority. Most of the designs were in response to requirements for characteristics other than raw speed, and none appear to have stretched the respective production technologies to the achievable limit of cycle time. Additionally, some Japanese and European companies, including Fujitsu, Hitachi, LEP (Philips), and Mitsubishi, have developed GaAs SRAMs, initially for R&D purposes, internal consumption, and/or technology exchanges.

An excellent example of a special-purpose SRAM chip design was recently reported by Texas Instruments. The TI chip, called a programmable delay line element (PDLE), contains 4,096 bits of SRAM and 750 gates of control logic. It is processed to 1.0 micron, recessed-gate, E/D MESFET design rules and incorporates two-layer metal interconnects. Chip I/O levels are ECL 50-ohm line compatible, and the ICs are cascadable to form as long a delay line as required for a given application.

Another example of a special-purpose GaAs IC containing a combination of RAM and logic gates is Vitesse's VSC20K8R, described as a 20,000-gate array with embedded 8K SRAM. The chip, based on Vitesse's Fury Series, has eight independently addressable 256- x 4-bit SRAMs, surrounded by approximately 20,700 2-input NOR gates. Gate delays (unloaded) are 90ps and SRAM cycle times are 3,500ps. The IC is packaged in a 344-pin leaded chip carrier and allows 256 signal I/Os that may be ECL, TTL, or GaAs compatible. Vitesse offers other SRAM-gate array combination options to the user, with embedded SRAM array sizes to 16Kb and gate counts to 30,000. Fujitsu has an alternate source agreement with Vitesse for all Fury Series devices, including the VSC20K8R.

Vitesse has also announced a 4K SRAM having a "clear-all-bits-to-zero" capability. The 28-pin, ECL-compatible device has a maximum cycle time of 5ns and dissipates less than one watt. The chip features registered inputs, latched outputs, and internal write-pulse generation, which simplifies system control logic.

RECENT DEVELOPMENTS IN GaAs SRAMs

Recent development activity in GaAs SRAMs has largely been limited to refining previously announced products. Titles of papers to be presented in the near future include the following:

- "A GaAs Pin-for-Pin Replacement for the ECL 100474 4K SRAM" by A. Fiedler (GigaBit Logic)
- "Development of SRAMs Using Complementary HIGFET Technology" by D. Grider et al. (Honeywell)
- "A High-Speed GaAs 16Kb SRAM of 4.4ns/2W Using Triple-Level Metal" by H. Nakano et al. (Mitsubishi)
- "A Low-Power 16K GaAs HMESFET SRAM with Built-In Redundancy" by T. Tsen et al. (Rockwell)

DATAQUEST CONCLUSIONS

Progress in GaAs RAMs has been limited more by the extent of resources applied than by any particular technical problem or class of problems. Much inertia has resulted from some companies' fears of phantom competition, causing US GaAs suppliers to allow silicon RAM suppliers to continue dominating the high-performance end of the IC RAM marketplace.

Niche markets exist, notably in special-purpose SRAMs, fast medium-density DRAMs, and the emerging photonic and optoelectronic memory markets, for innovative GaAs RAM products. However, as is the case throughout the IC world, there is the attendant, ever-present risk of growing competition. As Douglas MacArthur said, "There is no security on this earth. Only opportunity."

Gene Miles

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Research *Bulletin*

VARIAN OEICs ENABLE OPTICAL TRANSFER OF ELECTRICAL POWER

Varian Associates, Incorporated, has developed optoelectronic integrated circuits (OEICs), which enable the optical transfer of electrical power through a fiber cable. This breakthrough makes possible a host of applications that were heretofore not feasible and promises incremental growth in the GaAs OEIC market.

GaAs OPTICAL POWER CONVERSION

Because GaAs circuits respond to incident light and may be designed to operate at light-wave frequencies, it is possible to build ICs that convert light into electrical power. Varian's VRC PR-6C power receiver is one of an emerging family of GaAs OEICs that accomplish this task in a single chip. Electrical power operating a laser diode is converted to light at a frequency at or near the visible spectrum; the light then is transferred through a fiber-optic cable to a point near the VRC PR-6C, which converts the light back into electrical power at an efficiency that can approach 50 percent. Thus, the power receiver is operating in a fashion similar to that of a group of interconnected solar cells.

VARIAN'S APPROACH

The VRC PR-6C is believed to be the first OEIC capable of converting optical energy to a 6V electrical output of up to 1 watt. To produce the device, Varian uses proven GaAs IC production technology, including air bridges to interconnect the circuit sections. The active area of the chip is relatively small, with a diameter of 3 millimeters. Because the device responds efficiently to light of wavelengths in the range of 800 to 850 nanometers as well as to IR light of wavelengths longer than 900 nanometers, the chip can be used in systems where power and data are transferred over a single fiber cable.

POTENTIAL APPLICATIONS

A multitude of needs are uniquely met by the optical transfer of electrical energy. The elimination of electrical power transfer in situations involving life support or intrusion of the human body, for example, lowers the risk of shock. Spark hazards in volatile atmospheres can be similarly reduced. Electromagnetic interference (EMI) in such applications as aircraft control systems and other critical sensor systems can be virtually eliminated. By transferring power and data over single fibers at optical frequencies, interconnections within computers may be greatly simplified.

DATAQUEST OBSERVATIONS

Dataquest believes that Varian's accomplishment in developing the VRC family of power receiver chips is significant and merits recognition. Like the operational amplifier IC and the microprocessor, the existence of optical power converter ICs is expected to increase the pervasiveness of monolithic chip technology in everyday life. Dataquest believes that this breakthrough is just the first in a new stream of developments that will impact the direction of future design of systems employing IC technology

Gene Miles

SIS Newsletters 1990 GATA

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Research Newsletter

GaAs MATERIALS REVISITED: THE SHAKEOUT TAKES ITS TOLL

SUMMARY

Two years ago, Dataquest reported that more than 40 companies were addressing the issues involved in the economic production of high-quality GaAs wafers and other compound semiconductor wafers. Since that time, the massive oversupply has resulted in significant structural adjustments. This newsletter updates our clients on these changes and reviews the current situation in this area of technology.

DISCUSSION AND ANALYSIS

Following our 1988 newsletter on this subject, GaAs-on-silicon production quickly surpassed market demand, and molecular beam epitaxy (MBE) technology grew in importance. Although MBE has gained acceptance in microwave, millimeter wave, and optical (OEIC and photonic) applications, neither approach has made major inroads into existing technology for GaAs digital IC (digIC) production.

Volume consumption of GaAs wafers has grown rapidly, driven by the emergence of large-volume GaAs digIC markets and other factors. However, GaAs wafer consumption has grown less rapidly than has the GaAs device market, as a result of declining prices and improvements in users' yields. InP and other III-V wafer volumes remain at very low R&D levels.

Dropouts

Several companies have ceased operations or have de-emphasized GaAs materials since our 1988 newsletter on this subject. These companies include Commercial Crystal Laboratories, GAIN Electronics Corporation, MSC (Siemens), Morgan Semiconductor (Ethyl Corporation), OMVPE Technologies, and Spectrum Technology Corporation.

Acquisitions and Mergers

Other compound semiconductor materials suppliers have been acquired by or have merged into larger organizations. Chemetall GmbH, a Frankfurt-based holding company, acquired Bertram; Bertram acquired Epitronics. Enimont, an Italian company, acquired Cryscon. MCP acquired ICI Wafer Technology Ltd.'s GaAs wafer facilities and moved MPC's existing GaAs wafer operation to the ICI plant. Semitronic acquired Boliden Finemet, based in Sweden.

Start-Up Activity

The number of recent start-up companies in GaAs materials decreased to one: Bandgap Technology Corporation, which introduced products in 1989. Another start-up venture, to be located in southern California, is rumored; Dataquest believes that Asian-sourced capital has been invested in the acquisition of some of Spectrum Technology's wafer production equipment.

GaAs Materials Market, Volume, and Pricing

The overall GaAs wafer market is still dominated by a relatively small number of major suppliers—namely, Hitachi Cable, MMK, Sumitomo, and Wacker. Sumitomo, which shipped more than 30 percent of the world consumption of GaAs wafers in 1988, is probably still number one, although its share of the US market has dropped into the range of 15 percent. Wacker is believed to be the major supplier to the US market now, at approximately 25 percent, having reversed roles with Sumitomo in the US market over the last two years.

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Sumitomo remains the number one supplier in Japan, followed by Hitachi Cable in second position and Dowa Mining, third. Wacker is the leading European supplier of GaAs wafers. MMK is believed to be number three in the worldwide market.

Reportedly, the first order over $1 million for unprocessed GaAs wafers was placed by Vitesse with Wacker earlier in 1990. The order value was estimated to be near $1.5 million for more than 5,000 100mm semi-insulating GaAs wafers to be used in producing GaAs digICs.

Presently, undoped LEC wafers cost users approximately $23 per square inch, or approximately $280 each for 4-inch wafers, in large volume. This cost represents approximately a 10 percent per year decline in raw wafer prices since mid-1988. Epitaxial wafers cost several times more, depending on quality; MBE wafer costs range to more than $1,500 for 3-inch material. Corresponding reductions in epi wafer pricing should follow as volumes increase. Epi wafer costs are expected to decline further as metalorganic chemical vapor deposition (MOCVD) and MBE equipment throughputs increase.

Present Supplier Base

Table 1 provides an update of the GaAs and other III-V compound materials suppliers' product offerings. Parent companies are shown in parentheses.

Table 1
III-V Wafer Suppliers and Products

Company	Location	Wafer Sizes (Inches)	III-V Products
Airtron (Litton)	Morris Plains, NJ	2, 2.5, 3, 4	GaAs wafers, other advanced materials
Atomergic Chemetals	Farmingdale, NY	2, 3	GaAs,GaP, InP ingots and wafers; GaAs epi
ATTC (Chemetall GmbH)	Hsin Chu, ROC	2, 3	GaAs, GaP, and InP ingots and wafers
Bandgap Technology	Broomfield, CO	2, 3, 4	III-V epi wafers
Bertram Labs (Chemetall)	North Branch, NJ	2, 3	GaAs, GaP, InP wafers
Chemetall GmbH	Frankfurt, W. Ger.		Holding company
Crystacomm	Mountain View, CA	2.5	LEC-grown InP wafers
Crystal Specialties (Akzo N.V.)	Colorado Springs, CO	2, 3	HB and VGF wafers
Dowa Mining	Japan	2, 3	GaAs, InP wafers
EMCORE Corp.	Somerset, NJ		GaAs, InP epi services; MBE and MOCVD systems
EML	Ely, UK	2, 3	GaAs epitaxial wafers
Enimont	Italy	2, 3	Epi wafers
Epitaxx	Princeton, NJ	2, 3	InGaAs epi on InP
Epitronics (Bertram)	Phoenix, AZ	2, 3	AlGaAs and other epi wafers and services
Furukawa Electric	Tokyo, Japan	2, 3	GaAs, InP wafers, and GaAs epi wafers

(Continued)

TABLE 1 (Continued)
III-V Wafer Suppliers and Products

Company	Location	Wafer Sizes (Inches)	III-V Products
Hitachi Cable	Ibaraki, Japan	2, 3, 4	LEC GaAs and InP ingots, wafers, and epi wafers
Hitachi Metals	Hitachi City, Japan		GaAs ingots
Iwaki Handotai	Fukushima, Japan	2, 3	LEC GaAs (epi) wafers
Johnson Matthey	Spokane, WA	2, 3, 4	GaAs, GaSb, InAs, and InSb wafers
Kopin Corporation	Taunton, MA	2, 3, 4, 6	GaAs-on-Si, GaAs epi wafers, others
M/A-COM	Burlington, MA	2, 2.5, 3	GaAs ingots, wafers, epi
MCP Ltd.	Milton Keynes, UK	2, 3, 4	GaAs, InP, and II-VI wafers
Metal Specialties (MCP)	Fairfield, CT	2, 3	LEC- and HB-grown GaAs, GaP, GaSb, InAs, InP, and InSb wafers
Meteaux Speciaux	Moutiers, France	2	LEC InP ingots and wafers
Mitsubishi Metal	Omiya, Japan	2, 3	HB, LEC GaAs wafers
Mitsubishi-Monsanto Kokusai	Tokyo, Japan	2, 3, 4	GaAs and GaP wafers
Nippon Mining	Tokyo, Japan	3	InP ingots, wafers; GaAs and CdTe ingots
Picogiga	Les Ulis, France	2, 3	GaAs MBE epi wafers
Preussag	Gossiar, W. Ger.	2, 3, 4	GaAs wafers
Raytheon	Bedford, MA	2, 3	LEC, HB GaAs wafers
Semitronic	Sweden	2, 3	HPLEC wafers
Showa Denko	Tokyo, Japan	2, 3	MLEC InP wafers; GaAs and GaP NDF wafers
Siemens Opto Division	Cupertino, CA	1.6 to 3	HB-grown GaAs wafers
Spire Corporation	Bedford, MA	2, 3	GaAs and AlGaAs epi wafers and systems

(Continued)

TABLE 1 (Continued)
III-V Wafer Suppliers and Products

Company	Location	Wafer Sizes (Inches)	III-V Products
Sumitomo Electric	Hyogo, Japan	2, 3, 4	GaAs, GaP, GaSb, InP, InSb, InAs ingots and wafers; epi wafers
United Epitaxial Tech.	Beaverton, OR	2, 3	Advanced materials including GaAs epi
Wacker	Burghausen, W. Ger.	2, 3, 4	Semi-insulating and doped GaAs wafers

Note: The parent company is indicated in parentheses.
Source: Aztek Associates

DATAQUEST OBSERVATIONS AND CONCLUSIONS

Consolidation has taken place among GaAs wafer producers in the last two years. Although some shakeout has occurred, the III-V compound semiconductor materials marketplace is still supported by a broad range of increasingly capable suppliers, each dedicated to continual improvement of its products and services. Pricing has declined under the intense competitive pressure, although not as fast as expected by some chip suppliers. Digital GaAs IC chip suppliers still prefer "raw" GaAs wafers for use in an implant process (proton and/or ion rather than GaAs-on-Si or epitaxial GaAs wafers). Dataquest believes that GaAs wafer overcapacity still exists and that further consolidation is likely.

Gene Miles

Research *Bulletin*

HBTs INTENSIFY THE GaAs-VERSUS-SILICON ECL BATTLE

SUMMARY

The GaAs-versus-silicon emitter-coupled logic (ECL) competition has wavered back and forth as both technologies continue to evolve. In 1988, the silicon cost advantage was virtually eliminated with the advent of GaAs standard cell and gate array chips of 10,000-gate density, forward priced at parity with silicon ECL gate arrays of similar density. Now, less than two years later, a major process breakthrough in GaAs promises to tilt the price/performance curve permanently against silicon. This bulletin highlights recent developments in the two technologies.

WHY HBT TECHNOLOGY?

The GaAs ECL logic functions presently available are built with FETs, whereas true silicon ECL logic uses bipolar transistors. Compared with bipolar transistors, FETs are notoriously poor performers in terms of driving capacitive loads regardless of substrate type (silicon or GaAs). This lack of performance results in a speed disadvantage in currently produced GaAs circuitry, particularly in highly parallel logic designs. Thus the full speed potential of GaAs over silicon has not yet been realized.

A heterojunction bipolar transistor (HBT) structure constructed with AlGaAs and GaAs offers remarkable digital circuit performance. In 1988, NTT reported implementing GaAs ECL gates with delay times of 5.5 picoseconds per gate, using HBT technology. Last year, Rockwell presented results on several frequency-divider designs using HBTs that operated at 17 and 25 GHz, respectively, and Hughes developed 48-GHz HBTs using a process incorporating AlInAs and GaInAs on an InP (indium phosphide) substrate.

Also in 1989, NTT described a GaAs 35-GHz frequency divider that used relatively small HBT transistors (emitters of 2 x 3 microns and collectors of 4 x 5 microns), believed at the time to be the fastest frequency divider ever reported. IBM has been notably silent in discussing any work it may be doing in HBT technology.

The speed advantage gained in each of the instances described above is possible primarily because of the high current gain inherent in bipolar transistor structures. High current gain allows faster charging and discharging of base capacitance, interconnect capacitance, and other stray impedance involved in both the chip itself and in the supporting package and interconnection hardware.

WHY THE DELAY IN PRODUCING HBTS?

Until recently, there was a major problem in the known HBT device-processing methodology. The p-type dopant used in the base region (usually beryllium or zinc) rediffuses during subsequent heat treatment steps. Although carbon is known to have a lower diffusivity, no reliable procedure was known to exist for achieving carbon diffusion at very high concentrations. These limitations have heretofore prevented the economically feasible production of GaAs HBTs.

In March 1990, AT&T Bell Laboratories researchers described a method for growing carbon-doped base AlGaAs/GaAs HBTs using a process that incorporates both MOMBE (metal organic molecular beam epitaxy) and MOCVD (metal organic chemical vapor deposition) in the growth sequence. In the AT&T process, layers are grown in the following sequence, starting with a semi-insulating GaAs substrate:

- MOMBE-grown subcollector—6,000 angstroms of n^+ GaAs
- MOMBE-grown collector—4,000 angstroms of n^- GaAs

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- MOMBE-grown base—400 to 800 angstroms of GaAs, carbon-doped at 1×10^{19} to 1×10^{20} atoms per cubic centimeter
- MOMBE-grown GaAs spacer—50 to 100 angstroms thickness
- MOCVD-grown emitter—1,200 angstroms of n^+ AlGaAs in two layers with silane doping varied for each layer
- MOCVD-grown emitter contact layers—1,500 angstroms of n^+GaAs followed by 300 angstroms of graded n^+ AlGaAs

Metallization used for the emitter and collector layers was AuGeNi, and alloyed AuBe was used for base ohmic contacts. The DC current gain achieved was 20. AT&T expects this process to prove useful in the production of AlGaAs/GaAs HBTs.

What's Happening in the Silicon ECL World?

Silicon ECL technology has reached a practical limit at present production levels. Although gate delays have approached approximately 100 picoseconds, the associated power (exceeding 30 watts per chip) now prohibits the use of air cooling for arrays of useful density. To achieve higher densities, silicon suppliers recently have resorted to the same tactics previously used by GaAs chip suppliers; namely, to incorporate FET structures internal to the chips and to set ECL levels at the chip interface. However, from the standpoint of performance, this is a self-defeating approach in that the bipolar silicon speeds are already marginal for next-generation, high-performance computing, and FET structures are inherently slower. The silicon ECL suppliers are, in the vernacular, "caught between a rock and a hard place." This is abundantly clear in Cray's choice of GaAs for the CRAY 3 supercomputer CPU logic.

Dataquest Conclusions

The world of high-speed digital hardware is facing some hard decisions. Although silicon ECL has been the workhorse of high-performance logic designers, the technology is rapidly maturing. GaAs-based chips using some form of FET-device logic have allowed leading-edge equipment designers a generation or two of additional system-performance improvement. The next step in technology is to move on to GaAs bipolar designs, although no supplier base presently exists for such ICs. Just as the early 1970s required a round of custom silicon ECL- and CML-based IC designs by system houses to establish the silicon ECL 10K/100K standards, it appears that the early 1990s need a similar push in GaAs HBT-based chip designs. The remaining issues are who will be first to "bite the bullet" and invest in the technology, and who will remain in the high-performance chip business (and for how long) after this occurs?

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Research *Bulletin*

GaAs IC GROWTH OFFSETS DECLINE IN OPTO SEMICONDUCTORS

INTRODUCTION

The 1989 worldwide market for GaAs semiconductors was characterized by double-digit growth in ICs and microwave/millimeter-wave (uw/mmw) discretes, tempered by a 5 percent decrease in discrete optoelectronics. Discrete opto declined by more than $100 million to less than $2.1 billion in 1989 consumption. GaAs ICs now account for 14 percent of the total. Record GaAs device sales in all categories resulted from the continuing growth of IC market share in computers, telecommunications, instrumentation, and related electronic equipment applications.

1989 GaAs MARKET DEVELOPMENTS

GaAs IC devices, including optoelectronic integrated circuits (OEICs), led 1989 growth, followed closely by uw/mmw discrete devices. NRE (nonrecurring engineering) costs were lower in 1989 than in 1988, confirming the maturation of GaAs ASICs and certain developmental programs that have been under way for nearly 10 years. During 1989, GaAs IC growth was somewhat lower than expected, primarily due to tempering of the overall growth of the marketplace and the withdrawal of Tachonics, the merger of Adams-Russell's foundry with M/A-COM, and other factors. Although Vitesse and Fujitsu announced a partnership in GaAs ASICs, no significant effect on the size of the market is expected for another year or more. U.S. Department of Defense budget cuts have further tempered the near- and intermediate-term markets.

Major activities in 1989 included a decision by Cray Research to restart fabrication of GaAs ICs at its Colorado Springs facilities, which had the immediate effect of reducing the commercially available market by at least several million dollars per year. Countering this situation is the recent agreement between McDonnell Douglas and TriQuint involving coproduction of 64K GaAs SRAMs and other VLSI devices. Table 1 summarizes shipment estimates for GaAs and other compound semiconductor devices from 1985 through 1989.

DATAQUEST CONCLUSIONS

GaAs IC technology has reached a level at which it may be used by a broad-based electronics company to offset cyclical declines in its semiconductor business. Dataquest believes that astute semiconductor producers will consider this an important factor in rethinking their overall business strategies for the 1990s and beyond.

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TABLE 1
Worldwide GaAs Semiconductor Shipments (Millions of Dollars)

Category	1985	1986	1987	1988	1989	Percent Change 1988-1989
Total GaAs Semiconductors	1,517	1,902	2,183	2,723	2,743	0.7%
Analog/Linear ICs	80	107	138	157	187	19.1%
Devices	40	56	85	107	142	32.7%
NRE Costs	40	51	53	50	45	(10.0%)
DigICs	26	51	71	86	117	36.0%
Devices	6	21	35	51	88	72.5%
NRE Costs	20	30	36	35	29	(17.1%)
Optoelectronics	1,233	1,514	1,752	2,237	2,148	(4.0%)
Discrete Opto	1,213	1,486	1,709	2,179	2,071	(5.0%)
OEICs	20	28	43	58	77	32.8%
uw/mmw Discretes	178	228	222	243	291	19.8%

Notes: Columns may not add to subtotals and totals shown because of rounding.
Dataquest's merchant shipment figures include intracompany transfers for merchant suppliers at estimated market value. No full-captive supplier data are included.
Optoelectronics data for 1985-1989 include silicon emitters and detectors.

Source: Dataquest
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Research *Bulletin*

THE IMPACT OF PHOTONICS ON IC TECHNOLOGY

This is 1990, and already the technology of the next century is being sold at $2,000 a copy, presumably to anyone with the appropriate credentials. AT&T has done an about-face and is offering the most advanced semiconductor chip on the world market today to research labs. This bulletin briefly discusses this watershed event and its implications on the future of communications and information technology.

SILICON AND METAL REVERSE ROLES

In conventional electronic circuit technology, metal is used for interconnecting digital and analog functions, and silicon is used as the basic substrate material for accomplishing the amplification, switching, storage, and whatever other functions the designer chooses for components in a system. The advent of photonics technology, which takes advantage of the movements and other affects of photons instead of electrons, has reversed these roles. Compound semiconducting substrates such as GaAs and InP incorporate a metal such as gallium or indium in the wafer structure and take advantage of the photon-conducting properties of glass fiber (which is made of silicon) for the interchip connections. Because the sun and other light sources emit photons, the use of photonic technology to replace electronics elegantly solves many problems that demand many millions to billions of transistors to accomplish electronically. A simple example is image transfer in high-definition TV (HDTV); another is the switching of signals on 10-Gbps communications lines in a telephone switching center.

AT&T REMAINS THE LEADER

Since the inventions of Alexander Graham Bell, Claude Shannon (information theory), and others, the technology cloners of the world have beaten a path to Bell Labs' door. This year is no exception; however, the big surprise is that AT&T has offered a major R&D breakthrough at bargain-basement pricing. The invention of the self electro-optic effect device (SEED) allowed AT&T engineers to grow, atom by atom, structures containing 2,048 AlGaAs/GaAs photonic cells, each of which is a switch/gate/storage element that operates in the picoseconds range, the most complex structure ever produced using molecular beam epitaxy (MBE). These devices can interface directly with prisms, lenses, mirrors, and other optical devices.

Silicon chip electronic world, take note! The dilemma of what to do with billion-transistor chips may be resolved by very efficient competing technology. Some industry sources expect AT&T's breakthrough to cause hundreds of electronic companies to make major changes to their R&D plans.

WHAT IT MEANS

If simple glass lenses, mirrors, and prisms ultimately replace billions to trillions of transistors in many major systems, and sunlight replaces conventional energy sources to power the systems, whole corporate cultures may become obsolete. The internal combustion engine had a similar effect in terms of time compression and labor savings. The real issue facing electronics firms is, what happens when major applications of electronic devices, boxes, and systems become obsolete, and the end customers turn to companies that under-

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stand optics? Corporate managers may be well advised to rethink their position on the so-called electronic engineering shortage. The issue facing the university student is, should I plan on a career in saddles and buggywhips, or is it remotely possible that photonics technology will surprise all of us before graduation day (as Sputnik did in the late 1950s)?

DATAQUEST CONCLUSIONS

AT&T clearly remains the leader in information and communication technology and is willing to share much of what it learns. Dataquest believes that photonics technology may enter the mainstream of high-end equipment designs long before 1999.

Gene Miles

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Research Newsletter

1989 ASIAN ACTIVITIES IN GaAs TECHNOLOGY

INTRODUCTION

This newsletter summarizes many of the Asian government, company, and university activities in GaAs and related compound semiconductor technologies reported during 1989. The items are described chronologically as received by Dataquest.

THE YEAR IN REVIEW

January

A study supported by the National Science Council of the Republic of China (ROC) resulted in successful growth of GaInP/GaAs on silicon substrates. The buffer layer of GaAs was grown by low-pressure MOCVD. The work is under way at National Sun Yat-Sen University, Kaohsiung, Taiwan, ROC. Another National Science Council study is directed toward modeling and demonstrating hot-electron effects in heterostructure bipolar transistors (DHBTs). This work was performed at National Taiwan University, Taipei, Taiwan, ROC.

Fujitsu has fabricated lateral-current-injection multiple-quantum-well (MQW) lasers using zinc- and silicon-induced disordering of AlGaAs/GaAs QWs. The company achieved differential quantum efficiency of 18 percent per facet (pulsed) at room temperature. Fujitsu expects to develop OEICs incorporating the new structure.

February

NTT researchers have developed GaAs-on-silicon (GaAs-on-Si) solar cells for use in satellite power generators on Japanese satellites to be launched in the 1990s. The approach uses a sandwich of alternating InGaAs and AlGaAs layers to provide relief of the stress caused by the 4 percent lattice mismatch of GaAs atoms and silicon atoms. GaAs-on-Si offers a 50 percent weight reduction compared with the use of GaAs-only wafers.

Varian's new equipment facility in Ansan City, South Korea, will assemble and test ion implanters and other plant equipment for semiconductor makers such as Daewoo, Goldstar, Hyundai, and Samsung—all multibillion-dollar companies producing compound semiconductors. The new plant strengthens Korea's infrastructure for making state-of-the-art GaAs ICs, which use all-implant processing (eliminating the diffusion steps).

Oki Electric started sampling the KGL-4101, a GaAs 256-bit shift register. Initial pricing is ¥40,000 ($320) for the 1.2-GHz version. The company initially is pursuing the instrumentation market with this device.

Japan's fiscal 1989 defense budget will grow 5.9 percent to $30.9 billion, marking the third annual increase of nearly 6.0 percent and the second year it has exceeded 1.0 percent of the country's GNP. Included are $3.2 billion for the purchase of 109 aircraft and unspecified amounts for military ICs and other electronics. Beneficiaries include Fuji, Kawasaki, Mitsubishi, and other major Japanese companies.

Oki Electric's Compound Semiconductor Devices Center reported test results for a new version of its superluminescent diode (SLD) laser, made of alternating GaInAsP and InP layers on an InP substrate. The laser generated 1mW coupled power at 150mA and 1.3-micron continuous-wave (CW) operation. Oki began developing such devices before 1985.

Mitsubishi is also developing 1.3-micron GaInAsP/InP lasers. The company has operated a low-threshold CW device at current levels of 3.1mA at 1mW output. The fabrication process is a hybrid MOCVD/LPE approach. Mitsubishi found that negative differential resistance (tunneling) was

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induced by the diffusion of the impurities Zn and Te into the GaInAsP layer.

Fujitsu reported that it is the first to integrate AlInAs/GaInAs high-electron mobility transistor (HEMT) and InP/GaInAs PIN photodiodes on a monolithic die. The company is developing this technology for use in optical networks for video database, CATV, and related applications.

Engineers at Fujitsu Laboratories have fabricated OR/NOR gates, D-type flip-flops (FFs), and toggle FFs using a 0.6-micron gate-length GaAs MESFET process. The OR/NOR gates exhibited 45/35ps rise/fall times, and the FFs operated at 8-GHz divide rate. Cutoff frequency for the MESFETs is 47 GHz. Fujitsu is developing the chips for digital optical transmission systems.

Fujitsu Laboratories Ltd., Atsugi, Japan, has built and successfully characterized GaAs HEMTs using a quarter-micron gate-length MBE process. Drain current/voltage measurements at 77°K indicate the formation of transverse domains due to intervalley electron transfer. A WSi/Ti/Pt/Au gate was used to minimize noise. Cutoff frequency of 61 GHz was achieved.

NEC's Optoelectronics Research Laboratories has fabricated a device that it believes will have much the same impact on optoelectronic ICs as the 1K NMOS DRAM had on electronic ICs. The 32x32 array is fabricated on a $1mm^2$ die using a superlattice of alternating layers of GaAs and AlGaAs on a GaAs substrate. The light power required for element switching is 2.6 microwatts. The pnpn structure allows data retention time of 10 microseconds without refresh. The OEIC meets NEC's minimum requirements for use in optical computer systems developments.

March

Asian university activities in compound semiconductor research have intensified. Table 1 shows examples of recent studies in this technology.

April

Engineers at Kyoto University, Kyoto, Japan, analyzed results of wafer-containing AlGaInP lasers in a dual-purpose effort to fabricate short-wavelength visible lasers and to evolve a process for higher-speed optical logic circuits. The group's MOMBE growth tests defined the conditions under which InP defects and phosphorus evaporation can be controlled.

The Tsukuba Research Laboratory of Nippon Sheet Glass Company Ltd. is studying methods for growing high-quality zinc selenide (ZnSe) homoepitaxial layers on ZnSe substrates using MOVPE processing. This approach eliminates the 7 percent mismatch-induced defects experienced when using GaAs as the substrate and can be used to produce blue LEDs.

Under a grant from Japan's Ministry of Education, Science, and Culture (MESC), scientists at Shizuoka University in Hamamatsu, Japan, are studying ZnTe-ZnSe superlattices as candidates for blue LEDs. The layers are grown by hot-wall epitaxy (HWE) on GaAs substrates. This work is classified as "Scientific Research in Priority Areas."

For several months, Oki Electric Industry Company has been increasing its level of investment in AlGaAs laser diodes for applications in erasable optical recording systems, laser printers, and telecommunications. The company is now moving from pilot production to volume production of 830nm wavelength (±10nm) AlGaAs lasers having 45mA threshold current, 190mW maximum power, 10 to 30 degrees beam divergence, and 67 percent external differential quantum efficiency.

AT&T and Japan's Kokusai Denshin Denwa (KDD) began operating the Pacific Link, the first submarine fiber-optic cable to span the Pacific Ocean, in April. The link, which has compound semiconductor repeaters buried in the cable, can handle 40,000 simultaneous telephone calls.

May

Sumitomo Heavy Industries is offering to purchase all of the outstanding shares of Lumonics Inc. of Kanata, Ontario, Canada, for $7.75 per share. This acquisition will provide Sumitomo with industrial laser capability for such operations as semiconductor-manufacturing robotics. The companies have been collaborating for more than a year in selling laser systems to the Japanese materials processing market.

NTT reported that it has successfully operated a 1.8-Gbps fiber link with repeater spacing of 127 miles. This development is expected to lead to major cost savings in long-haul transmission systems.

TABLE 1
Recent Asian University Research in Compound Semiconductors

Institution	Location	Topic(s)
Academy Sinica	Beijing, China	LPE growth of GaAs; defect studies of bulk GaAs crystals
Birla Institute of Technology	Mesra, India	GaInAs/InP superlattice photodiodes
Burdwan University	West Bengal, India	Refractive index studies of III-V and II-VI semiconductor alloys
Calcutta University	Calcutta, India	Magnetic field effects on GaAs devices; GaAs and GaInAs QWs
Chung Shan Institute	Lung-Tan, Taiwan	Defect studies of MBE-grown GaAs epi layers
Institute for Physical and Chemical Research	Wako, Japan	Analysis of MOVPE-grown GaAs
Kurume University	Kurume, Japan	Studies of Cd-doped InSe crystals grown by Bridgman process
Meiji University	Kawasaki, Japan	AlGaAs/GaAs heterostructure MESFETs
Nagoya Institute of Technology	Nagoya, Japan	Thermal annealing of GaAs wafers
National Sun Yat-Sen University	Kaohsiung, Taiwan	LP MOCVD growth of InP-on-Si
Osaka University	Suita, Japan	Analysis of GaAs IMPATT diodes; recrystallization in MBE GaAs
Sardar Patel University	Gujarat, India	Growth of InSe thin films
Shizuoka University	Hamamatsu, Japan	Annealing and doping effects in MOVPE-grown GaAs epitaxial layers
Toyohashi University	Toyohashi, Japan	InN growth by microwave-excited MOVPE
Tsinghua University	Beijing, China	AlGaAs/GaAs heterojunction phototransistors (HPTs)
University of Tokyo	Tokyo, Japan	Studies of GaAs absorption of TMGa; rare-earth diffusion into InP and GaAs wafers

Source: Aztec Associates

NTT's Optoelectronics Laboratories of Kanagawa, Japan, have fabricated devices called MQW etalons, which have the property of optical bistability at room temperature. The devices consist of 99 alternating layers of InGaAs and InAlAs grown by MBE on InP substrates. NTT expects to use the devices in future optically controlled communications systems.

June

Scientists at Tohoku University in Sendai, Japan, have formed InAs layers by plasma-assisted epitaxy on GaAs, InP, and GaSb wafers to increase the integration level above discrete chips for optical applications. The work is sponsored and supported by Japan's MESC.

Fujitsu Laboratories in Atsugi, Japan, is studying 10nm, 20-period InGaAsP/InP quantum wells formed by low-pressure MOVPE at 570°C. Observed absorption coefficient shift is 1,500 to 1,530nm at 300°K. Possible applications are high-speed optical logic devices such as switches, flip-flops, and modulators.

The Central R&D Laboratories of OMRON Tateisi Electronics Company, Kyoto, Japan, is developing double quantum-well lasers using AlGaAs/GaAs layers on GaAs wafers. Enhanced properties include lower driving current, higher cutoff frequency, better temperature stability, and higher output power than available using previous methods.

Hitachi's Central Research Laboratories, Tokyo, Japan, developed an improved manufacturing process for its transverse-mode-stabilized AlGaInP lasers. A GaAs etch-stop enhances reproducibility.

Mitsubishi's Central Research Labs, Hyogo, Japan, demonstrated an optical comparator using AlGaAs pnpn optical switches connected in parallel. When three or more of the switches are connected in parallel, only the one with highest input intensity will switch on. The minimum switching energy was 1.7 picojoules.

July

NTT Transmission Systems Laboratories, Kanagawa, Japan, has fabricated and tested a GaAs carrier-injection type optical switch operable over the wavelength range of 1,060 to 1,550nm. The chip incorporates a carrier-blocking diffusion layer to improve the effective refractive index, which increases the efficiency of coupling in single-mode fiber systems. The broad-wavelength device is intended for use in WDM transmission of optical signals.

Scientists at KDD's Meguro R&D Labs, Tokyo, Japan, have reported the frequency stabilization of a 1,550nm-range GaInAsP quarter-wavelength-shifted DFB laser to a variance of less than one part in 100 billion for averaging times of more than one second, without frequency modulation of the diode. Previous approaches were more costly and complex, requiring a frequency modulator for this level of stabilization.

Process development at NTT's Atsugi LSI Labs, Tokyo, Japan, resulted in the growth of 3-inch GaAs crystals by a vertical Bridgman process using boron dioxide as an encapsulant to reduce dislocation density. NTT claims a two- to fivefold improvement, reportedly resulting in wafers of IC quality.

Scientists at the Electro Technical Labs in Tsukuba, Japan, claim to have accomplished the first MBE growth of single-domain InP films on silicon. This achievement is a first step toward developing InP-on-Si wafers.

Engineers at Osaka University, Ibaraki, Japan, claim the first growth of GaSb, InSb, and InGaSb layers on GaSb wafers using trimethyl gallium, trimethyl indium, and solid antimony. This development is expected to lead to new types of compound semiconductors having unique properties.

August

Starting in 1984, Matsushita has operated a 100-kilowatt photovoltaic energy system in support of its car battery manufacturing plant at Lake Hamanako, Shizuoka, Japan. The system was developed by the New Energy Development Organization (NEDO) with Japanese government support. It is composed of 1,440 single-crystal silicon modules, 1,056 polysilicon modules, and 48 CdS/CdTe solar cell modules, arranged to generate 230 volts. Matsushita reported that the roof-mounted facility supplies 21 to 41 percent of the total energy required for plant operation, depending on cloud conditions.

NTT recently reported the following GaAs digIC and MMIC developments:

- 8-bit ALU with 57ps LSCFL gates
- 10.6-GHz BFL static frequency divider
- 20.2-GHz BFL dynamic frequency divider
- 740-MHz 16-channel GaAs E/D DCFL time switch
- 4096-bit ROM with 1.2ns address access time

The company also reported a set of MMIC cells for a 26-GHz receiver, consisting of a 26-GHz LNA (low-noise amplifier), 6.5-GHz VCO (voltage controlled oscillator), 6.5/13- and 13/26-GHz frequency doublers, 26-GHz/1-GHz FET mixer, and 1-GHz IF amplifier. All of the MMIC circuits were combined on a single IC that also contains coplanar waveguides, slot lines, air bridges, FETs, and other required active and passive components.

September

A NASA contract with the University of Illinois resulted in an assessment of the state of the art of the design of multiprocessor systems for artificial intelligence (AI) applications, including the performance advantages to be gained through adaptation of advanced GaAs technology. A key scientist on the project has returned to Beijing, People's Republic of China (PRC), to pursue AI interests at the Institute of Computing Technology, Academia Sinica.

Scientists at Academia Sinica in Beijing have investigated the growth of Te-doped GaAs crystals grown in space, and they have determined that the space-grown crystals have a more homogeneous distribution of impurities than is the case for GaAs crystals grown on Earth. The source of the samples was not disclosed.

Several recent reports emphasize the PRC's research into advanced compound semiconductors. These include the investigations of MBE-grown GaAs on GaAs substrates, superlattices of alternating layers of AlGaAs on GaAs, and GaInAsP layers on InP wafers. Also,. Xiamen University researchers have reported low-temperature photoluminescence spectra studies of LPE-grown GaP crystals, and Academia Sinica (Changchun, PRC) is exploring MOCVD growth of InP.

Engineers at Matsushita's development labs in Osaka, Japan, reported a very compact millimeter-wave transmitter/receiver set for satellite video-link

TABLE 2
Japanese GaAs Chips Reported at GaAs IC Conference

Device/Technology	Company
7ns GaAs 16K SRAM	Mitsubishi Electric Corp.
0.5-micron SRAM process	Hitachi Company
0.5u WSi-MESFET gate arrays	NEC Corporation
8-bit slice logic LSI chip	Toshiba
3-Gbps 16-channel MUX/DEMUX	Fujitsu
15-Gbps HBT MUX/DEMUX chips	Toshiba
12-Gbps SONET chip set	Toshiba
32-bit serial interface chips	Oki Electric Co.
12-GHz 256/258 JFET prescaler	Sony Corporation
15.6-GHz dynamic prescaler	NEC Corporation
0.25-micron HEMT DCFL divider	Oki Electric Co.
34.8-GHz HBT divider	NTT LSI Labs
L-band GaAs MMICs	NTT Comm. Systems Labs
TV tuner mixer/osc. IC	Matsushita
Broadband MMIC mixer	ATR Labs, Kyoto
10-GHz laser-driver IC	NEC Corporation
Power MESFETs	Mitsubishi Electric Corp.
MMIC packaging	NTT Labs

Source: Aztec Associates

applications. It uses Fujitsu transistors in the DRO oscillator and frequency doublers to multiply 25-GHz operation and achieve 50-GHz operation.

October

The GaAs chip developments in Table 2 were presented by authors from the companies indicated, during the GaAs IC conference at San Diego, California.

November

Fujitsu announced that it will manufacture Vitesse's Fury Series of GaAs gate arrays and mixed logic/SRAM arrays. The Fury arrays will be manufactured in Japan using the Fujitsu self-aligned gate GaAs MESFET process. (Fujitsu claims that it invented self-aligned gate GaAs technology in 1980.) The agreement includes gate array densities from 3,000 to 30,000 gates and provides for joint development of additional products.

December

At the 1989 IEDM meeting in Washington, DC, NEC engineers reported the development of striped-channel MODFETs and ICs based on DCFL structures. NEC also described a two-dimensional transient simulator incorporating deep-trap modeling in another paper presented at the conference.

Mitsubshi has developed a GaAs BiFET structure for LSI applications. The approach achieves the speed of HBTs and the low power of MODFETs. A ring oscillator based on the BiFET structure has operated at 150ps gate delays with power dissipation of 3 microwatts per gate.

DATAQUEST CONCLUSIONS

The activities described herein encompass the full spectrum of GaAs and related compound semiconductor technologies. Vertically integrated Asian companies have accelerated their efforts to cash in on the emerging strategic markets in the 1990s. Asian university research also has intensified, assuring another decade of rapid progress.

The lead of such U.S.-based companies as AT&T is narrowing. Dataquest expects this trend to continue into the mid-1990s, as the U.S. government's budget pressures keep tight limits on the funds available for basic research.

Gene Miles

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Research Newsletter

PROGRESS IN GaAs DIGITAL ICS

GaAs digital ICs (digICs) have undergone rapid improvements in recent months, as demonstrated by current product offerings. This research newsletter briefly describes the state of the art of GaAs digICs and examines near-future product expectations.

GaAs DigIC COMPLEXITY

GaAs gate arrays and cell-based designs advanced to VLSI density level in 1989, with products available from GigaBit Logic, TriQuint, and Vitesse at 8,000 to 15,000 gates per chip. Last month, Vitesse announced a 30,000-gate GaAs array, and related reports indicate that the company plans to offer 100,000-gate GaAs ASICs within this calendar year. Dataquest believes that Vitesse's alternate-source agreement with Fujitsu will include the 100,000-gate chips because these chips are part of Vitesse's Fury Series. We believe that customers designing state-of-the-art systems for introduction late in 1990 should be considering such devices for possible use.

The recent rapid increase in GaAs digIC density is evolutionary, not revolutionary, in nature. The E/D MESFET process required to support GaAs chips of 100,000-gate complexity has been proven on both 3-inch and 4-inch wafers. Such processing involves fewer mask levels and operations than does either BiCMOS or bipolar ECL technology.

GaAs ASIC PRICING

In 1989, Dataquest's cost model of a 15,000-gate GaAs ASIC chip showed a break-even cost for an efficient supplier at less than two cents per gate. More than a dozen GaAs digIC suppliers in the free world are capable of sustaining the volume required to support this cost level; thus, it should not come as a surprise that GaAs VLSI suppliers are able to meet or beat the three- to five-cents-per-gate figures of ECL gate arrays.

Silicon ECL is now in the position—with respect to GaAs VLSI—of being slower, consuming more power, and presenting a price penalty at the device level. Armed with this advantage, GaAs digIC suppliers are taking a more aggressive posture in the marketplace.

RECENT GaAs DigIC PRODUCT INTRODUCTIONS

Several suppliers of GaAs digICs have introduced new products to the commercial marketplace within recent months. These chipmakers include Fujitsu, GigaBit Logic, TriQuint, Vitesse, and others. All of these companies are now using submicron enhancement-depletion (E/D) processing to fabricate their chips. Table 1 summarizes several of the major new product offerings from the companies named, showing performance and complexity specifications.

GROWTH IN GaAs DigIC APPLICATIONS

With GaAs digIC functional density growing faster than that of ECL and BiCMOS, many systems houses are actively pursuing the insertion of this technology into new designs, as well as considering retrofits to upgrade existing hardware.

TriQuint has indicated that its customers are increasingly demanding more tools for designing GaAs DDS (direct digital synthesis) functions. TriQuint has responded by adding to its library hard macros such as 256x8 ROMs and two-bit pipelined accumulator elements. These functions will help users save as much as two months in time to market when developing hardware for GPS (global

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TABLE 1
Recent GaAs DigIC Product Introductions

Company	Gates Per Chip	Process	Gate Delay (ps)	Gate Power (mW)	I/Os	Comments
Fujitsu	3,000-30,000+	E/D	90	0.3	256	Alternate source to Vitesse
GigaBit Logic	15,000+	HMED	50	Varies	96	Standard cell-based designs
TriQuint	10,000+	Q/ED	78	N/A	84	Up to 4K ROM macro available
Vitesse	30,528	E/D	90	0.3	256	344-pin ceramic LCC package

N/A = Not Available

Source: Dataquest
February 1990

positioning satellite) system applications, phase-tracking hardware, and test equipment.

The long-awaited SPARC-architecture GaAs RISC machine is being developed by Systems and Processes Engineering Corporation under a licensing arrangement with Sun Microsystems. The NASA contract is expected to result in a rad-hard multiprocessor based on Vitesse's standard-cell custom capability. The three-chip set includes an integer processor chip of approximately 25,000-gate density. Sun has retained the right to license back the designs for production by any of Sun's semiconductor licensees.

DATAQUEST CONCLUSIONS

Dataquest believes that GaAs VLSI products are here to stay. GaAs digital IC suppliers are strengthening their positions with aggressive product offerings, and GaAs VLSI products are realizing new applications. Despite the delay in shipment of the first CRAY-3 and the demise of Prisma, we expect 1990 to bring the introduction of major digital equipment designs based on cost-effective GaAs digIC technology.

Gene Miles

MEMORY NEWSLETTERS
1990

5957 1. SIS Memory New Products Newsletters
Ladd/Jan

6670 2. The DRAM Marekt of 1990: Temporary Shortage or 1988 Revisited
Galligan/Apr

6711 3. SIS Memory Quarterly New Products Newsletter
Ladd, Jones/Apr

7051 4. BiCMOS Turbocharges the FAST SRAM Race
Ladd, Galligan/June

7444 6. SIS Memory Quarterly New Products Newsletter
Ishii, Ladd/July

3
9054 7. SIS Memory Quarterly New Products Newsletter
Ishii/Dec

9069 8. DRAM Product Life Cycles - A View From The Industry
Ishii, Grenier/Dec

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Research Newsletter

DRAM PRODUCT LIFE CYCLES—A VIEW FROM THE INDUSTRY

INTRODUCTION

At the Dataquest Semiconductor Industry Conference held in October in Monterey, California, a half-day session was dedicated to the subject of DRAMs. Six speakers discussed DRAM topics that included DRAM product life cycles, manufacturing costs, average selling prices (ASPs), capacity, packaging trends, technical characteristics, and applications. This newsletter focuses on DRAM product life cycles, one of the DRAM topics presented at the conference.

The DRAM product life cycle for each new generation of DRAMs is a subject of great interest to Semiconductor Industry Service (SIS) clients. A secure knowledge of DRAM product cycles helps participants at all levels of the electronics industry--including equipment and materials suppliers, device manufacturers, and device end users--better plan their future company activities.

Three of the invited speakers presented their views of DRAM product life cycles, which, in the interest of our clients, we present in this newsletter. David Sear, vice president, Standard Products Operations, Integrated Circuits Division, Fujitsu Microelectronics, gave Fujitsu's view; Dr. Tsugio Makimoto, director and general manager, Semiconductor Design and Development Center, Hitachi, presented Hitachi's view; and Robert J. Brown, senior vice president and group executive, Semiconductor Operations Group, Toshiba America Electronic Components, presented Toshiba's view. We also augment the speakers' viewpoints with Dataquest's perspective.

DRAM PRODUCT LIFE CYCLES

Figures 1, 2, and 3 show Fujitsu's, Hitachi's, and Toshiba's views of DRAM product life cycles, respectively. The figures show the life cycles of each DRAM generation and the projected worldwide unit demand throughout the DRAM's life cycle. The three figures probably were meant to present general industry projections rather than official company forecasts, and Dataquest does not want to manipulate these data to arrive at decisions unwarranted by the accuracy of the data. Nevertheless, significant differences exist among the general viewpoints of these companies, such that the reader should examine the charts in more detail. (The charts also use different scales, so the reader should be careful with direct comparisons of the charts.)

For Fujitsu, worldwide peak unit production for each new generation of DRAMs surpassed that of the previous generation. Toshiba's view is similar to Fujitsu's, at least for the 256K, 1Mb, and 4Mb generations. Hitachi's view is somewhat different: It projects that peak production, at least for the 1Mb, 4Mb, and 16Mb DRAMs, essentially is the same for each new generation and lower than the peak production for 256K DRAMs. Table 1 shows some rough data that Dataquest extracted from Figures 1 through 3. Using the 16Mb DRAM as an example, Fujitsu forecasts peak unit production to be 1,500 million units, twice Hitachi's estimated peak production of 750 million units.

Fujitsu estimates that worldwide DRAM demand will exceed 500 million units for each DRAM generation from 1Mb through 64Mb for six to seven years, while Hitachi estimates that worldwide demand will exceed 500 million units for only three to four years for the 1Mb, 4Mb, and 16Mb DRAM generations.

When Fujitsu's higher peak unit production and longer time for the DRAM generation to be above 500 million units is compared with Hitachi's lower peak production and shorter time above 500 million units, it is clear that Fujitsu forecasts a much larger number of units for each DRAM generation than does Hitachi.

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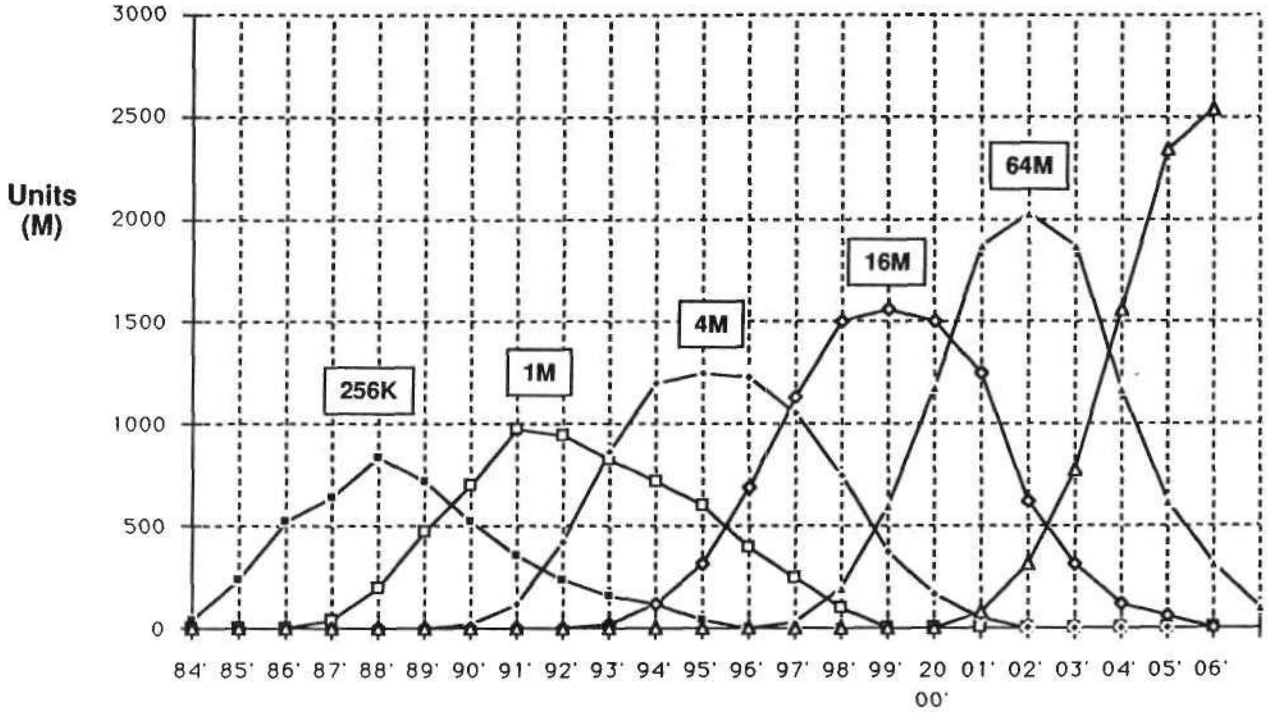
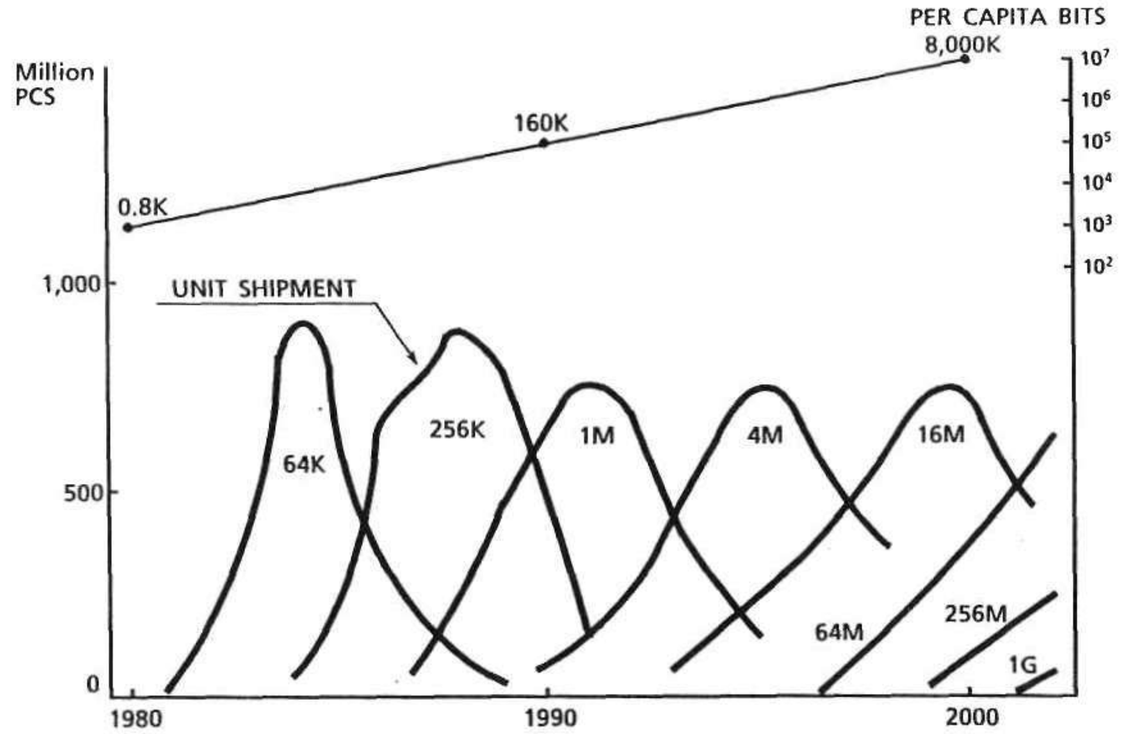
FIGURE 1
Fujitsu's Projected DRAM Life Cycle



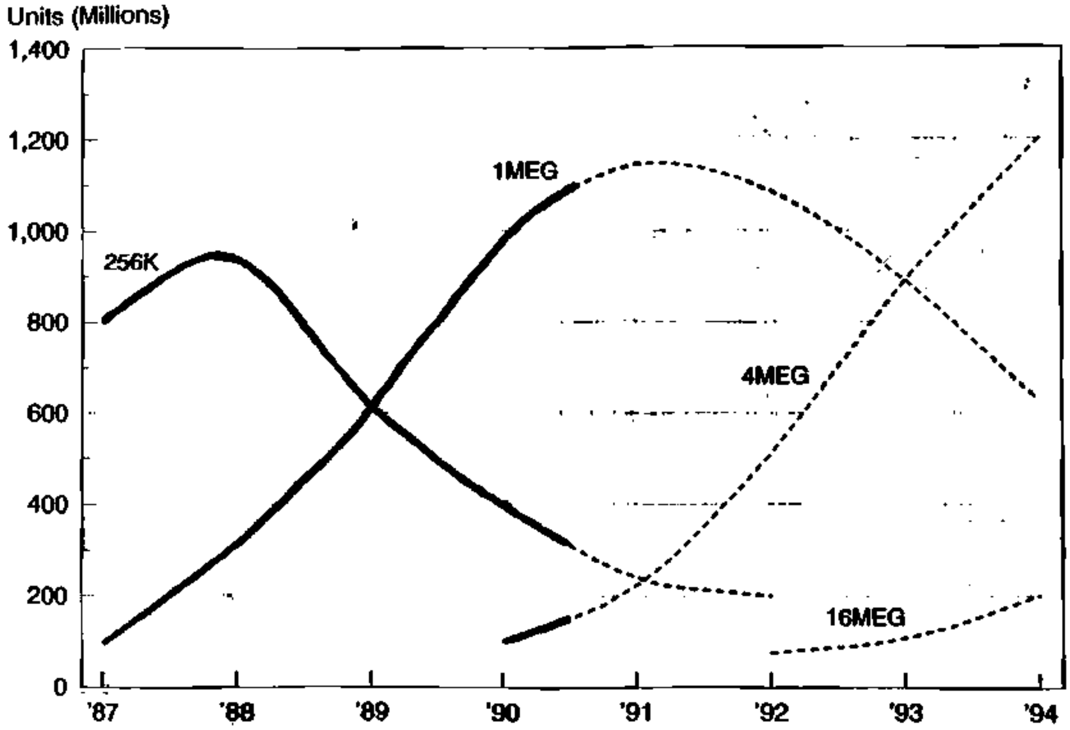
Source: Fujitsu

FIGURE 2
Hitachi's DRAM Trend



Source: Hitachi

FIGURE 3
Toshiba's DRAM Market Forecast



Source: Toshiba

Although these are only a few companies' views of the future, the fact that they are disparate leads to caution. The semiconductor industry in general needs to have a fairly consistent view of the future in order to avoid the cyclicality that has characterized the industry. For instance, if the consensus forecast is for high worldwide demand, then capital expansions are more likely to be made to meet the projections, and the companies making expansions will be able to share in the rising market. On the other hand, if actual demand turns out to be lower than was originally forecast, the industry will have an overcapacity situation with all the concomitant problems that such a situation brings to the semiconductor manufacturers and the equipment and material suppliers.

Similarly, if the forecast is for a lower worldwide demand, then fewer capital expansions will be made, and the companies moderating their expansions will not find themselves in an overcapacity situation. However, if the actual demand proves to be much higher than originally forecast, then the industry will find itself in an undersupply situation with all of the problems that entails for the end users of the devices.

Table 1 shows that the three companies agree on the year of peak unit production for each DRAM generation--1991 for the 1Mb, 1995 for the 4Mb, and 1999 for the 16Mb. Fujitsu estimates that the 64Mb DRAM will reach peak production between the years 2002 and 2003. The figures also show that DRAM generation life cycles for the 1Mb, 4Mb, and 16Mb devices are approximately nine to ten years or more.

DATAQUEST PERSPECTIVE

Dataquest's projections for peak unit production of the 64K through 4Mb devices also are shown in Table 1.

Dataquest estimates that the 1Mb DRAM will reach a peak unit production of 1,075 million units during 1991, which is similar to Fujitsu's and Toshiba's projections, but considerably higher than Hitachi's forecast of 750 million units. We believe that 1Mb suppliers currently are in an oversupply and overcapacity situation, which continues to drive down prices for 1Mb DRAMs. We also believe that major European and Japanese DRAM suppliers are cutting back production volumes of 1Mb devices. The number of cutbacks and the timeliness of these cutbacks may not be adequate to reduce the estimated oversupply for the

TABLE 1
DRAM Market Trends—Different Views
(Millions of Units)

	64K		256K		1Mb		4Mb		16Mb		64Mb	
	Peak Year	Units at Peak	Peak Year	Units at Peak	Peak Year	Units at Peak	Peak Year	Units at Peak	Peak Year	Units at Peak	Peak Year	Units at Peak
Fujitsu	NA	NA	1988	800	1991	1,000	1995	1,200	1999	1,500	2002-2003	2,000
Hitachi	1984-1985	900	1988	875	1991	750	1995-1996	750	1999-2000	750	NA	NA
Toshiba	NA	NA	1987-1988	950	1991	1,150	NA	NA	NA	NA	NA	NA
Dataquest	1984	852	1988	963	1991	1,075	1995	1,200	NA	NA	NA	NA

NA = Not available
Source: Fujitsu, Hitachi, Toshiba, Dataquest (December 1990)

remainder of this year and 1991. With the increasing availability of and demand for 4Mb DRAMs, many end users may consider purchasing more 1Mb devices to protect their investments in products that require the 1Mb device.

Considering the 4Mb DRAMs, we estimate that peak unit production will occur in 1995 and will be more than 1,200 million units.

A number of semiconductor manufacturers have announced availability of 16Mb DRAM engineering samples starting in either the fourth quarter of 1990 or the first quarter of 1991. The manufacturers include Fujitsu, Hitachi, Matsushita, NEC, Samsung, Siemens, Texas Instruments, and Toshiba. Engineering complications still exist for the 16Mb DRAM, including the trench or stacked capacitor cells and standardized packaging dimensions. We believe that volume shipments of the 16Mb DRAM will not occur until 1992 and that peak production occurring in the years 1999 to 2000 is realistic.

Hitachi announced late last summer that it has a prototype of a 64Mb DRAM and is rapidly working toward a fully functional sample. It is unlikely that this sample will be available until after 1992.

DATAQUEST CONCLUSIONS

For equipment and materials suppliers, DRAM product life cycles indicate when each new generation of equipment and materials is required. Dr. Graydon Larrabee of Texas Instruments has estimated that development of manufacturing processes and production equipment for each new generation of semiconductor devices must begin about eight to ten years before the year in which volume shipments of the device first occur. For instance, the projections shown in Figures 1 and 2 indicate that volume shipments of the 64Mb DRAM will commence around 1997. This start date means that 64Mb DRAM processes and equipment must already be under substantial development, and, indeed, this is the case indicated by Hitachi's 64Mb DRAM announcement.

The eight- to ten-year development cycle also means that equipment and material suppliers need a long-term approach to R&D that includes both near-term and long-term projects. The challenge is how can the smaller equipment and materials suppliers generate sufficient R&D funds to accomplish such a strategy? The challenge extends to the smaller semiconductor manufacturers as well—are they making sufficient R&D investments in long-term projects to ensure their future survival? U.S. wafer fab equipment manufacturers and semiconductor manufacturers already are sustaining an R&D investment rate of about 14 percent of sales, which is among the highest of any industry.

Ione Ishii
Joe Grenier

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Research Newsletter

SIS MEMORY QUARTERLY NEW PRODUCTS NEWSLETTER

This newsletter contains a synopsis of detailed memory product news events gathered from the trade press and company releases during the second quarter (April through June 1990). This newsletter is meant to be used as a reference guide of new products for competitive analysis, monitoring technology trends, and tracking future developments and improvements. Dataquest assumes no responsibility for the accuracy of the contents.

Table 1 shows the new products for the second quarter of 1990.

Table 1
New Memory Products—Second Quarter 1990

Company	Density and/or Type	Speed
	DRAM Developments	
Micron Technology	1Mb	NA
	1Mb, 256Kx4	80ns
	1Mb, 64Kx16	80ns
	1Mb	80, 100, 120, 150ns
Toshiba	1Mb	80, 100ns
	4Mb	60ns
	SRAM Developments	
Hitachi	32Kx8	25ns
Samsung Semiconductor	64K	8, 12, 15, 20ns
	64K, BiCMOS	12ns
Sony Corporation	1Mb, 256K	NA
Paradigm Technology	1Mb	25ns
Micron Technology	144K cache	24, 28ns
	64Kx32	NA
	16Kx32	NA
Toshiba	256K	17ns
	64K	10, 12ns
	1Mb	85, 100ns

(Continued)

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Table 1 (Continued)
New Memory Products—Second Quarter 1990

Company	Density and/or Type	Speed
ISSI	256K, 32Kx8	25, 30, 35ns
	1Mb	70, 85, 100ns
MOSel	4K	45 to 100ns
Logic Devices	16K, 64K	8ns
Texas Instruments	16Kx5	20ns
Sharp	Dual-port SRAM	35, 45, 55ns
Motorola	32Kx9	20ns
	256K	15, 17ns
	256K	15ns
Quality Semiconductor	64K	12ns
Rohm Corporation	2Mb module	NA
Mitsubishi	1Mb	70, 85, 100, 120ns
	Nonvolatile Memory Developments	
AMI	2Mb, 4Mb CMOS mask ROM	150ns
SEEQ Technology	1Mb EEPROM	120ns
ICT	1Mb EPROM	45ns
Toshiba	4Mb EPROM	120, 150ns
Mitsubishi	Mask ROM	150ns
AMD	1Mb EPROM	45ns
Cypress Semiconductor	64K PROM	30ns
	Specialty Memory Developments	
Cypress Semiconductor	2Kx9 FIFO	30ns
Samsung Semiconductor	512x9, 1,024x9 FIFO	20, 30ns
VLSI Technology	2,048x9, 1,024x9, 512x9 FIFO	20, 30ns
	128K, data cache SRAM	NA
Micron Technology	1Mb pseudo-SRAM	80ns
	Cache card	30ns
Mitsubishi	DRAM memory card	150ns
	SRAM & OTPROM memory card	NA

NA = Not available
Source: Company literature, Dataquest (December 1990)

DRAM DEVELOPMENTS

Micron Technology

Micron Technology introduced the 1Mb extended-temperature DRAM. This DRAM functions in temperatures ranging from -40°C to 85°C for PCs and in temperatures ranging from -40°C to 125°C for automotive DRAMs. The devices are packaged in standard ZIP, DIP, and SOJ packages in 1Mbx1 and 256Kx4 configurations.

A 256Kx4 CMOS quad CAS Fast-Page-Mode 1Mb DRAM also was announced by Micron. The component is available in 24- and 26-pin SOJ packages.

In addition, Micron announced the availability of a 64Kx16 DRAM specifically targeted toward applications with wide memory array requirements. The device is available in a 40-pin SOJ package, with a 40-pin ZIP package to be introduced later. The component is a CMOS process with a typical active power of about 175mW and a standby power of just 5mW.

Also announced by Micron was the 1Mb DRAM, which is housed in 18-pin DIPs, 20-pin rectangular leadless chip carriers (LCCs), and 20-pin flatpacks. The device is intended for military processes and was in the second stage of military qualification at the time of the announcement.

Toshiba

Toshiba announced its 1Mb DRAM family, organized in a 64Kx16 configuration. The device is available in byte-write (TC511664) and write-per-bit (TC511665) versions. The operating power range is from 413mW to 633mW. The devices operate from a single 5V power supply with a 10 percent tolerance. The packaging is JEDEC standard 40-pin plastic SOJ or plastic ZIP.

Toshiba began marketing a smaller chip size (5.4mm x 15.1mm) 4Mb DRAM featuring the 300-mil SOJ package at 60ns access time and using a 0.7-micron design rule. Toshiba uses trench-cell technology on this product, as well as its earlier generation of 4Mb DRAMs.

An addition to Toshiba's line of 1Mb CMOS SRAMs was introduced in a 525-mil SOP package. Two versions of this device are organized as 128Kx8, with low-power dissipation of 5 milliamperes (mA) operating from a single 5V power supply with a 10 percent tolerance.

SRAM DEVELOPMENTS

Hitachi

Hitachi has announced the HM62832H, a 256K SRAM. It is organized as 32Kx8 and has an access time of 25ns. The SRAM is available in both JEDEC standard 300-mil plastic DIP and SOJ packages. The HM62832HL is a low-power version with a typical standby current of 6ua and battery backup mode at 3vdc.

Samsung Semiconductor

Samsung Semiconductor released the KM68B65, a 64K SRAM. It has an 8Kx8 configuration, with access times of 8, 12, 15, and 20ns. It is available in standard 300-mil 28-pin plastic SOJ and DIP packages. The KM68B65 has a standby mode of 20mA, with 120mA to 160mA in operation.

Samsung began sampling its 64K BiCMOS SRAM in multichip modules. The device is available in 8Kx8 configurations with a 12ns access time.

Sony Corporation

Sony Corporation now offers both 1Mb and 256K SRAM devices in TSOP packages. The SRAMs will measure 18.40mm x 8.00mm x 1.07mm. The 256K will have a standby current of 5uA; the 1Mb will have a standby current of 20uA.

Paradigm Technology

Paradigm Technology, located in San Jose, California, announced its 1Mb SRAM, which is organized as 128Kx8. The product number is PDM41024S, and it has standard power in a ceramic DIP package. Military grades will be manufactured, and packaging options include 400- and 600-mil 32-pin DIPs, SOJs, LCCs, and cerpacks for surface-mount applications.

Micron Technology

Micron Technology's SRAM division made numerous announcements in the second quarter. The MT56C2818, a 144K cache data SRAM configured at 8Kx18 or dual 4Kx18 for use in the 80486 systems, was announced. Access times of

24ns for the 33-MHz systems and 28ns for the 25-MHz systems are available. Both come in the industry-standard 52-pin PLCC package and the new 52-pin low-profile plastic quad flat package PQFP.

Micron also announced two additions to its SRAM module product line. Both the 64Kx32 (MT85C3264ZN) module and the 16Kx32 SRAM (MT85C3216ZN) module have been clocked at 15ns. These products require only a single 5V power supply, resulting in low power consumption.

Toshiba

Toshiba announced four new high-speed SRAMs based on the highly reliable 1.0-micron CMOS process. Two of the devices are organized as 32Kx8, with the other components organized as 64Kx4. All four products are molded in standard plastic DIPs or SOJs, which meet JEDEC standards, with 300-mil width for high-density surface assembly.

Toshiba also announced its first BiCMOS SRAMs with access times of 10 and 12ns. Two devices, TC55B417 and TC55B88, are configured as 16Kx4 and 8Kx8, respectively. The devices have a low operating current of 120 or 135mA, while consuming a maximum of 10mA in standby mode. Both devices meet the specific organization JEDEC standards.

ISSI

Integrated Silicon Solution, Inc. (ISSI), located in Sunnyvale, California, announced two 256K SRAMs configured in 32Kx8, one in low-power and the other in high-speed CMOS. The low-power device, IS62C256, has a low active power of 75mW; speeds of 70, 85, and 100ns; low standby power of 10mW; and a single 5V power supply. The high-speed device, IC61C256, has speeds of 25, 30, and 35ns, with a low active power of 400mW. Both devices have PDIP packages.

Another new device for ISSI is a 1Mb SRAM with a 238Kx8 configuration. The device has a low active power of 75mW; speeds of 70, 85, and 100ns; low standby power of 10mW; and a 32-pin DIP package.

MOSel

MOSel, also located in Sunnyvale, California, announced a continuation in its TTL-compatible CMOS SRAMs with 4K SRAMs. The new devices include the MS6395, which is organized as 8Kx8; the MS6397, organized as 12Kx8; and the MS6398, organized as 16Kx9. All three devices feature a power-down ship enable along with access times ranging between 45 and 100ns. The devices are available in 28-pin 300-mil plastic DIP or 330-mil SOG packages.

Logic Devices

Logic Devices announced the availability of a family of 16K and 64K SRAMs offering access times under 8ns. All chips in this family have TTL-compatible I/O lines and are fabricated with full CMOS six-transistor memory cells.

Texas Instruments

TI introduced two unusually configured 16Kx5 and 2Kx16 cache tag devices that use 0.8-micron CMOS technology. Both devices are available in 32-pin plastic leaded chip carriers (PLCCs).

Motorola

A family of BurstRAM SRAMs was introduced by Motorola. The family is made up of three fast CMOS application-specific memories, all organized as 32Kx9, intended to be used with 80485, 68030/40, or SPARC microprocessors. All three devices are based on 1.0-micron CMOS technology and have access times of 20ns. They are available in 44-pin PLCC packages.

Motorola also announced the availability of 256K, 15ns SRAMs in 256Kx1 and 64Kx4 configurations, with plastic DIPs and SOJ packages.

Motorola introduced its latest fast SRAMs in the 256K family; the devices are configured as 32Kx8 and 32Kx9. The devices, aimed at cache memory applications, have access times of 17ns. Also introduced by Motorola is a new 64K (8Kx8 and 8Kx9) fast SRAM with an access time of 15ns. All devices are available in 300-mil plastic SOJ and PDIP.

Motorola also announced two very fast 256K SRAMs, organized as 256Kx1 and 64Kx4 and made with 1.0-micron silicon-gate CMOS technology. The devices meet JEDEC standards and pinout and are available in 300-mil plastic DIP and plastic SOJ packages.

Quality Semiconductors

Quality Semiconductors, a recent Silicon Valley start-up, announced a line of five SRAMs, configured as 16Kx4, which use 1.0-micron technology and are capable of speeds up to 12ns.

Rohm Corporation

Rohm Corporation announced its 32-pin DIP 2Mb static RAM module. The device has a single 5V power supply; its data-retention voltage (2V) makes it suitable for a variety of applications.

Mitsubishi

Mitsubishi announced its 1Mb SRAM, which is available in a TSOP package. The package is sized 8.0mm x 20.0mm, is 1.2mm thick, and is organized as 128Kx8. The package is 32-pin with an active power dissipation of 385.00mW and standby power of 0.27mW at 3V. Access times are 70, 85, 100, and 120ns.

NONVOLATILE MEMORY DEVELOPMENTS

Gould AMI

Gould AMI, located in Pocatello, Idaho, announced 2Mb and 4Mb CMOS mask ROMs, with a response time as fast as 150ns. The 4Mb model 634000 and the 2Mb model 632000 meet JEDEC requirements with 32-pin DIP or 32-lead surface-mount plastic LCC packages.

SEEQ Technology

SEEQ Technology announced volume production of a 1Mb EEPROM with a 120ns access time and low-power requirements of 80mA and 350uA in standby mode. The product is available for both commercial and military applications.

ICT

ICT and AMD jointly announced a fast 45ns 1Mb EPROM.

Toshiba

Toshiba is marketing a mask ROM-compatible 4Mb EPROM with access times of 120 and 150ns. The device is fabricated using a 0.8-micron design, a 60mA operating current, and a 100-microampere standby current. The device is available in a 40-pin CERDIP.

Mitsubishi

Mitsubishi announced the availability of a 4Mb mask ROM at 150ns, which is targeted at the laser printer, PBX, and portable PC markets. The device is available in the TSOP package and features active current of 30mA and standby current of 0.1mA. The device, M5M23400AVP, is available in a 40-pin reverse pinout version and a 40-pin plastic DIP or SOP version.

AMD

Advanced Micro Devices (AMD) announced the existence of a new 1Mb EPROM with an access speed of 45ns. The AM27H010 uses the standard JEDEC pinout and is available in 32-pin plastic DIP and surface-mount packages.

Cypress Semiconductor

Cypress announced a family of four 8Kx8 reprogrammable PROM devices with access times of 30ns. The devices are available in 300-mil-sized packages, with an operating current of 100mA, and come in windowed DIP and LCC package types.

SPECIALTY MEMORY DEVELOPMENTS

Cypress Semiconductor

Cypress Semiconductor introduced the CY7C439, a 2Kx9 FIFO. The FIFO has an access time of 30ns. It is available in 28-pin 300-mil plastic, CERDIP, and SOJ packages, as well as in 28-pin plastic and ceramic LCCs.

Samsung Semiconductor

Samsung Semiconductor launched the KM75C101A (configurated as 512x9) and the KM75C102A (configurated as 1Mb). These two FIFOs have access times of 20 and 30ns. They are obtainable in 300- or 600-mil 28-pin plastic DIPs or in 32-pin PLCCs.

VLSI Technology

VLSI Technology announced the availability of its high-speed 128K SRAM, which is organized as 8Kx16 or two 4Kx16 memories. The devices can be used as data cache RAMs in conjunction with Intel's cache controller in high-performance 386 systems.

Micron Technology

Micron Technology announced the availability of its 1Mb pseudostatic DRAM. The device is available in a 128Kx8 SRAM pinout, is available in a 32-pin SOIC package, and has an access time of 80ns.

Micron also developed and announced its Xceed IIci-128 cache card for the Macintosh IIci.

Mitsubishi

With densities of up to 3MB, Mitsubishi announced its first DRAM memory cards. The DRAM cards have densities of 512K, 1Mb, 2Mb, and 3Mb; support a 16-bit data bus; and have a maximum access time of 150ns. The 60-pin memory cards feature a pin-and-socket connector with several options.

Mitsubishi also announced the availability of the 1Mb and 2Mb SRAM and one-time PROM (OTPROM) memory cards.

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Research Newsletter

SIS MEMORY QUARTERLY NEW PRODUCTS NEWSLETTER

This newsletter contains a synopsis of detailed memory product news events gathered from the trade press and company releases during the first quarter (January, February, and March) of 1990. It is meant to be a reference guide of new products for competitive analysis, monitoring technology trends, and tracking feature developments and improvements. Dataquest assumes no responsibility for the accuracy of the contents.

Table 1 shows the new products for the first quarter of 1990.

DRAM DEVELOPMENTS

Micron Technology

Micron Technology has announced the JAN 38510, a 1Mb DRAM. The DRAM is available in

TABLE 1
New Memory Products—First Quarter 1990

Company	Density	Speed
	DRAM Developments	
Micron Technology, Inc.	1Mb	80, 100, 120, 150ns
	256Kx4	70, 80, 100ns
Mitsubishi Electronics	1Mb	70, 80ns
NEC	1Mb	60ns
Samsung Semiconductor	4Mb	
	SRAM Developments	
Catalyst Semiconductor	256K	85ns
Cypress Semiconductor	64K	12ns
Dense Pac Microsystems Inc.	4Mb	85-150ns
Goldstar Technology	8Kx8	150ns
Hitachi America, Ltd.	4Mb	100ns
Integrated Silicon Solution, Inc.	8Kx8	20, 25, 30ns
Intel Corporation	32Kx8	25ns
Logic Devices Inc.	256K	12, 15ns
LSI Logic Inc.	NA	NA
Micron Technology, Inc.	256K	25, 35, 45, 55ns
Mitsubishi Electric	1Mb	35ns

(Continued)

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TABLE 1
New Memory Products—First Quarter 1990 (Continued)

Company	Density	Speed
Motorola, Inc.	256K	15, 20, 25ns
Philips International N.V.	8Kx8	55 to 70ns
Samsung Electronics Co.	1Mb	70, 80, 100, 120ns
Sharp	256K	12, 100ns
VLSI Technology, Inc.	1Mb	35, 45ns
	16K	12, 15ns

Company	Density	Type	Speed
	Nonvolatile Memory Developments		
Advanced Micro Devices	2Mb	EPROM	100ns
Cypress Semiconductor Corporation	256K	PROM	35ns
International CMOS Technology	1Mb	EPROM	55, 70, 90ns
Microchip Technology		EEPROM	
Mitsubishi	4Mb	EPROM	100, 120, 150ns
Sharp Electronics	16Mb, 4Mb	ROM	200, 100ns
Texas Instruments	256K	EEPROM	
Toshiba	1Mb	EPROM	85ns
	1Mb	EPROM	55, 70ns
	4Mb	EPROM	120, 150ns
White Technology	4Mb	EEPROM	150ns
	Specialty Memory Developments		
Advanced Micro Devices	512x9	FIFO	25, 35ns
Brooktree	256x24	Ramdac	
Inmos Ltd.		Color lookup table	
NEC	4Mb, 2Mb	Muse HDTV	21ns
Samsung Semiconductor	512x9	FIFO	20ns
SGS-Thomson Microelectronics	1,024x9, 512x9	FIFO	35ns
Sharp	512X9	FIFO	15, 20ns
Texas Instruments	16Kx5	Cache address comparators	18, 20ns

NA = Not available
Source: Various publications, Dataquest (July 1990)

an 18-pin DIP, a 20-pin rectangular LCC, and 20-pin flatpack. It is available in 80, 100, 120, and 150ns.

Also announced by Micron Technology is a 256Kx4 fast static-column DRAM. It features access speeds of 70, 80, and 100ns. The DRAM is obtainable in four package types: plastic DIP, ceramic DIP, plastic ZIP, and plastic SOJ, all with industry standard dimensions.

Mitsubishi Electronics

Mitsubishi Electronics has introduced two 1Mb CMOS DRAMs in a thin small-outline package (TSOP), the M5M41000BVP/RVP organized 1Mbx1, and the M5M44256BVP/RVP organized 256Kx4. Both are attainable in 24/20-pin, 300-mil TSOPs and have access times of 70 and 80ns.

NEC

Released by NEC are two 1Mb DRAMs—the uPD421000-60, 1Mbx4-bit and the uPD424256-60, 256Kx4-bit. Both have an access time of 60ns and are packaged in DIPs, SOJs, and ZIPs. Each DRAM measures 4.55x10.4mm and consumes 90mA.

Samsung Semiconductor

Samsung Semiconductor is now offering the KM41C-4000, a 4Mb CMOS DRAM. It is available in a JEDEC standard pinout plastic SOJ package.

SRAM DEVELOPMENTS

Catalyst Semiconductor

Introduced by Catalyst Semiconductor is a new 256K CMOS SRAM. The CAT71C256LPI has a configuration of 32Kx8 and a maximum access time of 85ns.

Cypress Semiconductor Corporation

Cypress Semiconductor has announced a family of 64Kb BiCMOS SRAMs. The CY7B160, B161, B162, B164, and B166 are 16Kx4 chips, and the CY7B185 and B186 are 8Kx8 chips. The B185 is available in a 300-mil-wide package and the B186 is available in a 600-mil-wide package. All of the chips are available in plastic DIP versions with an access time of 12ns. The RAMs consume 600mW when active and 200mW when the dissipation drops.

Dense Pac Microsystems Inc.

Introduced by Dense Pac Microsystems is a 4Mb CMOS SRAM, the DPS512S8. Its configuration is 512x8 bits, and it is packaged in a 32-pin DIP. It is a 600-mil module that conforms to the JEDEC standard pinout. The SRAM has access times ranging from 85 to 150ns.

Goldstar Technology

Goldstar Technology is selling 8Kx8 SRAMs, which are attainable in 28-pin DIPs and SOPs with an access time of 150ns. The SRAMs have 40 milliamps in operating current and 100 microamps in standby.

Hitachi America, Ltd.

Hitachi America is now offering the HM658512 series, a 4Mb pseudo SRAM (PSRAM). The PSRAM is configured as 512Kx8 and has an access time of 100ns. It is available in a 600-mil, 32-pin DIP package and a 525-mil, 32-pin surface-mount SOP package.

Integrated Silicon Solution, Inc.

Integrated Silicon Solution has launched the IS61C64, a 8Kx8 SRAM that is available with access times of 20, 25, and 30ns. The SRAM is packaged in the JEDEC standard 28-pin, 600-mil DIP, 300-mil DIP, and SOP.

Intel Corporation

Released by Intel Corporation are two 32Kx8 SRAMs, the M51256 and M51256L. Both have an access time of 25ns and are available in four different package types: a 28-pin ceramic DIP; a 32-lead pin grid array; a 32-pin LCC; and a 32-lead J-lead gull-wing chip carrier.

Logic Devices Inc.

Logic Devices is sampling 256K SRAMs: the L7C197 (256Kx1), the L7C194, 195, and 196 (64Kx4), the L7C191 and 192 (64Kx4 with separate I/O), and the L7C199 (32Kx8). All have an access time of 15ns except for the L7C197, which has an access time of 12ns. The SRAMs are obtainable in plastic DIP and SOIC packages; CERDIPs, LCCs, and flatpacks are offered for military applications.

LSI Logic Inc.

Released by LSI Logic is a new SRAM, the L64212. A 30-MHz version is now attainable in a 95-lead ceramic pin-grid array.

Micron Technology, Inc.

Micron Technology has announced the JAN 38510, a 32x8 256K SRAM. The device is offered in 300- and 600-mil DIPs and 28- and 32-pin LCCs. The SRAM has speeds of 25, 35, 45, and 55ns.

Mitsubishi

Being sample-released by Mitsubishi Electric are two 1Mb SRAMs. Both have an access time of 35ns and measure 6.1x15.84mm. The M5M51001 is configured as a 1Mbx1 construction, and the M5M51004 is configured with a 256Kx4 construction. The SRAMs are available in a 400-mil-wide, 28-pin SOJ package. DIP and TSOP packages will be available soon.

Motorola Inc.

Motorola introduced the MCM6207 (256Kx1), MCM6208 (64Kx4), and MCM6209 (64Kx4 w/OE). All of the fast SRAMs have access times of 15, 20, and 25ns. They are obtainable in standard 300-mil PDIP and plastic SOJ packages.

Philips International NV

Now being offered by Philips International NV is the FCB1C65, an SRAM-configured 8Kx8. It has access times between 55 and 70ns and is offered in a 600-mil 28-pin DIP and a 330-mil SOP.

Samsung Semiconductor

Samsung Semiconductor has launched a 1Mb high-speed SRAM. The KM681000/L is available in speeds of 70, 80, 100, and 120ns and is packaged in a 32-pin DIP (600 mil) and 32-pin SOP (450 mil).

Sharp

Sharp has begun sampling the LH51256, a 256K SRAM. The LH51256-10L is offered at a speed of 100ns, and the LH51256-12L is offered at 12ns. It is offered in a 600-mil, 28-pin DIP and a 450-mil, 28-pin SOP.

VLSI Technology, Inc.

VLSI Technology, along with Hitachi, has released a 1Mb (256Kx4) SRAM, known both as the VT624256 and the VT624256L. The SRAM is presented in a 400-mil, 28-pin SOJ package. It has a fast access time of 35ns, but also is available in 45ns. Both access times offer an extremely low power consumption of 350 milliwatts in active mode and 100 microwatts in standby mode.

Also introduced by VLSI Technology are two high-speed SRAMs, the VT20C19 (2Kx8) and the VT20C79 (4Kx4). Both have access times of 12 and 15ns.

NONVOLATILE MEMORY DEVELOPMENTS

Advanced Micro Devices

Offered by Advanced Micro Devices is the 2Mb Am27C020 (256Kx8) EPROM. It has an access time of 100ns and is available in a 32-pin DIP or an LCC.

Cypress Semiconductor Corporation

Cypress Semiconductor has released a threesome of 256K PROMs, the CY7C279, CY7C271, and CY7C277. All three have an access time of 35ns and are offered in 300-mil-wide 28-pin DIPs. A fourth PROM, the CY7C274, is housed in a 600-mil-wide DIP and has a standard EPROM pinout.

International CMOS Technology

International CMOS Technology has introduced the 27CX010, a 1Mb EPROM with access times of 55, 70, and 90ns. It is configured 128Kx8 and is obtainable in a 32-pin windowed DIP.

Microchip Technology

Microchip Technology is sampling four families of EEPROMs. The 24C01A, 02A, and 04A are 1, 2, and 4Kb and have configurations of 128x8, 256Kx8, and 512x8. The 85C72, 82, and 92 are similar except for the different pin organizations. The 93C06 and C46 are available in 256- and 1,024-bit densities and are organized 16x16 and 64x16. Ultimately, the 59C11 is an enhanced version of the 93Cxx series, with an organization of 128x8 or 64x16. All of the chips are attainable in CERDIPs and plastic DIPs, as well as small-outline ICs.

Mitsubishi

Mitsubishi Electric is offering two 4Mb EPROMs. One has a bit construction of x8 and the other is x16. Both EPROMs are available with access times of 100, 120, and 150ns and have a power consumption of 30mA in active mode and 100uA in standby mode.

Sharp Electronics

Sharp Electronics has unveiled a 16Mb mask ROM with an access time of 200ns and is developing a 4Mb ROM with an access time of 100ns.

Texas Instruments

Being released by Texas Instruments are 256K flash EEPROMs. The EEPROMs have a 5V power supply. They are offered in 28-pin plastic and ceramic DIPs and in 32-pin PLCCs.

Toshiba

The TC57H1024D, a 1Mb EPROM, has been introduced by Toshiba. The EPROM has an organization of 64Kx16 and an access time of 85ns.

Toshiba launched two new 1Mb EPROMs with access times of 55ns (TC57H1025AD-55) and 70ns (TC57H1025AD-70). Both are available in a 40-pin cirdip DIP (JEDEC standard).

Also introduced by Toshiba is a 4Mb EPROM that is fully compatible with 4Mb mask ROMs. The 4Mb EPROM is configured in 512Kx8 or 256Kx16 and is available in 120 and 150ns. It will be packaged in a 40-pin CERDIP, a 40-pin plastic DIP, and a 40-pin plastic SOP. The EPROM has an operating current of 60mA and a standby current of 100uA.

White Technology

White Technology has announced the M4194E, a 4Mb EEPROM. The EEPROM is configured in three modes, 512x8, 256x16, or 128x32. All three configurations are available in a 76-pin flatpack and have a maximum speed of 150ns.

SPECIALTY MEMORY DEVELOPMENTS

Advanced Micro Devices

Advanced Micro Devices has unveiled the Am4601 CMOS FIFO. It is organized 512x9, with access times of 25 and 35ns. The 35ns chip is obtainable in a 28-pin 300-mil plastic DIP or 32-pin PLCC.

Brooktree

The Bt474 Ramdac has been released from Brooktree. The Ramdac offers a 256Kx24 color RAM and 15-color overlay. The Bt474 also can handle 640- by 480-pixel VGA graphics. It is attainable in a 84-pin PLCC.

Inmos Ltd.

Inmos has introduced a color lookup table, the IMS G176L. The device has a supply current of less than 10mA in standby. The G176L is available in three package types: a 28-pin plastic DIP, a 32-pin PLCC, and a 44-pin PLCC.

NEC

NEC now is offering the uPD42290DW, a 4Mb field memory that can adapt a Muse HDTV system. It has an access time of 21ns and is obtainable in a 64-pin ceramic DIP. NEC also is sampling the uPD42291R, a 2Mb product that is packaged in a 68-pin ceramic PGA.

Samsung Semiconductor

Samsung Semiconductor has announced two CMOS FIFOs, the KM75C01A-15 (512x9) and the KM75C02A-15 (1024x9). Both chips have an access time of 15ns and are 120mA in active mode and 15mA in power-down mode.

SGS-Thomson Microelectronics

SGS-Thomson Microelectronics has introduced the MK45H02 (1024x9) and the MK45H01 (512x9), two low-power, high-speed FIFOs. Both have an access time of 35ns.

Sharp

Sharp has announced the LH5496D-15, a CMOS FIFO with an access time of 20ns. The part is packaged in a 28-pin DIP or a 32-pin PLCC. It has an organization of 512x9.

Texas Instruments

Introduced by Texas Instruments are two cache address comparators, the SN74ACT2163 and SN7ACT2164. Both consist of a high-speed 16Kx5 SRAM array and a 5-bit high-speed comparator. These cache address comparators have access times of 18 and 20ns, are packaged in a 32-pin PLCC, and can operate from a single 5V power supply.

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Research Newsletter

BiCMOS TURBOCHARGES THE FAST SRAM RACE

INTRODUCTION

BiCMOS process technology combines bipolar and CMOS elements on a single chip to take advantage of the positive attributes of each—CMOS' low power and bipolar's speed. Producing a BiCMOS RAM initially entails about four additional mask layers, incurring approximately a 20 percent cost increase over CMOS. The majority of companies that currently offer these devices employ a CMOS or NMOS memory cell to which the bipolar elements are added in the speed-sensitive peripheral circuitry.

This newsletter states why Dataquest views BiCMOS as developing into a key SRAM technology for the 1990s through discussion of the major technology issues and driving applications and what they mean in terms of our forecast for this technology.

ADVANTAGES OF BiCMOS

BiCMOS is emerging as a growth market because of the advantages it offers over pure CMOS and pure bipolar devices. Major advantages of BiCMOS over these technologies are as follows:

- Has ability to operate with either emitter-coupled logic (ECL) or transistor-transistor logic (TTL) input/outputs (I/Os)
- Can achieve next-generation speeds at more conservative line geometries
- Has low power dissipation
- Has narrow speed-distribution curve

ECL and TTL I/O

The major benefit of BiCMOS is its ability to operate at both ECL and TTL I/O levels. Virtually all CMOS fast SRAMs have TTL I/O interfaces. In the past, system designers resisted using ECL I/O because it involved working with the high power dissipation of bipolar and the tight tolerances of ECL I/O, which include limiting the amount of signal swing and terminating transmission lines. Compared with TTL I/Os, ECL offers the advantages of a higher-speed interface and stronger drive capability. As the market moves to faster CPUs and designers push their systems to achieve faster speeds, the trade-offs to implementation of their designs in TTL or ECL I/O will start to increase in ECL's favor.

Higher Speeds

Speed is another major benefit that BiCMOS offers over CMOS and is one of the primary motivating factors to a supplier that is considering implementing a BiCMOS process. From a speed perspective, CMOS and BiCMOS will remain competitive in the near future in the TTL I/O market. To achieve ever-faster speeds from a CMOS process, a manufacturer must drive its CMOS process parameters by continuing to reduce line geometries and effective gate lengths. By comparison, producing BiCMOS devices entails the difficulty of incorporating CMOS and bipolar elements onto a single chip, but faster speeds can be achieved at more conservative line geometries. Although the implementation of BiCMOS incurs the incremental cost of the extra mask layers, this will become less significant a deterrent in the face of the escalating costs of pushing to feature sizes that are well below the submicron level.

Low Power Dissipation

The ability to combine the low power dissipation of CMOS with the speed of bipolar is a key

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advantage of BiCMOS technology. For instance, when comparing a bipolar device with a BiCMOS device, each featuring the same density, organization, and access time specifications, the BiCMOS device will dissipate about one-half the power of the bipolar device.

Narrow Speed Distribution

Because of the inherent characteristics of the bipolar elements, a narrow speed-distribution curve can be derived from a BiCMOS process, which permits the supplier to optimize the overall speed yield of the RAMs. This curve enables a supplier to target a specific market in terms of speed grade and limit the fallout of devices that do not perform within the desired speed range.

THE KEY TO THE MARKET: APPLICATIONS

As is the case with other memory devices, the move toward BiCMOS will be application driven, not supply pushed. As CPU speeds increase, all elements of the system will strive to keep pace. Initially, the development of BiCMOS SRAMs will be driven by the main memory needs of supercomputers. However, cache implementations will be the key driver of these devices, and Dataquest anticipates that this application will eventually consume almost one-half of all BiCMOS SRAM shipments. Although most BiCMOS RAMs are not sufficiently fast for use as the primary cache in the larger systems, their high speed, reasonable cost, and low power dissipation make them ideal candidates for a secondary cache in either ECL or TTL I/O.

In evaluating the cache demands of systems ranging from engineering to supercomputers, Dataquest's assessment of 1988 systems concludes that the majority of cache requirements were filled by bipolar and CMOS devices at that time. By 1991, however, CPU speeds will have accelerated to the point that BiCMOS' power, density, and speed attributes will be necessary in some systems, possibly filling the primary cache needs at the minicomputer performance level. By 1993, most systems will incorporate BiCMOS to meet secondary cache requirements with access times ranging from 15 to 8ns. For example, Dataquest anticipates that secondary caches of approximately 512KB in engineering workstations will be a likely use for BiCMOS TTL or ECL I/O RAMs. Furthermore, with the prospect of ECL I/O versions of standard RISC and CISC processors being introduced, more ECL I/O caches will be needed for use in systems starting at the workstation level and working up through more powerful systems. Momentum from current development activities to deliver ECL versions of RISC processors (e.g., the SPARC and MIPS processors and the 88000) together with anticipated ECL versions of CISC processors will serve to spur market growth of the ECL I/O market. Such advanced ECL processors will migrate down the performance scale of system configurations to the more volume-oriented workstation market, where they will represent significant revenue sources.

Other applications that will consume BiCMOS SRAMs will be very similar to those that use fast CMOS SRAMs, including pattern storage for IC testers, control code storage or registers for high-performance processors, and buffering for imaging and graphics systems.

TECHNOLOGY TRENDS

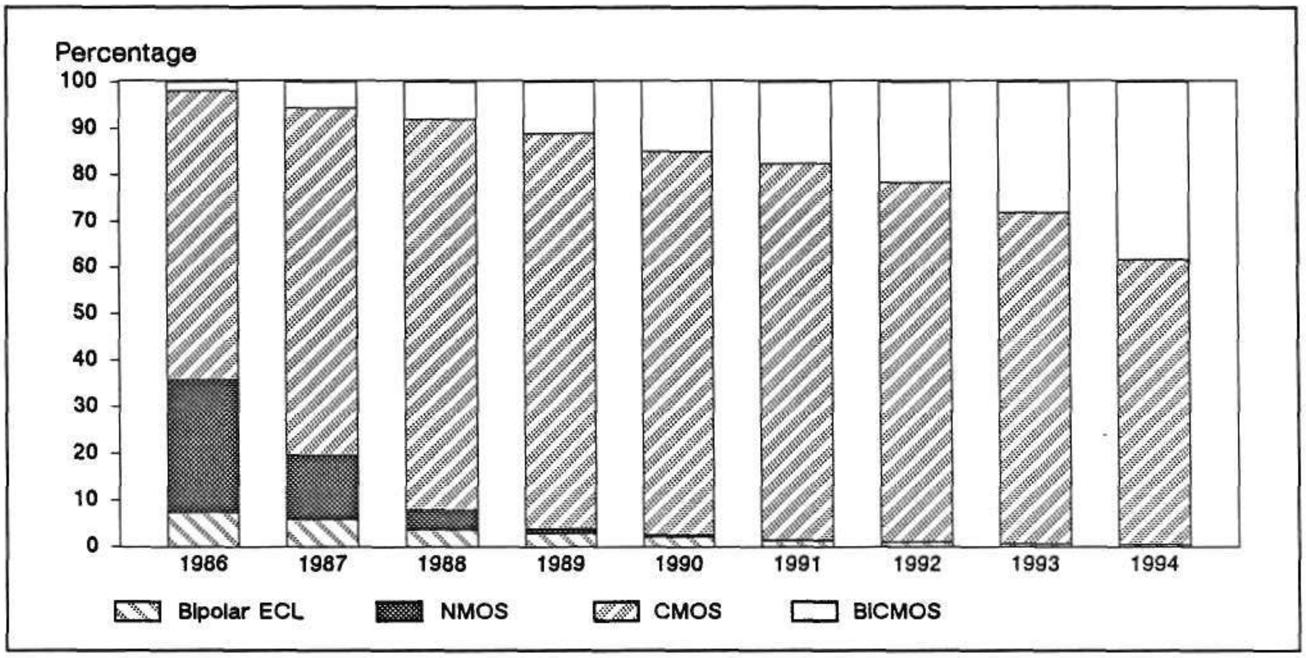
BiCMOS is well positioned to take advantage of the developments in both the ECL and TTL I/O markets, whereas CMOS for the most part is restricted to the TTL I/O markets. While the development of bipolar ECL RAMs will continue to focus on increased speeds at densities at and below 64K and CMOS will concentrate foremost on achieving ever-higher densities, BiCMOS will endeavor to breach the gap by evolving to drive down access times at the higher densities. Based on the percentage of bits shipped from each category, Figure 1 shows expected high-speed SRAM shipments based on bipolar ECL, NMOS, CMOS, and BiCMOS technologies. In the time frame shown, CMOS makes up the overwhelming majority of the market. Gradually, BiCMOS should capture an increasing percentage of market share as measured in bits shipped. Bipolar has difficulty maintaining a presence because its units are restricted to the smaller densities.

Future development of BiCMOS may involve increasing the percentage of bipolar in the RAM. As an alternative to selectively placing bipolar elements into speed-sensitive portions of a CMOS design, perhaps the opposite approach of using a few CMOS elements in power-critical sections of a bipolar design might be useful. Our analysis suggests that there would be demand for devices that could offer densities greater than 64K at speeds of less than 8ns. That type of combination seems to be achievable only through a bipolar-based BiCMOS process. Moreover, BiCMOS could also be a boon to the integration of analog capabilities on a digital device.

BiCMOS MARKET OUTLOOK

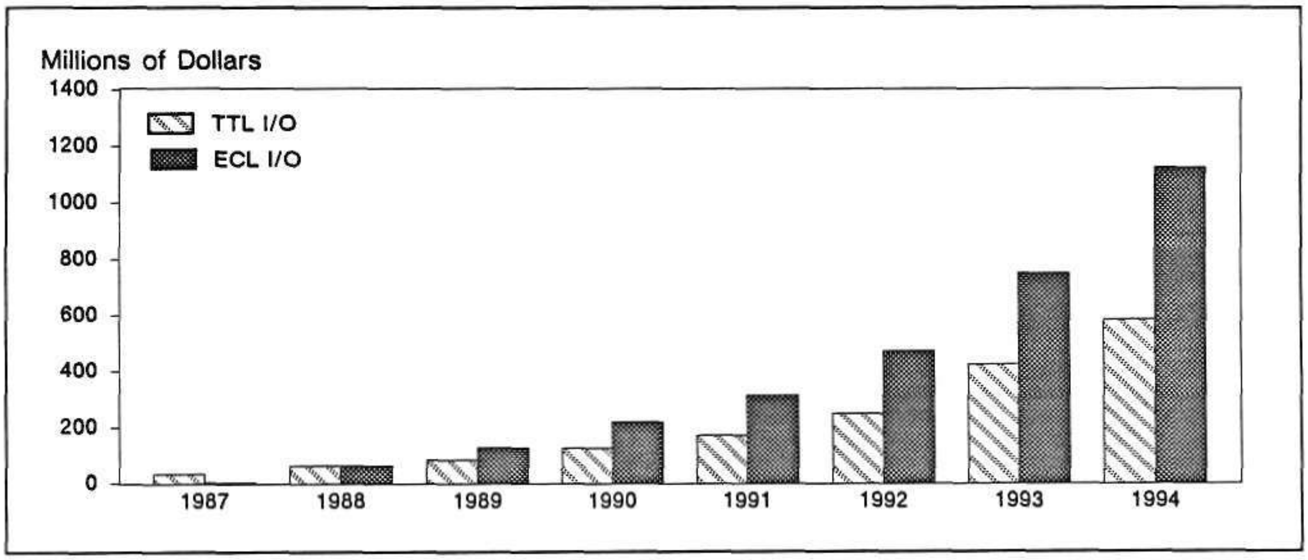
Dataquest's forecast for the high-performance BiCMOS RAM market is presented in Figure 2. The figure shows the split between TTL and ECL I/Os, reflecting the tremendous growth potential for

FIGURE 1
High-Speed SRAMs by Process in Percentage of Total Bits



Source: Dataquest (June 1990)

FIGURE 2
BiCMOS SRAM Revenue Forecast: TTL versus ECL I/O



Source: Dataquest (June 1990)

BiCMOS ECL I/Os. Although we expect both TTL and ECL I/O markets to continue to grow, faster CPUs and the diminishing barriers to using ECL I/O will encourage the conversion of increasing numbers of designs to ECL in order to take advantage of the speed and drive features it offers. Due to their heavy usage as main memory in supercomputers, we expect strong growth of 256K ECL devices, and eventually of devices at the 1Mb level. The possibility of standardization of pin-outs for ECL and TTL I/Os could provide a strong impetus to market growth for BiCMOS. Bipolar RAMs will experience slow growth because of market erosion from BiCMOS ECL. Currently, CMOS' performance is keeping pace with BiCMOS/TTL, and CMOS is gaining additional mileage to enhance its competitiveness through the integration of more logic functions on-chip.

In the future, the most significant impact on BiCMOS SRAMs will come from the use of the technology in DRAM manufacturing. At the 1Mb and 4Mb levels, BiCMOS will represent only a small portion of the market. However, because of the increased speed demands at the 16Mb level, BiCMOS could start to capture larger amounts of market share. If BiCMOS is incorporated into high-volume products such as DRAMs, it will drive the cost down and improve the manufacturability of BiCMOS, much as DRAMs did for CMOS. These factors would result in a much more cost-effective BiCMOS process, which implies that BiCMOS SRAM suppliers that are not also participating in the BiCMOS DRAM market could be placed at a cost disadvantage.

DATAQUEST CONCLUSIONS

Dataquest does not believe that BiCMOS will totally eclipse CMOS in the near- to midterm future the way CMOS did its predecessor, NMOS. Rather, we expect the two processes to coexist peacefully, at least in the near term. However, BiCMOS will challenge CMOS at the very fast strata of the market, and it eventually will dominate the ECL I/O market.

We believe that suppliers wishing to remain at the forefront of the fast SRAM market must have BiCMOS as an essential element of their strategy. Also, they will need to take into consideration future challenges that will arise because of cost improvements driven by BiCMOS DRAMs. Furthermore, BiCMOS could become a strategic process in the future, not only to memory devices but also to microprocessors and ASICs, as well as holding the promise to facilitate the incorporation of analog capabilities on a digital process.

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Research Newsletter

SIS MEMORY QUARTERLY NEW PRODUCTS NEWSLETTER

SUMMARY

This newsletter contains a synopsis of detailed memory product news events gathered from the trade press and company releases over the fourth quarter (October, November, and December) of 1989. It is meant to be a reference guide of new products for use in competitive analysis, monitoring technology trends, and tracking feature developments and improvements. SIS assumes no responsibility for the accuracy of the contents.

The new products for the fourth quarter of 1989 are listed in Table 1.

DRAM DEVELOPMENTS

Micron Technology

Micron Technology has released a static column version of its 1Mb DRAM. The MT4C4258 is a CMOS 1Mbx1 DRAM with

TABLE 1
New Memory Products—Fourth Quarter 1989

Company	Density	Speed
	DRAM Developments	
Micron Technology	1Mbx1	80ns
Motorola	4Mbx1, 1Mbx4	80, 100ns
Vitelic	256Kx4	85, 100, 120ns
Vitelic	256Kx9, 256Kx8	70, 80, 100ns
	SRAM Developments	
Dallas Semiconductor	256-bit	
Hitachi	256Kx4	35ns
Integrated Silicon Solution	16Kx4, 8Kx8	15 to 30ns
Logic Devices	16K, 64K	10 to 15ns
Micron Technology	2Kx8	100ns
Micron Technology	512K, 1Mb, 2Mb	15 to 30ns
Motorola	128Kx8	80, 100ns
Motorola	64K, 256K	12 to 15ns
NEC	256Kx4	25ns
Paradigm	256K	20ns
	ECL I/O-Level RAM Developments	
Fujitsu	256Kx1, 64Kx4	15ns
National Semiconductor	64Kx4, 16Kx4	12, 10ns

(Continued)

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TABLE 1 (Continued)
New Memory Products—Fourth Quarter 1989

Company	Density	Type	Speed
	Nonvolatile Memory Developments		
Advanced Micro Devices	256Kx8	EPROM	100ns
Cypress Semiconductor	8Kx8	EPROM	30, 35ns
Cypress Semiconductor	32Kx8	EPROM	35ns
Microchip Technology	32Kx8	EEPROM	90ns
NEC	512Kx8	ROM	100ns
Sharp	4Mb	ROM	100ns
WaferScale Integration Inc	64Kx16	EEPROM	120, 200ns
White Technology	4Mb	EPROM	
	Specialty Memory Developments		
Integrated Device Technology	128Kx8	Shared Memory	50 to 120ns
Integrated Device Technology	512x18, 1Kx18	FIFO	20ns
Integrated Device Technology	32Kx9	Cache RAM	25, 35, 45 MHz
Integrated Silicon Solution	4Kx16	Cache RAM	25,35, 45ns
Logic Devices	4Kx4, 8Kx8	Cache-tag	10, 12ns
Samsung	512x9, 1Kx9		
2Kx9	FIFO	15, 20ns	
Sony	8Kx16	Cache RAM	30 to 55ns
Toshiba	8Kx18	Cache RAM	20ns

Source: Dataquest
April 1990

DRAM access times as fast as 80ns and 20ns in static column mode. This 1Mb DRAM is housed in four packages: a plastic DIP, a ceramic DIP, a plastic SIP, and a plastic SOJ.

Motorola

Motorola introduced its MCM514100 and MCM514400, 4Mb DRAMs organized as 4Mbx1 and 1Mbx4. They are manufactured from Motorola's 0.8-micron CMOS process and are available in 80ns and 100ns versions. These new devices are packaged in either a 350-mil SOJ or a 100-mil ZIP.

Vitelic

A high-speed, low-power 1Mb DRAM has been put on the market by Vitelic. The V53C104 is a 256Kx4 that offers row address access times of 85, 100, and 120ns. This new memory also features a power dissipation of 1.5mA CMOS level standby current that enables it to be used in portable battery-operated applications. This device is available in a 20-pin DIP and a 26/20-pin SOJ.

Vitelic also now offers 70, 80, and 100ns DRAM modules configured as 256Kx9 and 256Kx8. These devices are available in 30-lead SIPs and SIMMs.

SRAM DEVELOPMENTS

Dallas Semiconductor

Announced by Dallas Semiconductor is a 256-bit RAM in a plastic TO-92 package with three leads: power, signal, and ground. A complex multiplexing scheme enables the RAM to effectively use one pin for data, address, and control signals. Consequently, only one I/O line from a processor is necessary to access the RAM's memory. The device operates from a 1.5V power supply; it consumes 50nA in standby and 48 nanocoulombs when accessed. The RAM also has the added feature of a nonvolatile ID code that can be programmed in at the factory if required.

Hitachi

Recently introduced by Hitachi are two 1Mb CMOS fast SRAMs. The HM624256 and HM624257 are manufactured from a 0.8-micron CMOS process and are configured as 256Kx4. The HM624256 offers a common I/O and comes in a 400-mil 28-pin SOJ package; the HM624257 offers a separate I/O and is available in a 400-mil 32-pin SOJ package. Both devices offer access times of 45ns and 35ns.

Integrated Silicon Solution, Inc. (ISSI)

ISSI, a relative newcomer to the SRAM market, has made available its first high-speed SRAM products. Both devices are CMOS and 64K in density. They are configured as 8Kx8 (the IS61C64) and 16Kx4 (the IS61C66). The 8Kx8 has access times varying from 20 to 30ns and is packaged in a 28-pin DIP or SOG. The 16Kx4 has speeds ranging from 15 to 30ns, offers a fast output enable, and is packaged in a 24-pin DIP or SOG.

Logic Devices Inc.

Logic Devices has launched a family of 16K and 64K fast SRAMs to meet the growing needs of high-performance systems. The products that were introduced are as follows: L6116, 2Kx8 10ns; L7C168/170/171/172, 4Kx4 10ns; L7C167, 16Kx1 10ns; L7C185, 8Kx8 15ns; L7C164/165/166/161/162, 16Kx4 12ns; and L7C187, 64Kx1 12ns. The devices are packaged in ceramic or plastic DIPs as well as SOGs and SOJs.

Micron Technology Inc.

The MT5C167 is a 16K latched SRAM developed by Micron Technology. This device is configured as 2Kx8; it features an address latch and an access time of 100ns. The address latch eliminates the need for this function to be fulfilled with external circuitry. This device is ideal for multiplexed address/data bus applications and is targeted for applications in disk drives, industrial control, portable instrumentation, portable medical equipment, keyboards, printers, and the automotive market. The new SRAM comes in a 28-pin DIP.

Micron also has made available four SRAM modules. They are defined as follows: MT85C3216, 15ns 16Kx32 packaged in a 64-pin ZIP; MT85C3264, 25ns 64Kx32 packaged in a 64-pin ZIP; MT85C1664, 30ns 64Kx16 packaged in a 40-pin 600-mil DIP; MT85C1632, 30ns 32Kx16 packaged in a 40-pin 600-mil DIP.

Motorola

A 128Kx8 CMOS pseudo static RAM (PSRAM) is available now from Motorola. This new device—the MCM518128—is manufactured from a 1.0-micron CMOS process, comes in either an 80 or 100ns access time, and offers a typical operating current of 100uA and a maximum of 200uA. A 600-mil 32-pin DIP or 32-lead SOG are the package options.

Also recently launched by Motorola are two new 64K and two new 256K high-speed SRAMs. Using Motorola's 1.0-micron CMOS process, the MCM6288/90 (16Kx4), MCM6287 (64Kx1), MCM6208/09 (64Kx4), and MCM6207 (256Kx1) have been made available at 12ns access times for the 64K density devices and 15ns for the 256K density devices.

NEC

Two 1Mb fast SRAMs have begun sampling from NEC—the uPD431001LE (1Mbx1) and the uPD431004LE (256Kx4). Both RAMs feature a 25ns access time and are manufactured from a 0.8-micron CMOS double-layer aluminum process. The die size of these devices is 14.5 x 5.9mm, and they are available in a 28-pin 400-mil plastic SOJ.

Paradigm Technology

Paradigm has released three 256K fast SRAMs. The devices are organized as 64Kx4, 32Kx8, or 256Kx1. They have access times as fast as 20ns and are packaged in a 300-mil plastic and ceramic DIP, plastic SOJ, or ceramic LCC. Paradigm also offers a version of these products that complies with the MIL-STD-883 class C military specifications. The devices draw 350mW in active mode and 100uW in standby.

ECL I/O-LEVEL RAM DEVELOPMENTS

Fujitsu Microelectronics

Two 256K BiCMOS SRAMs have been launched by Fujitsu. These RAMs—the

MBM101C500 and MBM101C504—are organized as 256Kx1 or 64Kx4, have ECL input and output interface levels, and feature a 15ns access time. The products are available in ceramic DIPs, flatpacks, and LCCs; they are manufactured using a 1.2-micron design rule.

National Semiconductor

National introduced two x4 fast SRAMs—the NM5104/NM100504 (64Kx4) and the NM10494/100494 (16Kx4). These devices feature ECL interface levels and are manufactured from National's BiCMOS III process. The 64Kx4 has an access time as swift as 12ns, a 1W typical power consumption, and a 1.5W maximum at 50 MHz. The 16Kx4 offers a 10ns access time, typical power consumption of 1.0W, and 1.3W maximum at 50 MHz. Both devices are packaged in a 28-pin ceramic flatpack and side-brazed DIP.

NONVOLATILE MEMORY DEVELOPMENTS

Advanced Micro Devices (AMD)

AMD has introduced the AM27C020, a 2Mb EPROM with an access time of 100ns. The memory is structured as a 256Kx8 and will be available in a 32-pin DIP and PLCC. One-time-programmable devices in plastic DIPs are expected to be available in the near future.

Cypress Semiconductor

A faster family of 8Kx8 CMOS PROMs has been introduced by Cypress. The CY7C261/3/4/6 are 30ns (35ns military) reprogrammable PROMs designed to replace slower EPROMs in high-performance systems. These PROMs offer a power-down feature and use only 100mA under normal operation. They are manufactured from Cypress' 1.2-micron CMOS double-metal-layer process and are available in windowed DIPs and LCCs.

Also announced by Cypress is a new family of 256K CMOS 35ns reprogrammable PROMs. The family is made up of three 32Kx8 devices: the CY7C274, packaged in a 600-mil windowed DIP; the CY7C279, featuring an address register for use in microprocessor applications and housed in a 300-mil DIP; and the CY7C277, also packaged in a 300-mil DIP and offering registered outputs and an optional address latch for use in state machines and pipeline systems.

Microchip Technology

Recently made available by Microchip is a 32Kx8 EEPROM—the 28HC256—with an access time as fast as 90ns. This device comes in both commercial versions and 883C military versions; it has an operation current drain of 65mA and a standby current drain of 150uA. This EEPROM also features a "page write" mode in which 64 bytes can be written in 3ms.

NEC

NEC has released the uPD23H4001ECZ, a 4Mb 100ns ROM. This device is organized as 512Kx8 and is manufactured from NEC's 0.9-micron CMOS process. A 32-pin DIP or SOG are the available packages. The initial production of this device is reported to be 200Ku/mo.

Sharp

Sharp has begun accepting orders for its 4Mb ROM. The LH534600 is organized as a 512Kx8 or a 256Kx4 device and features a 100ns access time. The memory device comes in a 40-pin DIP or a 44-pin quad flatpack and has a power consumption of 60mA during operation and 100uA during standby.

WaferScale Integration Inc.

WaferScale has made available a 1Mb EEPROM that is organized as 64Kx16. The WS27C20L features access times ranging from 120 to 200ns and is targeted for use with 16- and 32-bit processors. This 1Mb EEPROM is packaged in a 44-pin ceramic quad flatpack and LCC or a ceramic DIP and PLCC.

White Technology

A 4Mb EEPROM memory module has been introduced by White Technology. The M4194E can be user configured as 512Kx8, 256Kx16, or 128Kx32 and is manufactured from 16 individual 32Kx8 memory devices. The module also includes features such as latches, buffers, decoders, control logic, and byte selection. The module measures 1.9 by 2.1 inches and comes in a 76-pin flatpack.

SPECIALTY MEMORY DEVELOPMENTS

Integrated Device Technology (IDT)

IDT has introduced a 128Kx16 50 to 120ns shared memory subsystem called the IDT7MB6036. This device functions like a dual-port memory by providing access to the same memory array from two separate ports. As an added feature, the device has a propriety arbitration chip to prevent problems that arise from simultaneous access from both ports. The IDT7MB6036 is targeted for use in processor-to-peripheral and processor-to-network communications. It is available in a 100-pin quad-in-line package on an FR-4 substrate.

The IDT72215 and IDT72225, 512x18 and 1Kx18 synchronous FIFOs, have been added to the IDT FIFO family. These devices feature a 20ns cycle time or a 12ns access time, which makes them ideal for use in systems operating at 50-MHz clock speeds. Both devices are housed in a 68-pin PGA or PLCC.

Also introduced by IDT, in a joint effort with S3 Inc., is the IDT71589 288K cache data RAM. The RAM is organized as 32Kx9 and is targeted for use with the 25-, 33-, and 40-MHz Intel i486 microprocessor-based systems. A 32-pin plastic SOJ and a plastic and hermetic DIP are the available packages.

Integrated Silicon Solution, Inc. (ISSI)

Two 64K CMOS cache RAMs have been introduced by ISSI, targeted for use in systems utilizing Intel's 80386 20- to 33-MHz microprocessors. The IS61C416 and IS61C308 are organized as 4Kx16 and 2x2Kx16, respectively. Both devices have access times of 25, 35, and 45ns and are housed in 44-pin PLCCs.

Logic Devices Inc.

Logic Devices has introduced two CMOS SRAMs targeted for the cache-tag market. The L7C180/181 (4Kx4) and the L7C174 (8Kx8) offer speeds of 10ns for the 16K density devices and 12ns for the 64K devices. Both devices come in plastic and ceramic DIP; the 4Kx4 is available also in an SOJ package, and the 8Kx8 is available also in an SOG package.

Samsung

Three new specialty memories have been introduced by Samsung. The first two—the KM75C01A (512x9) and the KM75C02A (1Kx9)—are standard FIFOs manufactured from a 1.2-micron CMOS process and have reached 15ns access times. These FIFOs feature flags indicating buffer-full and buffer-empty states to help prevent data overflow. The third is a fast parallel FIFO dual-port memory, the KM75C03A. This 2Kx9 device has an access time of 20ns.

Sony Corporation

Sony has announced the availability of its CXK7701J, a cache RAM designed for use with Intel's 80386 microprocessors and 82385 cache controllers. This RAM is structured as a two-way set-associative 8Kx16 cache data RAM, is manufactured from 0.8-micron CMOS technology, and has an access times of 30 to 55ns. These high speeds enable it to function with processors operating at 16 to 33 MHz. A 52-pin PLCC is the available package.

Toshiba

The TC55187T (2x4Kx18) and the TC55188T (8Kx18) are cache RAMs introduced by Toshiba. These devices feature: x18 organization for parity checking, 20ns access time, and output enable time of 10ns. The 187 is designed for a two-way set-associative cache, and the 188 is designed for a direct-map cache for use with the Intel 82385 cache controller or the MIPS 3000 RISC processor. Both devices are housed in a 52-pin PLCC.

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Research Newsletter

THE DRAM MARKET OF 1990: TEMPORARY SHORTAGE OR 1988 REVISITED?

INTRODUCTION

The oversupply situation that has existed in the memory market since the third quarter of 1989 appears to be leveling off. Free-falling DRAM prices have run their course and are giving way to greater stabilization. In fact, strong signs of real recovery are emerging. These signs are as follows:

- Book-to-bill ratio at greater than one for the past three months
- Reductions in manufacturers' inventories during mid-March
- Firming of contracts, with three- to six-month contracts being reported
- Rising spot and contract prices for both 256K and 1Mb DRAMs (not merely stabilized prices)
- Sizable increases in production orders of 4Mb DRAMs (even with the large price differential in relation to 1Mb DRAMs)

Suppliers are wondering if the industry has hit bottom, or whether the present market rebound really is indicative of short-term panic buying and not a recovery. Major Japanese and South Korean DRAM suppliers are very cautiously assessing the market, and many believe that the industry is a long way from recovery! Their posture in the face of uncertain industry signals and the decisions they now make will have a severe impact on the user community. Manufacturers are grappling with the basic decision of whether to remain relatively close to present production levels (i.e., flat) or to accelerate production if demand increases.

This newsletter discusses the anticipated outcome should major memory manufacturers be overly pessimistic about the future and the proposition that the DRAM shortages currently being experienced by some is not merely a short-term aberration.

THE PAST AS PROLOGUE: 1987/1988 REVISITED?

Although major Japanese manufacturers focused on production cuts in response to cancellations, increasing turns business, and plummeting prices, they may have lost sight of their customers' future requirements. In order to discuss future implications from our current vantage point, it would be instructive to review the events of the past year. Figure 1 visually represents the relationship that Dataquest has observed in terms of DRAM supply/demand trends. Figure 1 may tend to exaggerate the trends in order to illustrate historic and future market conditions.

Some important points to note are as follows:

- Dataquest advised many Japanese DRAM suppliers that an economic slowdown would occur in mid-1989 (point A on the diagram).
- The memory market, which typically lags behind the other semiconductor market segments in entering and exiting recessions, did not register the full impact of this slowdown until late in the third quarter of 1989 (point B).
- In the September/October 1989 time frame, manufacturers lowered their production volumes to compensate for reduced demand (point C).
- Subsequent tweaks to production rates were made by several companies in January and February 1990 (point D).
- Current indications reflect either a recovery from the industry slowdown or transitory panic buying (point E).

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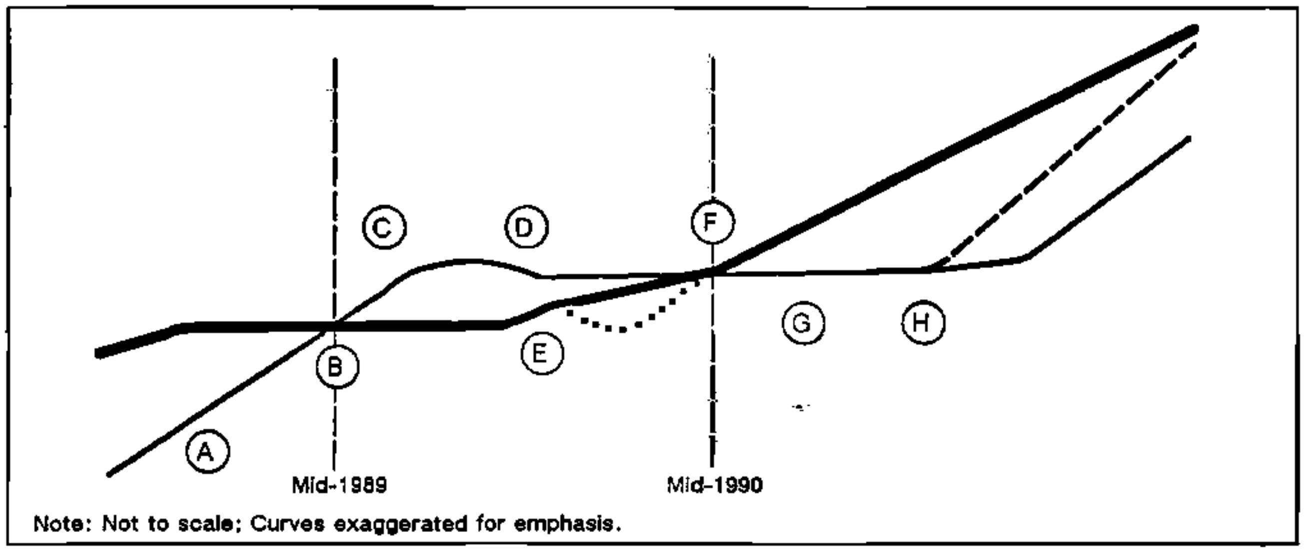
FIGURE 1
DRAM Supply/Demand Curve



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Source: Dataquest
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If the industry is indeed recovering, then supply and demand should reach parity sometime during the midyear. After the time frame represented by points E through G in Figure 1, suppliers will have to make decisions about increasing production capacity. If they choose to do so, increased output should occur about one quarter later, represented by point H on the graph. Manufacturers' assessment of the current market signs and the ensuing decision at this critical juncture will dictate which way the curve will trend.

The implications suggested by this figure are that if the market recovers and suppliers do not respond quickly enough, users could face another DRAM shortage. Although this scenario is reminiscent of the DRAM shortage that started in early 1987 and lasted two years, there is one major point of distinction: the problem in 1987 was aggravated by technical difficulties that some manufacturers experienced in bringing their 1Mb DRAM processes on-line.

RATIONALE FOR RECOVERY

Dataquest continues to believe that market recovery will occur in approximately mid-1990. In the short term, our forecast for the North American market in the second quarter of 1990 calls for a slightly negative quarter with growth of negative 0.6 percent over the first quarter and resumption of modest growth in the third quarter of almost 5.0 percent. We believe that this forecast is substantiated by recent stabilization noted in the semiconductor environment and described as follows:

- Modest improvement occurred in the computer and office equipment markets, according to the January report from the Department of Commerce (DOC). Shipments growth of 4.7 percent for the three-month period that ended in January could signal the end of the year-long deceleration in trend growth that shipments experienced in 1989.
- According to the March procurement survey conducted by Dataquest's Semiconductor User Information Service (SUIS), semiconductor order rates have stabilized. Since January, there has been a steady, higher level of order rates, partly in order to replenish inventories but primarily because of higher system sales.
- Actual inventories for both overall and computer OEMs have been lowered significantly in the last month, resulting in levels of 30 and 33 days, respectively, of on-hand inventory, while target

inventory levels have stabilized at 18 and 17 days, respectively.

- The contraction in February billings is likely a result of the decline in DRAM average selling prices (ASPs). If prices start to stabilize, the book-to-bill during the next few months could continue to rise.

Given these indicators—healthy inventories, order rate stabilization, fairly reasonable lead times, and greater pricing stability—we believe that the semiconductor industry is poised to rapidly translate any upward trend in systems orders booked into higher IC sales. Also, for the second consecutive month, the Dataquest monthly procurement survey reveals no negative sales expectations for the next six months on the part of any of the systems companies polled, while their overall sales outlook continues to increase in optimism.

Dataquest's current worldwide semiconductor forecast predicts a worldwide recovery commencing in the second quarter of 1990 with growth of 1.2 percent followed by growth of 4.6 percent and 5.5 percent for third and fourth quarters, respectively. This outlook basically synchronizes with The Dun & Bradstreet Corporation's short-term economic prognosis for the United States. In 1990, the real GNP growth is predicted to be approximately 2.5 percent in the United States, with the second half of the year looking decidedly better than the first. In terms of D&B's worldwide outlook, a recession is not anticipated, although growth should be slower. Generally, GNP growth in the other major worldwide regions is likely to outpace the United States.

DATAQUEST ANALYSIS

Dataquest already is observing signs of anticipated DRAM shortages from DRAM vendors. Recent indications from Dataquest analysts point to stabilization or firming of prices, while orders have strengthened. Users are being advised to expect longer lead times and higher prices. Strategically, availability limitations and higher 1Mb DRAM prices will foster accelerated 4Mb DRAM introduction. This acceleration means that manufacturers that have curtailed 4Mb DRAM production because of deflated 1Mb DRAM pricing will be able to resume 4Mb DRAM production as 1Mb DRAM pricing rises. Both Japanese and South Korean DRAM manufacturers have expressed an unwillingness to increase 1Mb DRAM wafer starts substantially until they see a full quota of recovery signs. We believe that a shortage of 1Mb DRAMs is almost certain to develop during the second half of 1990 as a result of Japanese and South Korean suppliers' strategies to hold production near present levels until they see absolute signs of a recovery. The severity of the shortage will depend on the rate of increase in demand, the time frame during which manufacturers increase production volumes, and the amount of production increases. This shortage could be averted if several sizable manufacturers increase production volumes in the near future. However, manufacturers are being very cautious, as none wish to get caught with large inventories. If manufacturers wait until third quarter to increase wafer starts from their present production levels and production output does not pace demand, the estimated number of 1Mb DRAMs that we forecast for this year could be overstated by as much as 130 million units! Revenue would not be affected proportionately because ASPs will be somewhat higher than currently forecast if a shortage situation prevails.

In the long term, the user community is attempting to address its strategic needs through various means such as user-vendor relationships, local content laws, and increased regional manufacturing capacity. However, in the short term, if a shortage situation occurs, the user community will be placed at the greater disadvantage: While the suppliers will need to guard their market shares, they have a greater vested interest in the status quo or in maintaining a finely tuned balance between supply and demand than in taking on the risks brought about by increased production.

O. Fred Jones
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Research Newsletter

SIS MEMORY QUARTERLY NEW PRODUCTS NEWSLETTER

This newsletter contains a synopsis of detailed memory product news events gathered from the trade press and company releases during the third quarter (July, August, and September) of 1989. It is meant to be a reference guide of new products for competitive analysis, monitoring technology trends, and tracking feature developments and improvements. SIS assumes no responsibility for the accuracy of the contents.

The following is a key to the publications reviewed during research for this issue:

Company News Release	CNR
Electronic Buyers News	EBN
Electronics	EL
Electronic Design	ED
Electronic Engineering Times	EET
JEE	JEE

Table 1 shows the new products for the second quarter of 1989.

TABLE 1
New Products

Company	Density	Speed
	DRAM Developments	
Sharp	1Mb	70, 90ns
Vitelic	64Kx8	70ns
Vitelic	64Kx4 video RAM	80ns
	SRAM Developments	
ICI Array	16Kx32, 32Kx16, 16Kx16	90 to 20ns
ILC Data Devices	64Kx16	55ns
Intel	4Kx4, 16Kx4	25, 35ns
Motorola	4Kx10, 4Kx12	20, 25, 35ns
Paradigm Technology	256K	20 to 45ns
Saratoga Semiconductor	16K	12ns
VLSI Technology	4Kx4, 2Kx8	12, 15ns
	ECL I/O-Level RAM Developments	
NEC	256Kx1	15ns

(Continued)

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TABLE 1 (Continued)
New Products

Company	Density	Type	Speed
	Nonvolatile Development		
Hitachi	32Kx8	EEPROM	150, 200ns
Intel	128Kx8	EPROM	250 to 150ns
Toshiba	32Kx8	Flash EEPROM	200, 250ns
Xicor	1,4,16K	EEPROM	
	Specialty Memories		
Austek Microsystems	Cache controller		25, 33 MHz
Integrated Device Technology	144K	FIFO	45ns
Matra Design	Cache controller		20, 25 MHz
Micron Technology	8Kx16	Cache RAM	25ns
Saratoga Semiconductor	4Kx4	Cache tag	12ns
Saratoga Semiconductor	8Kx16	Cache RAM	20, 25ns
Vitelic	8Kx16	Cache RAM	25, 33 MHz

Source: Dataquest
January 1990

DRAM DEVELOPMENTS

Sharp

Sharp introduced a 1Mb DRAM, the LH69128. The product is organized as a 128Kx8 or a 128Kx9, offers an access times of 70 or 90ns, and is available in a 28-pin 300-mil DIP. (JEE, August 1989)

Vitelic

Vitelic announced a 64Kx8 CMOS DRAM, the V53C864, which is targeted for use in VGA and laptop PC applications. It has an effective bandwidth of 160 MHz with a row access time of 70ns; during its fast page mode, it outputs an 8-bit word each 50ns for 256 cycles. The V53C864 is available in a 24-pin DIP and in a 26- or 24-pin SOJ package. (CNR, September 19, 1989)

The V53C261, a high-performance CMOS video RAM, also was introduced by Vitelic. The video RAM is organized 64Kx4, has an access time of 80ns, and has a serial access memory (SAM) of 256x4 that shifts data at 33 MHz. It is offered in a 24-pin plastic ZIP. (CNR, July 10, 1989)

SRAM DEVELOPMENTS

ICI Array

ICI Array introduced three new SRAM modules, the AT212SZ, AT612CP, and AT656CP. The AT212SZ, a 16Kx32 with access times of 15 and 20ns, is packaged in a 94-pin ZIP. The AT612CP and the AT656CP are organized 32Kx16 and 16Kx16, respectively, have access times ranging from 90 to 35ns, and are housed in a 40-pin DIP or SIP. (ED, August 10, 1989)

ILC Data Devices

Introduced by ILC Data Devices is the MEM-84002, a 64Kx16 CMOS full military SRAM module. It has an access time of 55ns and a 2V data retention voltage, which enables it to be used in battery backed-up systems. The module is made from four 32Kx8 SRAMs mounted on a 46-pin square flatpack. (ED, August 10, 1989)

Intel

Intel announced the 16K 51C68 and 64K 51C98. The 51C68 is organized 4Kx4, has an access time of 35ns, and is available in a 20-pin ceramic DIP. The 51C98 is organized 16Kx4, has an access time of 25ns and is available in a standard 22-pin ceramic DIP. (CNR, July 11, 1989)

Also introduced by Intel is the M5164, a 883C class B-compatible 8Kx8 SRAM. This military standard device has access times varying from 25 to 70ns and is packaged in a 600-mil DIP. (EBN, September 11, 1989)

Motorola

Released by Motorola are four new fast SRAMs. Packaged in a 44-lead PLCC are the MCM62963, MCM62973, MCM62974, and MCM62975, organized as 4Kx10 or 4Kx12. These devices will operate at speeds of 20, 25, and 30ns. (EET, September 18, 1989)

Paradigm Technology

Paradigm launched the PDM412XX family of 256K high-speed SRAMs. The family includes 256Kx1, 64Kx4, and 32Kx8 organizations, a variety of optional features, and speeds ranging from 20 to 45ns. Packaging for these RAMs will include the 28- or 32-pin 300-mil SOJ and DIP. (ED, September 14, 1989)

Saratoga Semiconductor

Saratoga Semiconductor introduced three new BiCMOS high-performance SRAMs: the SSM6116 (2Kx8), SSM6168 (4Kx4), and SS6170 (4Kx4). All three are TTL compatible and feature access times of 12ns. The SSM6170 is equipped with an output enable function. The SSM6116 is offered in several packages: a 24-pin 300-mil plastic and ceramic DIP; a 24-pad SOG, SOJ, and flatpack; and a 28-pad PLCC. The SSM6168 and SSM6170 are available in packages such as the 22-pin plastic and ceramic DIP and 24-pad SOG and SOJ. (CNR, July 12, 1989)

VLSI Technology

VLSI Technology announced speed improvement of three members of its 16K family of CMOS fast SRAMs. The company's 1-micron CMOS process has enabled the VT20C19 2Kx8, VT20C69 and VT20C79 4Kx4 to reach access times of 12 and 15ns. All are packaged in either 300-mil DIP or SOJ. (CNR, July 24, 1989)

ECL I/O-LEVEL RAM DEVELOPMENTS

NEC

NEC began sampling the uPD100500, a BiCMOS ECL I/O RAM. This RAM is organized as a 256Kx1 and has an access time of 15ns. Its die measures 12.05x4.81mm and is available in a 24-pin ceramic DIP. (JEE, August 1989)

NONVOLATILE DEVELOPMENTS

Hitachi

Hitachi announced the HN58C256, a 256K CMOS EEPROM. The die size of this 256K EEPROM is 5.23x6.34mm and the cell measures 6.7x7.8um. It has access times of 150 and 200ns and is available in DIP and SOG packages. (JEE, August 1989)

Intel

Introduced by Intel is a 1Mb EPROM that meets the 883C class B military standards. The M27C1010 is organized as a 128Kx8, is manufactured from Intel's 1-micron CHMOS process, and features an access time of 150 to 250ns. This device is designed for use in systems such as missiles, portable radios, and artillery coordinate computers. It is available in a 32-pin CERDIP. (EBN, September 11, 1989)

Toshiba

A 256K flash EEPROM was introduced by Toshiba. The product was made from Toshiba's 1.2-micron CMOS process. The TC58257A has access times of 200 and 250ns and offers an operating power of 30mA at 5.9 MHz and 100uA in standby mode. The TC58257A is available in a 28-pin plastic DIP and SOG. It is designed for use in applications such as point of sale systems, printer font storage, memory cards, and telecommunications. (CNR, September 8, 1989)

Xicor

Xicor extended its family of CMOS serial EEPROMs. The X24LC01 (1K), X24LC04 (4K), and X24LC16 (16K) all feature a wide operating range of 3 to 6 volts, which makes them ideal for portable applications. All are capable of being housed in an 8-pin mini DIP or SOG. (CNR, September 5, 1989)

SPECIALTY MEMORIES

Austek Microsystems

To support the Intel 80386 microprocessor systems, Austek introduced the A38202 cache controller chip. The A38202 can drive a direct-mapped or two-way set associative 32KB, 64KB, and 128KB cache for system speed at 25 and 33 MHz. The controller is packaged in a 160-pin quad flatpack. (EET, September 18, 1989)

Integrated Device Technology

The IDT7MB2002, a bidirectional FIFO module, was announced by Integrated Device Technology (IDT). This module is ideal for processor-to-peripheral communication, is organized as a 4Kx36 or a 16Kx9, and operates at 45ns. (ED, July 13, 1989)

Matra Design

Released by Matra Design are two cache controllers to support systems based on Intel's 20-and 25-MHz 80386 microprocessor. The C395e supports a 256KB cache in direct-mapped, two-way set associative, and four-way set associative caching schemes. The C385i is compatible with Intel's 82385 and supports a 32KB direct-mapped or two-way set associative caching schemes. The C395e is packaged in a 164-pin quad flatpack and the C385i is housed in a 132-pin PGA. (EET, September 4, 1989)

Micron Technology

Micron Technology introduced the MT56C0816, a 128K cache RAM. It is organized as an 8Kx16 or as two 4Kx16 arrays. This RAM is available with an access time of 25ns and is designed for use with the Intel 82385 cache controller and 80386 microprocessor. (EL, July 1989)

Saratoga Semiconductor

Launched by Saratoga Semiconductor are two BiCMOS cache tags, the SSL4180 and SSL4181. Both are configured 4Kx4 and have an address-to-compare output time of 12ns to meet the needs of a 33-MHz processor. The SSL4180 features a totem pole match output, and the SSL4181 offers an open-drain match output. They are available in 22-pin 300-mil plastic and ceramic DIP and 24-lead plastic SOG and SOJ packages. (CNR, July 31, 1989)

Saratoga Semiconductor released a 8Kx16 cache data RAM, the SSM51186. It has access times of 20 and 25ns. The device is targeted for use with the Intel 80386 processor and is packaged in a 52-lead PLCC package. (CNR, July 31, 1989)

Vitelic

Vitelic announced the release of a 8Kx16 cache data RAM, the V63C329. It has access times fast enough to meet the caching demands of the Intel 25 and 33-MHz 80386. It is available in a 52-pin PLCC package. (CNR, August 2, 1989)

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Research *Bulletin*

TAIWAN'S NOTEBOOK CHALLENGE: CCL COMMANDS CONSORTIUM

OVERVIEW

The week after Comdex, an Industrial Technology Research Institute (ITRI)-sponsored delegation visited Dataquest and explained the short- and long-term strategies of Taiwan's notebook PC industry. The delegation will compile information from Comdex and its visit to Dataquest and make a presentation to Taiwanese industry leaders in early 1991. The goal of ITRI's Computer and Communications Research Laboratories (CCL) is to catalyze development of low-cost, state-of-the-art notebooks in time for Comdex 1991.

Several notebook products from Taiwan were shown at the November Comdex Show in Las Vegas, Nevada. More than 40 Taiwanese companies exhibited notebooks at the show. On the surface, Taiwan's embryonic notebook industry appears fragmented, competitive, and undeveloped; however, unlike Taiwan's desktop-clone PC industry, the notebook industry is maturing in an organized and systematic fashion. A variety of competitive forces are compelling the Taiwanese government and many PC companies to chart their notebook future carefully. This bulletin explains the reasons for Taiwan's island-wide interest in notebooks and the significance of a government-industry alliance to the industry's growth.

TAIWAN'S NEXT PC GENERATION: NOTEBOOKS

Until now, laptop and portable PC manufacturers have had limited success in penetrating overseas markets. Only 124,000 laptop models were exported in 1989; of those models, 67 percent were based on the 80286 CPU. Taiwan's entire PC industry shipped approximately 2.2 million units in 1989. The following factors explain why most of Taiwan's rival PC companies are pursuing strategic alliances through a government-led consortium:

- Local profit margins on desktop and laptop models are declining because of production costs and falling market prices.
- Small and medium-size companies do not have the export wherewithal to meet strict technology-specific import regulations (especially from the U.S. Federal Communications Commission) and mobbed marketing channels.
- Taiwan's PC industry depends on Japanese sources for lightweight liquid crystal display (LCD) components and other technologies. Without high-quality LCD screens, these machines' displays are not as sharp as that of a standalone desktop monitor.
- Signs of South Korean manufacturers' entry into the portable market threaten Taiwan's domination of the PC clone industry.
  - The deep pockets and large-scale manufacturing capability of South Korea's chaebols (conglomerates) pose a threat to Taiwan's industry, which traditionally relies on small-scale operations.
  - Once a company such as Trigem has product specifications, it is a matter of sourcing components from Japan and the United States before it can produce millions of units.

Dataquest forecasts that the portable PC market will reach approximately US$37.7 billion (manufacturers' suggested retail value) by 1994. Portable PCs will represent 37.0 percent of the global PC market in just four years, and desktop PCs will decline from 89.3 percent to 63.0 percent of the total global PC market. The fastest-growing segment of the portable PC market is notebooks,

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growing from 0.9 percent to 16.1 percent of the global PC market by 1994.

THE NEW ROLE OF CCL

ITRI's Electronic Research Service Organization (ERSO) has been in the business of acquiring, developing, and disseminating key electronic technologies and products to Taiwan's electronic equipment and semiconductor companies for almost two decades. (ERSO is one of six divisions of ITRI.) As a result of ERSO's recent restructuring, the organization recently split responsibilities of computer technology and semiconductors into the CCL and ERSO, respectively. CCL will be devoted to the development of computer, communications, and consumer system technologies.

CCL also is organizing a Notebook Consortium, which will reposition Taiwan's desktop clone makers for the growth of a huge worldwide notebook market. Currently, 46 members belong to the consortium; key Consortium members as of November 30, 1990, include ADI Corp., Jamicon, Mitac International Corp., Proton, Sinoca Enterprises Co., Sun Moon Star, and Tatung. (Note: For a complete company list, please contact Dataquest's Asian Semiconductor and Electronics Technology Service.) CCL's creative solution to a typically dispersed industry is to assign technology task groups to its members. CCL will in turn select a superior technology and the most cost-effective manufacturer in each of the designated component groupings. Dataquest estimates that CCL is likely to speed the concept-to-prototype time period to approximately three or four months by early 1991. The consortium avoids research duplication, facilitates the flow of proprietary technology, and streamlines global marketing. Consequently, Taiwan's notebook industry will be ready to offer inexpensive 80386 processor notebook PCs with VGA when large-scale ramping begins in 1991.

DATAQUEST CONCLUSIONS

The reorganization of ERSO and CCL's notebook-focused development consortium reveals the urgency of the notebook market to both industry leaders and government industry planners. In the 1980s, ERSO was responsible only for technology R&D, while private companies marketed their own desktop PCs. CCL's new role as the notebook project leader will enable it to coordinate industry-wide R&D, manufacturing, and notebook commercialization. Taiwan's PC-concentrated electronics industry has too much at stake to miss the global move to portable PCs. Unlike ERSO's clone development experiment, which initiated Taiwan's PC "miracle," CCL's charter must be to protect a mammoth PC-related electronics industry by building a domestic technology base for Taiwan's next generation of laptop, notebook, and palm-top systems.

Dataquest forecasts the world notebook market to grow to US$6.07 billion by 1994. Early signs indicate that competition among Asian computer companies will be fierce, especially if there continues to be little functional differentiation among notebook manufacturers. Taiwan's portable industry will need to invest heavily in this segment of its computer industry during the next five years to overcome key technology and manufacturing-scale limitations. Contributions from Taiwan's communications, display, and audio-video consumer companies will be essential. The participation of Taiwan's large PC players (Acer has not yet joined) is necessary to ensure fluid global marketing channels for the consortium's notebook innovations. With the exception of Acer, Taiwanese companies suffer from lack of brand recognition in Europe and the United States.

Daniel Heyler

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Research *Bulletin*

CLARIFYING INTEL MICROPROCESSOR MIGRATION PLANS

INTRODUCTION

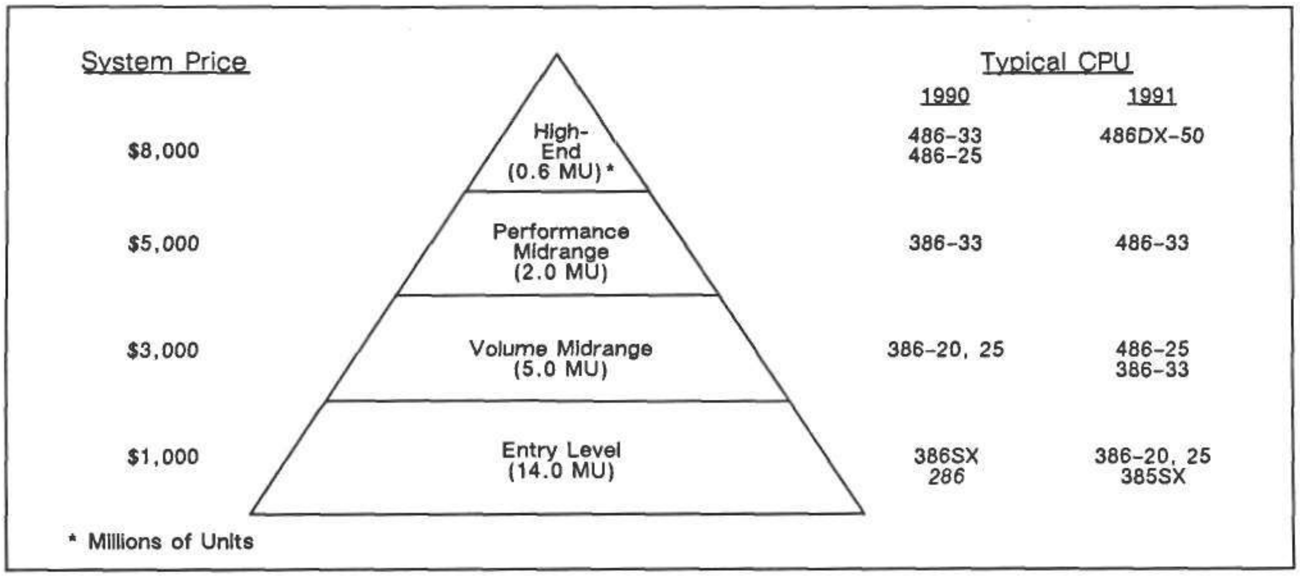
At its third quarter financial analysts meeting on October 25, Intel Corporation provided further insight into plans for its i386 microprocessor family. David House, general manager of the Microprocessor Components Group, presented a chart illustrating the system segment targets for the range of i386 products (see Figure 1). This information is important to system OEMs because it allows them to better plan their product development and support strategies. It is also important to semiconductor vendors participating in the PC peripherals and logic markets.

SYSTEM SEGMENT TARGETS

As the chart illustrates, Intel clearly will continue to target and position the i386 products in specific system market segments. Intel divides the market into four segments that correspond to specific system price ranges. The high-end segment, with a system price of about $8,000, was addressed by the 486-33 and 486-25 in 1990 and is expected to migrate to the 486-50 in 1991. The performance midrange segment, at approximately $5,000, is a 386-33 market moving to 486-33 in 1991. The volume midrange segment, at about $3,000, is 386-25 and 386-20 going to 486-25 and 386-33 in 1991. The entry-level segment costs approximately $1,000 and currently is served by the 286 and the 386SX. Intel intends to target the 386-25 and 386-20 as well as the 386SX at this segment. (The designations 386 and 486 are registered trademarks of Intel Corporation.)

System vendors have voiced concern recently about the rapid proliferation of new microprocessor products and speed grades, which in turn led to a

FIGURE 1
1991 PC Market Segmentation
(Approximate 1991 Volumes)



Source: Intel

SIS Newsletters 1990 Microcomponents

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proliferation of system products. Such proliferation has caused an increased burden for the system vendor, in terms of new product development and support, and has helped to blur the lines of product differentiation. When asked why Intel continues with this proliferation, Mr. House answered that he would be glad to slow the pace of development and spend fewer R&D dollars if he could only convince Intel's competitors to do the same.

In fact, it is clear from the chart and from other remarks made at this meeting that Intel understands this issue and is attempting to better control product segmentation. Intel intends to continue driving the technology at a rapid pace but will not necessarily proliferate products through speed upgrades. New products will be based on architectural and manufacturing process improvements. Horizontal versions that address specific application or form factor issues, such as the 386SL, also will be forthcoming.

OBSOLESCENCE AND THE ANTICLONE STRATEGY

Mr. House admitted that the 386DX shipments had peaked in 1990, the product is being "squeezed at both ends" by the 486 and the 386SX, and it will be phased out. The 386DX-16 is not going to be supported, therefore, and it is not likely that there will be a 40-MHz version of the part. Intel's goal is to establish the image of performance and desirability for the 486 product. This goal probably will mean substantial price reductions for the 486, particularly the 486-25, during 1991. We can see also from Figure 1 that there will not be a 40-MHz version of the 486. The company intends to go directly from a 33-MHz to a 50-MHz version.

As for the 286, apparently it falls off the chart in 1991. However, it is not clear from the figure either when or if Intel plans to discontinue support of the 286. What is clear is that the company does intend to continue emphasizing the 386 family (which includes the 486 and, presumably, the 586) and promoting the move toward 32-bit computing. No matter how strongly some protest, the 286 is in the waning years of its product life cycle. The product may get a temporary reprieve as a result of its use in notebook PCs and possibly from a boost in sales to Eastern Bloc countries, but this reprieve will be short-lived.

A more interesting issue than the fate of the 286 is the potential for 386 clones. Advanced Micro Devices is expected to release a 386 clone, and others may follow. Intel's campaign to kill off the 286 already is giving way to a similar effort to obsolete the 386DX, as evidenced by remarks at the analysts meeting that the 386DX will be phased out. Intel hopes that the rapid introduction of new generations of microprocessors, along with horizontal versions such as the 386SX and 386SL, will keep pursuers lagging far behind.

Ken Pearlman

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Research Newsletter

THE RESOLUTION EVOLUTION OF IBM PC GRAPHICS

SUMMARY

The graphics market continues to evolve toward higher image quality, faster display speed, and lower costs. This evolution has been achieved largely with higher integration. Both demand and supply for advanced products remain strong. Dataquest expects these trends to continue in the long term as manufacturers keep moving toward the maximum quality of images that can be perceived by the eye.

Dataquest believes that IBM will place the functions that it has offered in the 8514/A into its next-generation video graphics array (VGA)-compatible part. This feature would make it suitable for desktop as well as laptop motherboards.

BACKGROUND

Although nearly photographic-quality images have been possible in expensive, specialized products for years, we believe that what drives the IBM PC graphics market is the commercial availability of higher-quality and higher-performance imaging hardware and the software that is used.

Commercial feasibility in the 1990s PC market, however, implies a high-performance graphics subsystem (graphics board or chip set) for high-resolution color. Dataquest believes that it must take up a minimum amount of board space and sell at a price well below $500. The question, therefore, is not so much the desirability of the following:

- Higher resolution
- More colors
- Higher performance
- Compatibility with full VGA
- Fast graphical user interface (GUI) response

But rather, the question is what is the most optimal way to achieve these qualities. A number of approaches exist, including the following:

- High-resolution VGA only
- VGA with add-on 8514/A
- VGA and 8514/A together
- Texas Instruments Graphics Architecture (TIGA) with close-coupled VGA
- VGA with built-in hardware assists

We believe that the optimal way to achieve the best price/performance with minimal board space for GUI support in the near term is a single-chip VGA with built-in hardware assisted features, regardless of whether those features are 8514/A-compatible or third-party proprietary with software drivers.

WHAT IS THE PROBLEM OR NEED?

Dataquest believes that, in this rapidly evolving graphics market, it is important to examine periodically the changing market needs that must be addressed.

Higher Spatial Resolution

Whether this need for more pixels than 640 x 480 VGA already existed or is being created by suppliers, the net effect is the same.

Higher Color Resolution

Whereas standard VGA offers 16 colors (at 640 x 480), realistic rendering requires many more, and 256 colors is a reasonable next step. This need will become much more apparent as NTSC-video inputs become more common.

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Speed

With respect to graphical user interfaces (which is the biggest issue for the mainstream market), requirements that affect speed are as follows:

- BITBLT with raster operations
- Line-drawing assistance
- Multiple color lookup tables
- High bandwidths for data transfer
- Little penalty for higher resolutions and colors

Additional features must be scrutinized for their benefits versus their costs, overhead, or board space requirements.

Agreement on How to Implement These Functions

Agreement on how to implement the higher spatial resolution, higher color resolution, and increased speed is something the Video Electronics Standards Association committee set out to do. It is preferable for all parties to adhere to one standard rather than every board or chipmaker having its own drivers. However, availability of standards continues to be a luxury available only in the Macintosh (QuickDraw) arena. And until IBM puts such a capability into an integrated VGA/high-resolution chip set, Dataquest does not expect third-party vendors to standardize in the short term.

Very Low Cost

It is necessary to have a cost such that boards can be list priced at well below $400 to $500. We believe that the product ceases to be a mainstream or mass-market product above that price-point range. Whether this price is achieved with a single bit map, as with IIT's chip (which is preferable), or with a hardware-assisted next-generation VGA remains to be seen.

Low-Cost Monitors

With 48-KHz (1,024 x 768) Sony Trinitrons selling for about $500, we believe that the low-cost monitor requirement is beginning to be met. We would prefer to see more 16-inch monitors along with the 14-inch monitors.

Others

Other options such as NTSC-video display, *all* of the above requirements, and full VGA compatibility in one graphics board (or on the motherboard as one graphics module) are desirable—in other words, the need for integration for the least possible power and board-space requirement. This need for integration is becoming critical as we move into laptop-size mass-market computers.

WHAT ARE THE POSSIBLE SOLUTIONS?

Dataquest looks at each possibility with respect to the needs of the mainstream or mass market.

The Texas Instruments' TMS 340X0 Approach

Texas Instruments' (TI's) TMS 34010/34020 programmable processor is an outstanding IC family for a variety of compute-intensive drawing and transformation functions essential to design applications. Its strength lies in being both general purpose and programmable, and it can be used effectively in many graphics applications, from display boards to fax machines. However, the predominant needs of a GUI for the mass market are lots of BITBLTs and faster operations. Therefore, the TMS 340X0's additional programmable capabilities (in hardware and software), although helpful, become less necessary for the mass market.

The other critical issue is VGA compatibility. A TI-based solution additionally requires a VGA chip set even when both the 340X0 and the VGA are sharing the same bit map (the current standard 8514/A also has this requirement). This extra chip set requirement becomes a board space issue. So the TI approach, even if it competes well against an add-on 8514/A, is less desirable than a complete VGA-compatible high-resolution/high-performance single-chip solution for the mass market. Here again is a case where more is, in fact, less.

The IBM, Western Digital, and Chips & Technologies Approach

The main advantage of the IBM-style controller (both Western Digital's and Chips' parts are meant to be 100 percent IBM 8514/A-compatible) is that it is not only an IBM standard in an environment where a single standard is sorely needed, but it does a reasonably good job of meeting a specific set of GUI requirements. We maintain that, for GUI requirements, any of the 8514/A vendors can be price/performance competitive with a TI approach. All vendors claim superior performance for each set of favored functions. However, the Western Digital part appears to offer superior speeds in certain areas.

The problem is that the 8514/A also is an add-on and an additional bit map to the omnipresent VGA. This problem could be solved by integrating either the 8514/A or a subset of it with VGA in the next generation of its implementation for a motherboard installation.

Meanwhile, however, we expect the 8514/A to continue to be important for compatibility with IBM as an add-on controller. We also expect 8514/A vendors to try to integrate more closely with their own VGA chips.

The IIT, S3, and Beta Systems Approach

IIT has attempted to combine both full VGA and 8514/A on the same RISC-based part, which takes care of the architectural objections to any high-resolution product that must live with the VGA. The question really is how soon and how well will it work (the VGA portion is a previous Trident Microsystems design and is subject to some market criticism) and for what low price can the finished product (for graphics board or motherboard) be sold.

Beta Systems is a German company with another high-performance RISC-based chip that combines full VGA and 8514/A capability. Beta Systems is in the process of introducing its product to the US market.

S3, the promising new start-up spin-off from Chips & Technologies, will offer what essentially is the true next-generation VGA (what Dataquest calls VGA III). What differentiates the future S3 product from previous VGAs is its set of hardware-assisted functions, such that its single-chip solution promises TI or 8514/A-like performance (in limited mainstream GUI functions) without the complexity and cost of TI-based products and without asking the system vendor to choose another nonestablished standard. In a graphics market that lacks clear direction and leadership—from IBM or anyone else—this technique may be potentially the best in the interim.

The Likely IBM Successor to VGA

For the VGA market and its applications, any follow-on product has to be VGA-compatible. It also has to offer performance and functionality essential for GUIs. We believe that IBM will implement either all or a subset of the necessary functions it has offered in the 8514/A into its next-generation VGA-compatible part. The part then would be suitable for desktop as well as laptop motherboards.

Dataquest Analysis and Conclusion

Dataquest believes that the graphics mass market is prone to the same price and competition pressures as the overall personal computer market. It would be unrealistic to expect the mass market to pay $700 to $1,000 even for capabilities that cost $3,000 a year or two ago. On the contrary, we argue that high performance and resolution will be delivered for $200 to $500 for graphics boards in the near future (high-resolution color monitors will be priced approximately the same). If this is true, then the question arises as to what is the most effective way to pack all the requirements of a high-performance graphical user interface into a competitively priced machine.

We believe that the answer is a very highly integrated, single bit-map, single-chip controller (preferably IBM-compatible in multiple-resolution modes) that is fully VGA-compatible. Although no such controller is on the market yet, new companies such as Beta Systems, IIT, and S3 are leading this market. We believe that other third-party vendors, as well as IBM itself, eventually will follow.

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Research *Newsletter*

EUROPE AND THE RISC IN 32-BIT MICROPROCESSORS

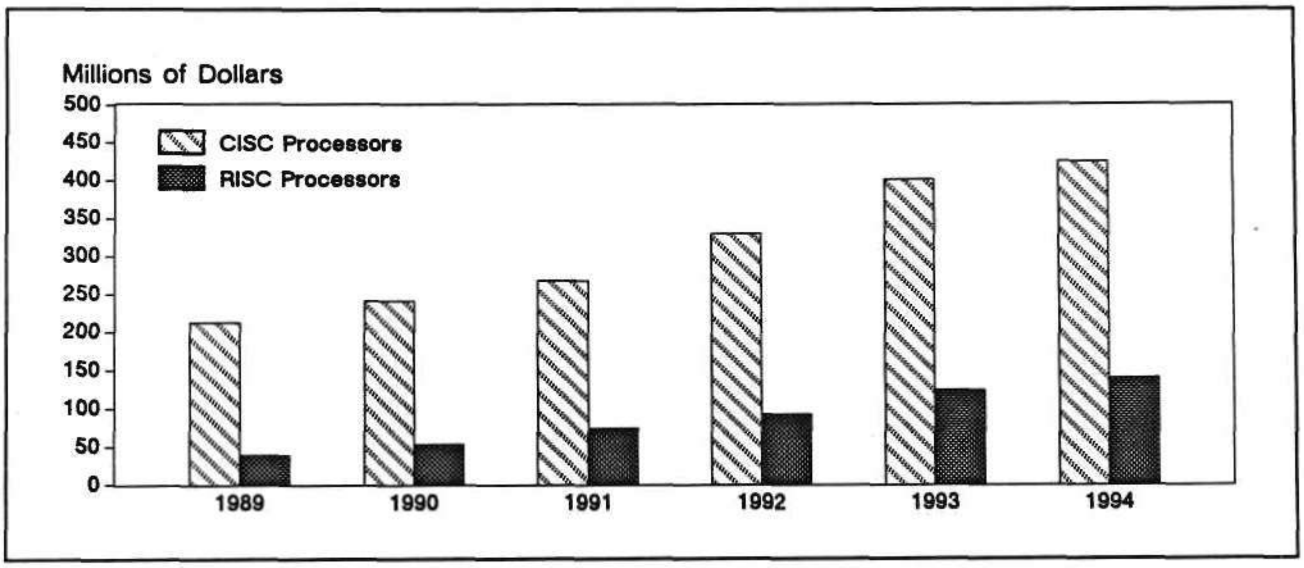
SUMMARY

The 32-bit microprocessor is the most advanced semiconductor product being manufactured today. Although it accounts for only 17 percent of total European MOS microcomponent revenue, 32-bit microprocessor design sockets are one of the fiercest battlefields in our industry.

Europe represented 22 percent of the world 32-bit microprocessor revenue in 1989. In that year 32-bit complex-instruction-set computing (CISC) processors represented 85 percent of the units shipped in Europe. Reduced-instruction-set computing (RISC) processors amounted to only 15 percent of the European market, estimated at $252 million in 1989. By 1994 the market is estimated to reach $565 million, growing at a compound annual growth rate (CAGR) of 14.8 percent between 1989 and 1994. By then, CISC processors are expected to represent 75 percent or $425 million of the total and RISC processors 25 percent or $140 million (see Figure 1).

From the vendor perspective, Europe's big three semiconductor suppliers, Philips, Siemens, and SGS-Thomson, now have backed their chosen

FIGURE 1
European 32-Bit Microprocessor Market—RISC and CISC Shipments



Source: Dataquest (October 1990)

architectures—all of which are RISC processors. Philips licensed SPARC, the Sun architecture, while Siemens has licensed the MIPS architecture and SGS-Thomson has backed the Transputer by acquiring Inmos.

With regard to applications, Europe sees the same characteristic uses for RISC as North America or Japan, but in different proportions. There are the classic data processing applications, along with new emerging 32-bit embedded control applications. European workstation and minicomputer manufacturers are just starting to announce their RISC-based products and are one to two years behind their North American rivals. This highlights a problem that European OEMs face in gaining access to the latest semiconductor technology.

EUROPEAN MARKET STATUS

Table 1 shows the European 32-bit microprocessor market by vendor and by processor type. Dataquest estimates that a total of 1.1 million units were consumed in Europe in 1989, amounting to a market worth $252 million. The table splits out CISC processors from RISC processors, and it is clear that CISC represented the largest proportion of unit shipments at 85 percent of the total.

Intel clearly shipped the most processors with its 80386DX. Indeed, the top four CISC processors all out-shipped the leading RISC processor, the Inmos T800, which shipped 62,000 units.

The Transputer was the largest-shipping RISC processor in Europe last year, also with the highest unit shipments of any RISC processor worldwide. Together, the T800 and T414 shipped 200,000 units worldwide, out-shipping the SPARC group's 190,000 units and the MIPS group's 100,000 units.

The second highest-selling RISC processor in Europe was the Acorn ARM processor supplied by VLSI Technology with the part number VL86C010. However, nearly all of the 40,000 units went to Acorn for use in its Archimedes PC. Of the other RISC offerings available in Europe, the SPARC camp shipped 7,800 units and the MIPS camp 6,000 units. Motorola, AMD, Intergraph, and Intel offerings made up the rest.

It is important to note that the 6,000 units shown here for MIPS do not truly represent the total MIPS usage in Europe. There is a tendency for companies that have decided to use MIPS architecture to begin system building by buying board-level MIPS system products and packaging them on an OEM basis. In this case, Dataquest records silicon sales at the point where the board was assembled in North America.

EUROPEAN MARKET FORECAST

Figure 1 shows Dataquest's forecast for the European 32-bit microprocessor market split by CISC- and RISC-based processors. In 1989 the total market was worth $252 million, with CISC processors amounting to $213 million or 84.5 percent, and RISC processors $39 million or 15.5 percent.

By 1994 the market will be worth $565 million. This figure represents a compound annual growth rate (CAGR) of 17.5 percent between 1989 and 1994. The RISC processor market is expected to grow at a CAGR of 29.1 percent to reach $140 million by 1994. However, it will still only represent 25 percent of the total market by then. The CISC market, with a CAGR of 14.8 percent, will reach $425 million and still represent 75 percent of the market's total value.

Two factors will sustain CISC-based processors:

- The continued strength of the PC market
- Momentum from the massive application software base

EUROPEAN VENDOR POSITIONING

The big three European semiconductor vendors have now taken their various positions in the 32-bit arena. This follows Intel's and Motorola's decision not to have second sources for their 32-bit generation processors and beyond, which presented a number of European vendors with a problem. For, until the 32-bit generation, Siemens, Matra MHS, and Philips had been second sources for successive Intel processor generations and SGS-Thomson for Motorola's family. Indeed, the fact that there were so many sources for Intel and Motorola architectures was one of the primary reasons for their success.

Clearly, the lack of second-source licensing in 32-bit CISC was one of the main reasons these European vendors (as well as others in a similar predicament including AMD, Harris, and Hitachi) have chosen to back RISC. It is important to note that none of the 32-bit CISC products are second-sourced, and that includes National Semiconductor and NEC products. Table 2 shows the latest RISC supplier status. For completeness, Harris's RTX2001A is included, although this is a 16-bit RISC processor, and Dataquest has recorded no sales for it in Europe so far.

Philips has chosen the SPARC group, although it is not the latest member. The most

TABLE 1
European 32-Bit Microprocessor Unit Shipments 1989

Vendor	Device	Architecture	Thousands of Units
RISC			
Inmos	T800	Proprietary	62.0
Inmos	T414	Proprietary	46.0
VLSI Technology	VL86C010	ARM	40.0
Motorola	88100	Proprietary	3.2
AMD	AM29000	Proprietary	2.4
Cypress	CY7C601	SPARC	2.3
Fujitsu	S-20/25	SPARC	2.2
IDT	R3000	MIPS	2.0
LSI Logic	LR64801	SPARC	2.0
LSI Logic	R3000	MIPS	1.8
Intergraph APD	C300	Proprietary	1.7
Fujitsu	MB86900	SPARC	1.3
Performance	R3000	MIPS	1.2
Performance	R2000	MIPS	1.0
Intergraph APD	C100	Proprietary	0.8
Intel	80860	Proprietary	0.5
BIT	B5000	MIPS	0
Sony	R6000	MIPS	0
MEDL	Viper 1A	RSRE	S
Total RISC			170.4
CISC			
Intel	80386DX	Proprietary	394.0
Motorola	68020	Proprietary	264.0
Motorola	68030	Proprietary	164.0
National Semiconductor	32X32	Proprietary	90.0
NEC	V60	Proprietary	8.0
Intel	80486	Proprietary	3.0
NEC	V70	Proprietary	3.0
Fujitsu	MB90XXX	Proprietary	0
Hitachi	H32/200	Proprietary	0
Total CISC			926.0
Total 32-bit			1,096.4

S = Sample quantities
Source: Dataquest (October 1990)

TABLE 2
RISC Suppliers

Designer	Design	Sources
Motorola	88000	Motorola
Intel	i860	Intel
Sun	SPARC	BIT, Cypress, Fujitsu, LSI Logic, Philips, TI, Matra MHS
MIPS	RXXXX	IDT, LSI Logic, NEC, Performance, Siemens, Sony
Acorn	ARM	VLSI Technology, Sanyo
AMD	AM29000	AMD
Intergraph	Clipper	Intergraph, Samsung
RSRE	Viper 1A	MEDL
Hewlett-Packard	Spectrum P.A.	Hitachi, Samsung
Inmos	Transputer	Inmos
Harris	RTX2001	Harris

Source: Dataquest (October 1990)

recent announcement has come from Matra MHS, which will be a second source for the Cypress SPARC product. One of the incentives Sun has for licensing a European vendor is to establish a European source for silicon, as the company nears completion of a manufacturing plant in Scotland. But, you may ask, surely one source is enough; why license two European companies? The reason is linked to Sun's drive to make SPARC an industry-standard architecture, because Philips and Matra MHS have included SPARC in a plan to develop a European microprocessor under an ESPRIT proposal, formerly known as "European Microprocessor Initiative," which is now called the "Open Microprocessor Initiative" (OMI). The other reason for licensing Matra MHS is the close technology-transfer relationship between Cypress and Matra MHS that has developed over the past five years.

Siemens has licensed the MIPS architecture. This is expected to strengthen Siemens' relationship with some of its key customers, most notably Digital. Its decision to support MIPS demonstrates some synergy between Siemens' computer division and Nixdorf, which has also chosen MIPS for its RISC-based offerings, at a time when Siemens is in the process of acquiring Nixdorf.

SGS-Thomson now supports the Transputer through its acquisition of Inmos. Like DRAMs, microprocessors are core to SGS-Thomson's strategy to be a world-class semiconductor vendor. The Transputer is, indeed, a well-established and powerful processor. SGS-Thomson is pressing to have the Transputer included in the OMI.

Linked into OMI is the architectural know-how of the Acorn designers that created the ARM processor. Olivetti, which owns Acorn, has brought together these designers with the Inmos Transputer team, Inmos now being owned by SGS-Thomson. Meanwhile, VLSI Technology has been developing the ARM processor and is taking the design in its own direction with the help, now, of Sanyo.

The other European RISC effort that must be noted is the UK Royal Signals and Radar Establishment (RSRE) Viper 1A processor. Presently, MEDL is the only licensee; Plessey Semiconductors was offered a license but decided not to take it. MEDL has produced samples, and it has found an application in a railway-signaling system in Australia.

PROCESSORS ENABLE APPLICATIONS

Microprocessors are one of the key semiconductor products that enable new applications. However, the leading worldwide application for 32-bit microprocessors is one that has been with us for a decade or more—the personal computer. Here, powerful 32-bit processors are blurring the line that divides workstations from PCs. So it could be said that the Intel 80386DX and Motorola 68030 are *enabling* low-cost workstations to be made available to everyone.

The PC is also the number one application for 32-bit microprocessors in Europe. Most of Intel's 80386DXs were used by IBM, Olivetti, et al, in their PCs. We must also take into account that a significant proportion of Motorola's 68020 and 68030 devices went into Apple's PCs made in Ireland.

The PC is a microprocessor CPU application in the traditional sense, along with workstations, minicomputers, and so on. If we look beyond these traditional applications that the Intel and Motorola CISC devices serve, we see emerging a new set of 32-bit embedded-control applications.

The following are the key applications of RISC processors:

- Graphics workstations
- Compute/file servers
- Superminicomputers
- Supercomputers
- Notebook computers
- Embedded control
  - Graphics accelerators
  - Imaging peripherals—laser printers, faxes, scanners, etc.
  - Telecoms—PBXs
  - Instrumentation and control

Although substantial growth in graphics workstations, compute/file servers, superminicomputers, supercomputers, and notebook computers will provide considerable demand for RISC processors, the use of RISC processors in graphics accelerators, imaging peripherals, and other areas of embedded control is expected to exceed its use in traditional CPU applications.

Much marketing hype surrounds RISC. As a result, it is perhaps easy to forget that CISC processors are also being used in most of the applications shown above. Intel and Motorola CISC devices are most certainly being used in workstations and minicomputers. Also, National Semiconductor's 32X32 family is proving extremely successful as embedded controllers in imaging peripherals.

Following Canon's decision to tailor the NS32X32 processors for use in its laser printers, National has developed a very powerful family of CISC-based imaging products for use in laser printers, fax machines, scanners, and terminals. Completing the discussion of CISC applications, there have been no European designs yet for the Japanese TRON (The Real-Time Operating Nucleus) offerings represented by the Hitachi and Fujitsu processors shown in Table 1.

EUROPEAN RISC APPLICATIONS

As elsewhere, in Europe the number one application for CISC processors is the PC. But to understand RISC applications in Europe, we must look at current design activity. We have come up with a list of 125 design wins for RISC processors, including 55 European designs. This is by no means an exhaustive list, but it enables us to draw some conclusions about where the various RISC processors are being used most effectively.

The processor with most design wins is the Transputer. This is hardly surprising, as the Transputer is a very well-established architecture and the 32-bit product has been available for over two years. Clearly an architecture ahead of its time, it gives an indication of where RISC may expect to find applications in Europe.

Of the European design wins, 16 fall into the CPU category including workstations, minicomputers, and others. However, there are 34 embedded-control applications of various types. Within this grouping are 16 imaging/graphics applications, which include only 2 page printer sockets; 10 instrumentation and control applications, including 6 military systems; and 6 communications applications. There are 4 VME board applications. The others are in computer storage and a consumer games compendium.

The following paragraphs discuss the design wins and applications for the individual RISC processors.

The Intel i860 clearly is winning a niche in graphics; in Europe, Olivetti intends basing its computer products on it. Kontron and, particularly, PCs are reflecting a more global trend to use the i860 as a graphics coprocessor.

The Motorola 88000 is winning designs in workstations and minicomputers, taking sockets that may have used its CISC offerings had RISC not arrived on the scene. The 88000 has found its way into workstations in Europe, but VME boards and control systems also seem to be proving popular.

MIPS and SPARC, not surprisingly, are finding their way almost entirely into workstations. The only exceptions are two European designs in military embedded control by Sagem and Electronique Serge Dassault.

The RSRE Viper 1A has found only one design so far, in a railway-signal system.

Acorn's ARM processor has only been used by Acorn in its Archimedes PC so far, but it has four other European design wins including an Olivetti laser printer design; Hewlett-Packard is reported to be evaluating it. It is Sanyo, though, that is working with VLSI Technology on new versions and is intending to use it internally.

The AMD 29000 is a processor that is now being focused heavily on embedded control. In Europe it has been successful in graphics and FDDI node control. This reflects well upon the designs it is winning worldwide.

The Inmos Transputer is a guide for the new RISC players. The spread of applications that it is designed into typify the design spread that other RISC products are just beginning to penetrate. We can also draw some interesting conclusions from the European design wins. With SPARC and MIPS, European OEMs are just beginning to design workstations that are essentially clones of North American machines based on the same processors. Because these European companies tend to be one to two years behind in getting silicon samples of new devices, they must adopt a strategy of either producing clones for their own national markets (and rely on their European brand name), *or* try to get the most high-performance versions of the processors and focus on a niche high-end market. With the Transputer, we see a string of applications for very high-performance computers. European computer companies have been forced to retreat to the high ground because of this technology gap.

The Intergraph Clipper has won European design sockets in graphics and imaging applications. However, with the advent of the i860, some of these applications are now transferring to the Intel camp.

There are no European applications yet for the proprietary Hewlett-Packard Spectrum Precision Architecture RISC processor. HP has only recently licensed it to Hitachi and Samsung. Equally, the Harris RTX2001A has no European design wins yet.

DATAQUEST CONCLUSIONS

The European 32-bit microprocessor market continues to be dominated by CISC processors from Intel and Motorola. Most applications for 32-bit processors are as CPUs, and with the mass of compatible software for Intel and Motorola architectures, we do not expect this situation to change in the next five years. The leading application for 32-bit processors in Europe is in IBM-compatible personal computers, where Intel's CISC architecture reigns supreme.

The main high-volume embedded control application that employs RISC on a worldwide basis is imaging peripherals, including laser printers, fax machines, and scanners. Few world-class European equipment companies are present here. We must wait for those Far Eastern companies that lead this field to begin manufacturing in Europe before the European market will benefit. European companies' key embedded-control applications are in graphics and imaging, military, communication, control, and instrumentation. Here, Europe's leading players are currently deciding on the appropriate RISC product.

Inmos was the only European vendor present in the 32-bit arena in 1989. As a result, European vendors have only a 10 percent market share of their own market. In 1989, European companies supplied 18 percent of Europe's total microcomponent needs, with North American companies having 60 percent market share. Overall, European vendors supplied 5.3 percent of the world's microcomponents in 1989. Matra MHS, Philips, and Siemens have now joined the fray and will attempt to redress this imbalance.

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Ken Pearlman
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Research Newsletter

THE 32-BIT MICROPROCESSOR FORECAST: RISC TO ACCOUNT FOR 48 PERCENT OF MARKET BY 1994

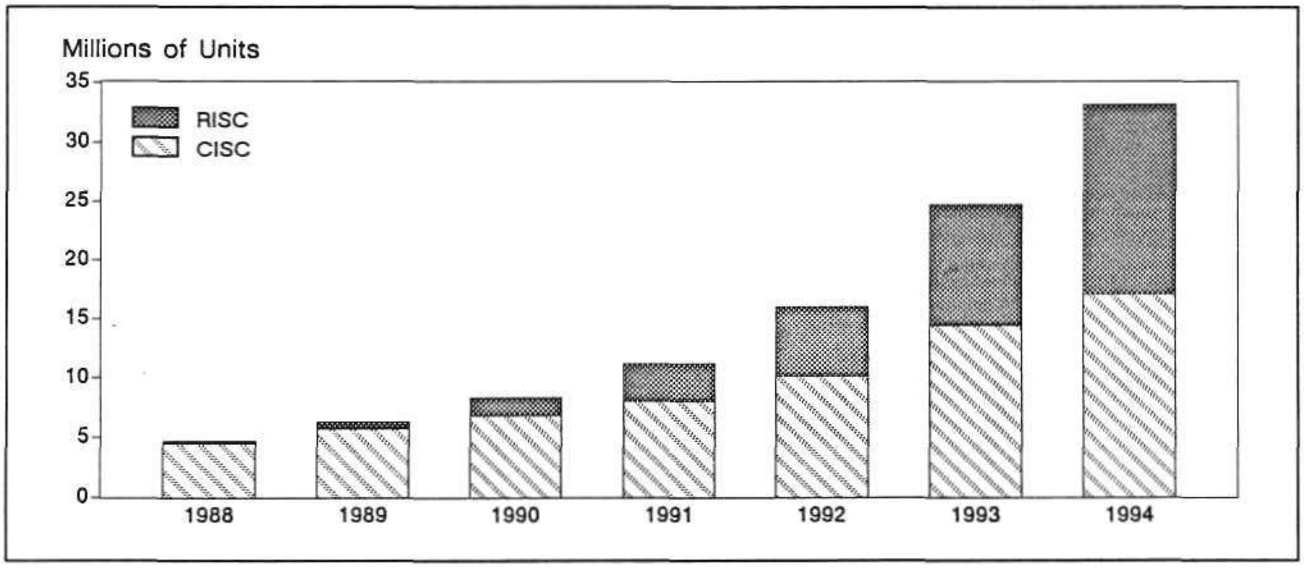
SUMMARY

The 32-bit microprocessor market grew 11.1 percent in 1989 to $1,118 million. The number of units grew 34 percent to 6.3 million. The major portion of the market is CISC-based, which accounted for approximately 91 percent of the units, with the remaining being RISC-based. The RISC segment is small but is growing rapidly, with unit volume increasing by 200 percent in 1989. The forecast compound annual growth rate (CAGR) for RISC for the 1988 to 1994 period is 49 percent compared with 5.7 percent for the CISC segment. Dataquest anticipates that by 1994, RISC-based microprocessors will account for approximately 48 percent of the total 32-bit market (see Figure 1). The RISC segment itself will continue to be dominated by the SPARC and MIPS RX000 architectures.

BACKGROUND

Much attention has been focused on the 32-bit microprocessor market recently, as segmentation becomes cloudy and competition increases between high-end CISC-based PCs and RISC-based workstations. Dataquest's 32-bit microprocessor forecast is presented in Table 1. The markets for CISC-based systems and embedded applications are dominated by Intel and Motorola. There is little likelihood that another vendor with a competing CISC architecture could be successful.

FIGURE 1
Estimated Worldwide 32-Bit Microprocessor Unit Shipments



Source: Dataquest (July 1990)

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Table 1
Worldwide 32-Bit Microprocessor Forecast

	1988	1989	1990	1991	1992	1993	1994	CAGR 1988-1994
Revenue ($M)								
CISC	900	983	990	1,017	1,082	1,285	1,255	5.7%
RISC	106	135	224	410	620	913	1,158	49.0%
Aggregate	1,006	1,118	1,214	1,427	1,702	2,198	2,413	15.7%
Units (Millions)								
CISC	4.5	5.7	6.8	8.0	10.1	14.4	17.1	24.9%
RISC	0.2	0.6	1.5	3.2	5.9	10.3	16.0	107.6%
Aggregate	4.7	6.3	8.3	11.2	16.0	24.7	33.1	38.4%
Average Selling Price ($)								
CISC	204.55	172.46	145.59	127.13	107.13	89.24	73.39	(15.7%)
RISC	353.33	225.00	149.33	128.13	105.08	88.64	72.38	(23.2%)
Aggregate	210.88	177.46	146.27	127.42	106.37	88.99	72.90	(16.2%)

Note: This forecast does not include the Intel 80386SX.
Source: Dataquest (July 1990)

The RISC market is growing rapidly and therefore offers a unique opportunity to microprocessor vendors. The market appears to be moving toward two dominant architectures—SPARC and MIPS RX000.

THE 32-BIT MICROPROCESSOR MARKET

In 1989, Intel had 45 percent of the 32-bit microprocessor market, with Motorola owning 38 percent (see Figure 2). In 1988, Intel's share of the market was 53 percent, up from 39 percent in 1987. Motorola's share for 1988 was 35 percent, which was down from 42 percent in 1987. These shifts in market share were caused by the timing of product introductions. Motorola's 68030 chip experienced dramatic sales growth in 1989, while Intel's 80386 sales grew rapidly in 1988.

RISC Market Begins to Take Shape

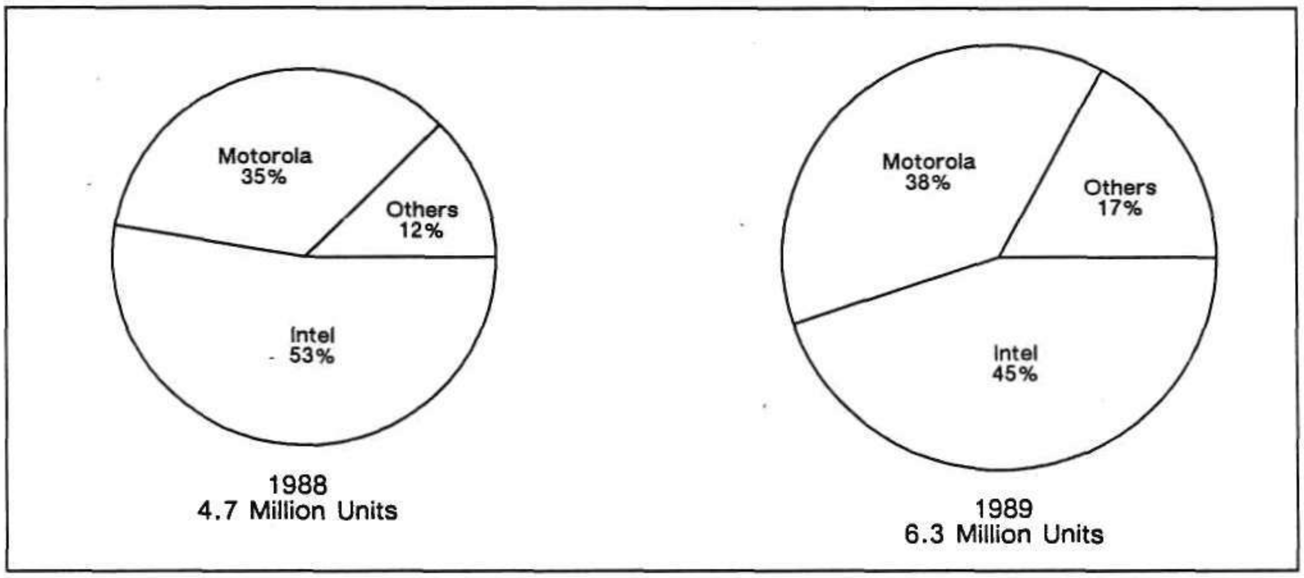
Dataquest's estimates of 32-bit RISC microprocessor market shares by architecture are presented in Figure 3. RISC-based designs accounted for 4 percent of all 32-bit microprocessor unit sales in 1988, growing to 9.8 percent in 1989. Combined SPARC and MIPS RX000 unit sales accounted for 9 percent of total 32-bit RISC volume in 1988, growing dramatically to 53 percent in 1989.

The dynamics of the competition within the RISC microprocessor segment parallel and are similar to the dynamics that have shaped the 32-bit market segment and the microprocessor market in general. Although more than 80 percent of all microprocessors sold are used in nonreprogrammable (embedded) applications, the market is focused on and heavily influenced by trends in the systems (PC and workstation) markets. Driven by end-user requirements, the overriding issues in the systems markets are standardization and compatibility. At the components level, these factors translate to a limited number of microprocessor architectures and result in a consolidation of suppliers.

The reason microprocessor suppliers focus on systems applications rather than embedded applications, even though the embedded market is much larger, is that systems constitute a single large-volume market. System design wins offer product exposure, allow volume efficiencies to develop, and foster the use of the product in fragmented embedded applications.

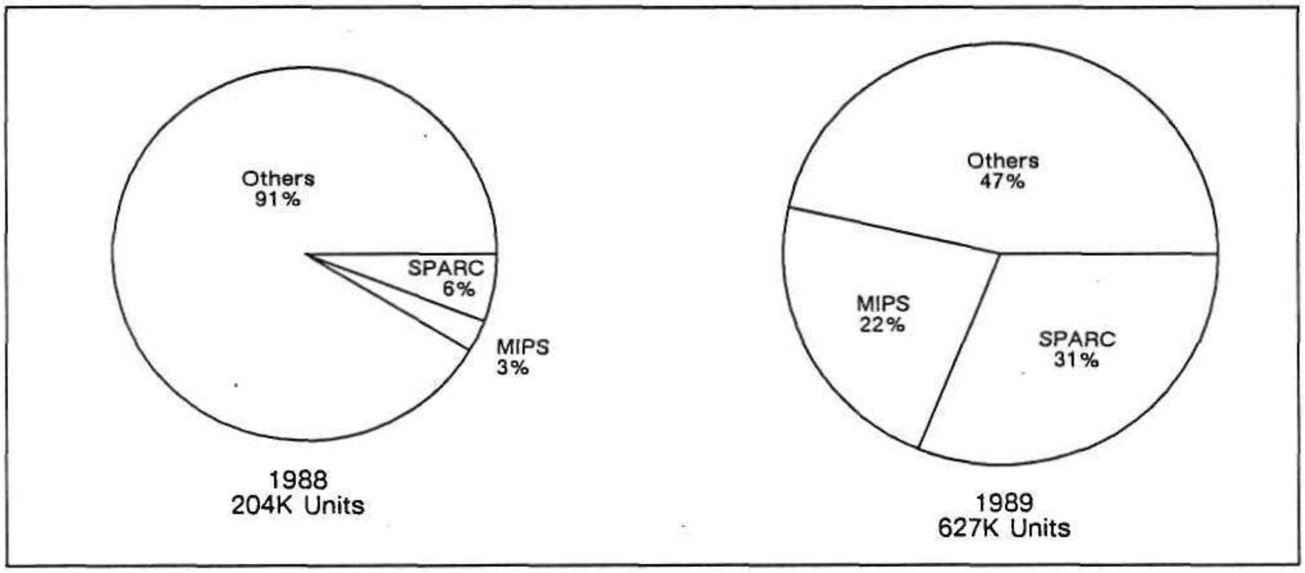
The need for standardization and the desire of microprocessor vendors to establish their architectures in the systems markets helps explain why the combined market share for SPARC and MIPS RX000 has gone from 9 percent to 53 percent of the RISC market in one year. There are currently six vendors each for SPARC- and MIPS RX000-based products that have licensed access to these architectures. A list of these vendors, along

FIGURE 2
32-Bit Microprocessor Market Share



Source: Dataquest (July 1990)

FIGURE 3
32-Bit RISC Market Share



Source: Dataquest (July 1990)

with other 32-bit RISC suppliers, is presented in Table 2. The open access to these architectures has avoided what would otherwise be a painful industry fragmentation with more than a dozen competing vendors and architectures.

Dataquest believes that the RISC market will continue to exhibit this consolidation, with SPARC- and MIPS RX000-based products commanding more of the RISC pie as total RISC sales command more of the total 32-bit microprocessor market.

TABLE 2
32-Bit RISC Microprocessor Suppliers and Architectures

Architecture	Processor	Suppliers
Acorn	ARM	Sanyo
		VLSI
Advanced Micro Devices	AM29000	Advanced Micro Devices
Hewlett-Packard	Precision Plus	Hewlett-Packard
		Hitachi
		Samsung
Inmos	Transputer	Inmos
Intel	80860	Intel
	80960	
Intergraph	Clipper	Intergraph
		Samsung
MIPS Computer Systems	R2000	Integrated Device Technology
	R3000	LSI Logic
		NEC
		Performance Semiconductor
		Siemens
		Sony
Motorola	88000	Motorola
		Thomson-CSF (military only)
Sun Microsystems	SPARC	Bipolar Integrated Technology
		Cypress Semiconductor
		Fujitsu
		LSI Logic
		Philips
		Texas Instruments

Source: Dataquest (July 1990)

DATAQUEST CONCLUSIONS

The 32-bit microprocessor market is moving toward parity between RISC and CISC architectures in the 1994 time frame. The RISC market is growing very rapidly, offering opportunity for microprocessor vendors. In the RISC segment, vendors have orchestrated a consolidation through the use of licensed standard architectures, perhaps avoiding painful competition and industry fragmentation. Dataquest expects this consolidation to continue, with SPARC and MIPS RX000 remaining the dominant architectures.

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Research *Newsletter*

DON'T COUNT YOUR PIXELS BEFORE THEY'RE HATCHED: VGA TO DOMINATE PC GRAPHICS CHIP MARKET

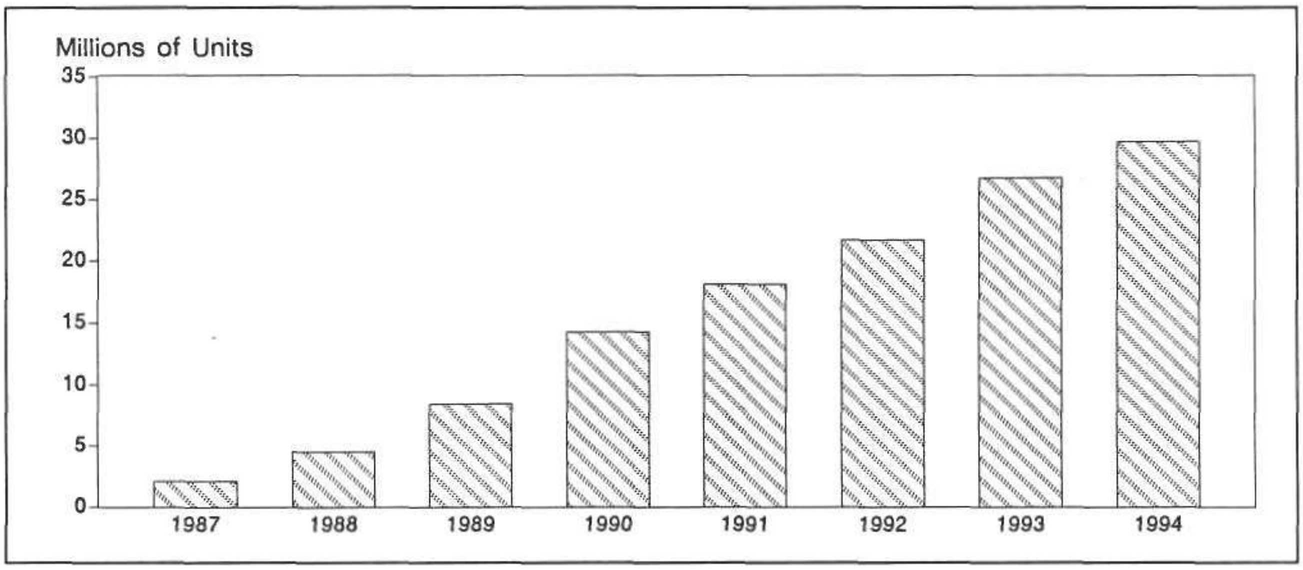
SUMMARY

Positive growth is expected through 1994 in the PC graphics chip market. Dataquest forecasts the merchant graphics chip market to grow to 29.7 million units by 1994 (see Figure 1). Growth in the PC AT market, spurred by growth in the notebook, laptop, and hand-held segments, will account for the growth in graphics chip shipments. Dataquest estimates that over 85 percent of all PCs produced will have graphics capability by 1994; the remaining 15 percent, consisting of hand-held and pocket PCs, are expected to have text capability only. VGA will continue to be the dominant standard throughout the forecast period. Super VGA (SVGA) has begun to emerge at the high end. The high-end market will be determined primarily by price and memory capacity.

PC GRAPHICS UNIT GROWTH FORECAST

The PC graphics chip forecast is derived from Dataquest's Personal Computer Industry Service (PCIS) forecast and a survey of worldwide graphics chip vendors. Table 1 illustrates the low-end PC graphics chip forecast. Total IBM PC-compatibles are broken down by PCs that will have graphics capability and PCs that will not. Dataquest estimates that the nongraphics solutions market will grow at a compound annual growth rate (CAGR) of 27.9 percent. The growth in nongraphics solutions reflects the growth expected in hand-held and pocket PCs. Dataquest believes that these products will be small-screen, text-only units with no real need for graphics. Standard graphics solutions will grow at a CAGR of 14.0 percent throughout the forecast period as graphics capability becomes a

FIGURE 1
PC Merchant Graphics Chip Unit Forecast



Source: Dataquest (July 1990)

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TABLE 1
Merchant Graphics Chip Market Estimated Worldwide History and Forecast (Thousands of Units)

	1987	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total IBM-Compatible PCs	11,000	15,500	19,586	23,198	26,500	30,072	35,184	40,316	15.5%
Growth Rate		40.9%	26.4%	18.4%	14.2%	13.5%	17.0%	14.6%	
Text-Only Solutions	1,790	1,705	1,763	2,022	2,390	3,276	3,788	6,022	27.9%
Growth Rate		(4.7%)	3.4%	14.7%	18.2%	37.1%	15.6%	59.0%	
Percentage of Total PCs	16.3%	11.0%	9.0%	8.7%	9.0%	10.9%	10.8%	14.9%	
Low-End Graphics Solutions	9,210	13,795	17,823	21,176	24,110	26,796	31,396	34,294	14.0%
Growth Rate		49.8%	29.2%	18.8%	13.9%	11.1%	17.2%	9.2%	
Percentage of Total PCs	83.7%	89.0%	91.0%	91.3%	91.0%	89.1%	89.2%	85.1%	
Captive/Proprietary/Discrete Solutions	7,103	9,271	9,456	6,988	6,027	5,091	4,709	4,561	(13.6%)
Growth Rate		30.5%	2.0%	(26.1%)	(13.7%)	(15.5%)	(7.5%)	(3.2%)	
Merchant Graphics Chips	2,107	4,524	8,367	14,188	18,083	21,705	26,687	29,733	28.9%
Growth Rate		114.7%	84.9%	69.6%	27.4%	20.0%	23.0%	11.4%	
Percentage of Low-End Graphics	22.9%	32.8%	46.9%	67.0%	75.0%	81.0%	85.0%	86.7%	
Merchant Graphics Chips ASP	26.13	23.89	20.29	15.73	12.44	9.89	8.61	8.13	(16.7%)
Growth Rate		(8.6%)	(15.0%)	(22.5%)	(20.9%)	(20.4%)	(13.0%)	(5.6%)	
Merchant Graphics Chips Revenue (Thousands of Dollars)	55,046	108,065	169,795	223,197	224,914	214,759	229,771	241,676	7.3%
Growth Rate		96.3%	57.1%	31.5%	0.8%	(4.5%)	7.0%	5.2%	

Source: Dataquest (July 1990)

standard item on PC motherboards. As a result, the merchant graphics chip market is expected to grow at a CAGR of 28.9 percent.

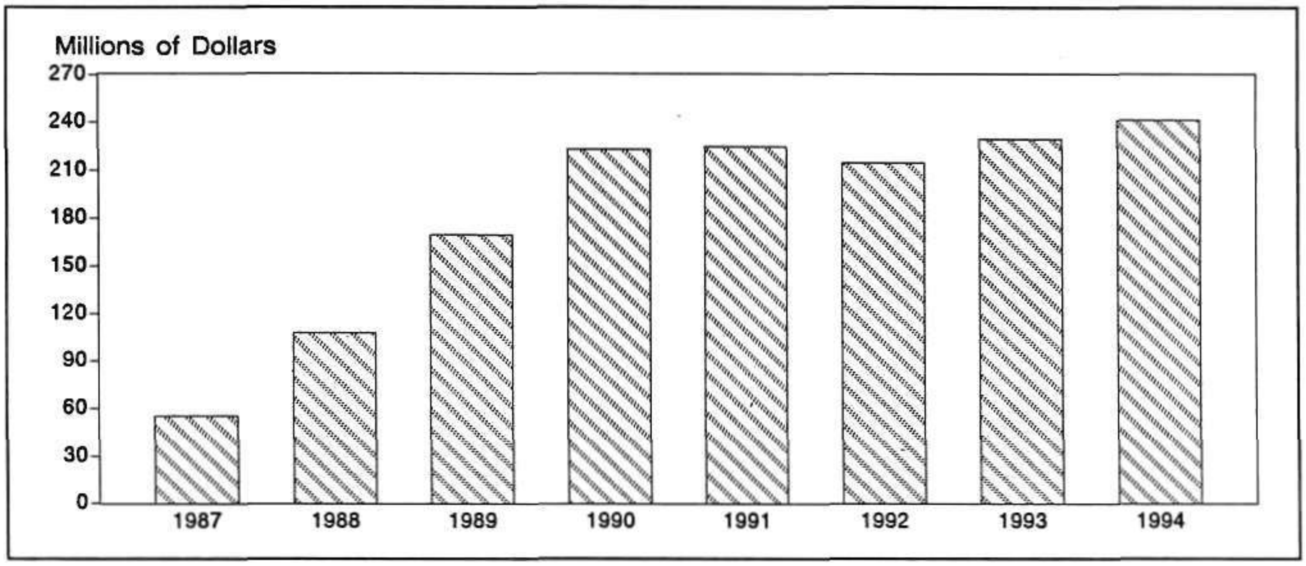
Revenue Growth Forecast for the Period

Dataquest forecasts that merchant PC graphics chip revenue will grow at a CAGR of 7.3 percent, as illustrated in Figure 2. However, 1991 should be a flat year for revenue growth as merchant chip unit shipments slow in growth and average selling prices (ASPs) drop. In 1992, we can expect to see the product mix begin to change as unit shipments for SVGA begin to increase, accounting for 16.0 percent of the merchant graphic chip market (see Figure 3). Merchant revenue in 1992 should drop 4.5 percent as prices start to fall for SVGA chips. SVGA prices will fall as high-resolution display monitor prices drop to a reasonable price point for PCs and the product mix for SVGA changes (i.e., when the current midrange 800 x 600-pixel resolution becomes the entry-level solution and high-end 1,024 x 768-pixel resolution becomes the midrange solution.) Merchant revenue in 1993 and 1994 should rise again as price declines start to level off and unit shipments continue to rise.

VGA: THE PREFERRED GRAPHICS STANDARD

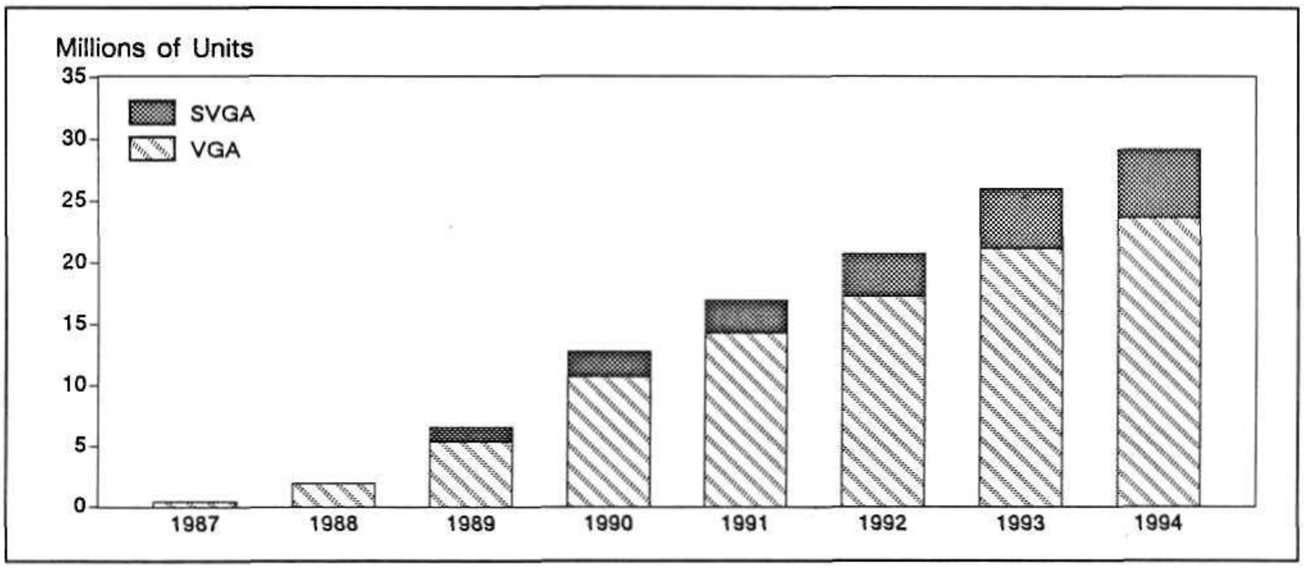
Dataquest believes that VGA is the dominant graphics standard, making up at least three-fourths of the graphics chip shipments through 1994.

FIGURE 2
Merchant PC Graphics Chip Revenue Forecast



Source: Dataquest (July 1990)

FIGURE 3
VGA vs. SVGA Unit Growth



Source: Dataquest (July 1990)

Based on Dataquest's PC forecast, AT-based PCs will dominate through 1994; we expect the majority to support VGA graphics on the motherboard. Additionally, low-end XT-based PCs will have monochrome VGA, and high-end XT-based PCs will have color VGA. Dataquest estimates that VGA prices will drop 18.2 percent CAGR during the forecast period.

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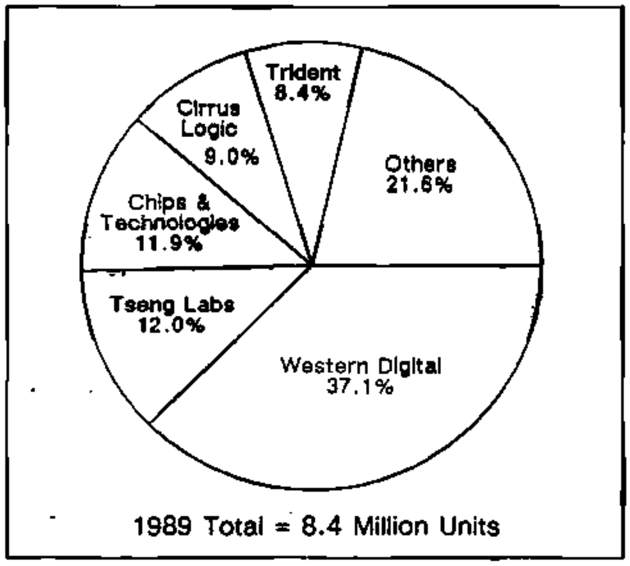
What Is in Store for Super VGA

At this point, SVGA is considered a high-end graphics solution. The SVGA market can be divided into entry-level, midrange, and high-end segments based on the number of colors available. Because this market is still very new, prices and solutions vary. How many SVGA chips will be implemented onto PCs will depend on the amount of memory available and the display monitor. High-end SVGA chips, with 1,024 x 768-pixel resolution and 256 colors, require 1MB of memory compared with the low-end, 800 x 600-pixel resolution with 4 colors, which requires only 256KB of memory. Dataquest estimates that the SVGA market will grow at a CAGR of 35.9 percent through 1994, making up less than 20.0 percent of the merchant graphics chip market. Exactly how this market pans out remains to be seen.

Western Digital Leads the Pack

For the second year in a row, Dataquest estimates Western Digital to be the number one player in the overall PC graphics chip market based on units shipped (see Figure 4). Following Western Digital are Tseng Labs and Chips & Technologies, with 12.0 and 11.9 percent market share, respectively. Emerging from the lethargic times following the Faraday acquisition, Western Digital has become a streamlined, highly focused operation. Western Digital's broad range of product offerings, which includes system logic, storage, data communications, and video chip sets, allows the company to service multiple segments as well as offer a full-system solution.

FIGURE 4
PC Graphics Unit Market Share by Manufacturer



Source: Dataquest (July 1990)

Dataquest Conclusions

Dataquest believes that overall, the merchant PC graphics chip market is going strong. It is reasonable to assume that just about every PC produced by 1994 will have some kind of graphics capability (excluding hand-held and pocket PCs). VGA will be the graphics standard throughout the mid-1990s, with SVGA playing a minor role. It will be interesting to see SVGA's role later in the decade—whether SVGA eventually will replace VGA or the next jump from VGA will be directly to a TIGA or 8514/A solution.

Lori Kulwin

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Research Newsletter

PC AT DOMINANCE DRIVES PC LOGIC CHIP SET FORECAST

SUMMARY

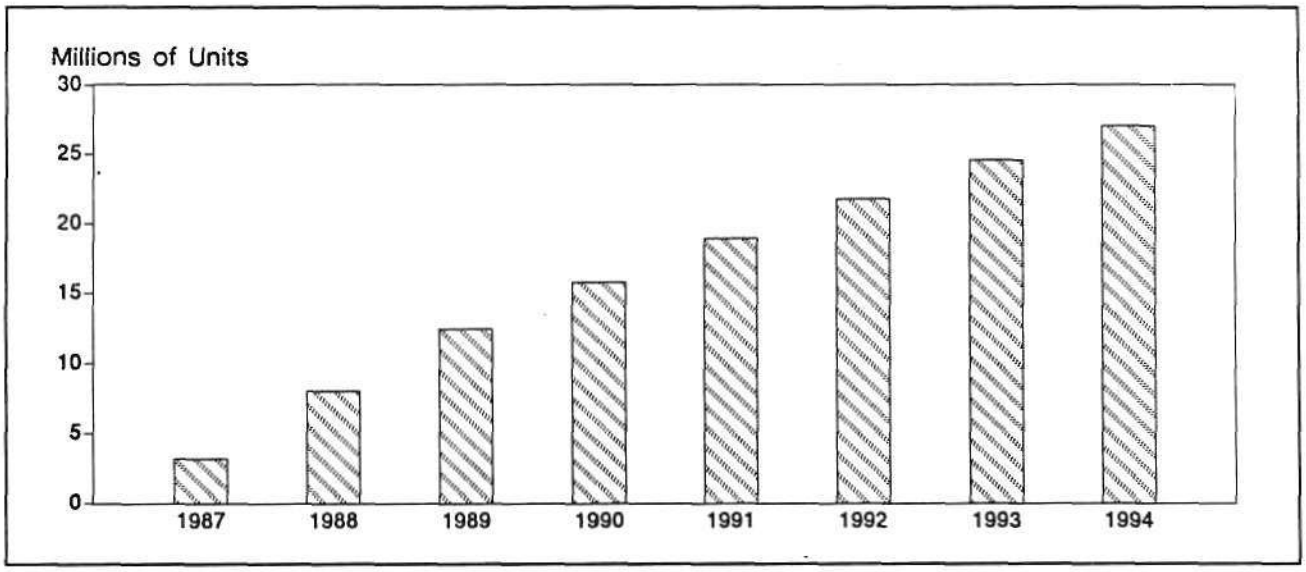
The PC logic chip set market continues to grow as the personal computer industry evolves. New generations and form factors bring new issues that must be incorporated into the forecast in order to get an accurate picture of the PC logic chip set market. For example, current standard bus architectures may not be appropriate to many of the hand-held computer applications. Dataquest estimates that the merchant PC logic chip set market will continue its growth through 1994, as illustrated in Figure 1. Dataquest believes that the anticipated high growth through the 1990s will result from the growth expected in the notebook, laptop, and pocket PC markets. The merchant chip set market is expected to grow at a compound annual growth rate (CAGR) of 16.8 percent through 1994.

WORLDWIDE PC LOGIC CHIP SET FORECAST

Standard Bus versus Nonstandard Bus

The PC logic chip set forecast is derived from Dataquest's Personal Computer Industry Service (PCIS) PC forecast and a survey of worldwide chip set vendors. The forecast is broken out into standard buses and nonstandard buses (see Table 1). Standard buses include PC XT, PC AT, EISA, and MCA. Included under nonstandard buses are those PCs that do not incorporate a bus or standard bus (for example, the new hand-held and pocket PCs). Dataquest expects to see the nonstandard bus market grow at a CAGR of 127.3 percent from 1989 through 1994, as hand-held and pocket PCs enter the market.

FIGURE 1
Estimated Worldwide Merchant PC Logic Chip Set—Unit Forecast



Source: Dataquest (June 1990)

SIS Newsletters 1990 Microcomponents

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Table 1
Estimated Worldwide PC Logic Chip Set Forecast (Thousands of Units)

	1987	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total IBM-Compatible PCs	11,000	15,500	19,586	23,198	26,500	30,072	35,184	40,316	15.5%
Growth Rate	NA	40.9%	26.4%	18.4%	14.2%	13.5%	17.0%	14.6%	
Nonstandard Bus PCs	0	0	86	398	800	1,472	3,084	5,216	127.3%
Growth Rate	NA	NA	NA	362.8%	101.0%	84.0%	109.5%	69.1%	
Standard Bus PC Shipments	11,000	15,500	19,500	22,800	25,700	28,600	32,100	35,100	12.5%
Growth Rate	NA	40.9%	25.8%	16.9%	12.7%	11.3%	12.2%	9.3%	
Discrete Solutions	6,800	4,559	2,550	1,502	518	0	0	0	(100.0%)
Saturation*	61.8%	29.4%	13.0%	6.5%	2.0%	0	0	0	
Total Chip Set Solutions	4,274	10,941	16,950	21,298	25,182	28,600	32,100	35,100	15.7%
Saturation*	38.9%	70.6%	86.5%	91.8%	95.0%	95.1%	91.2%	87.1%	
Captive Chip Sets	1,100	2,900	4,500	5,500	6,200	6,800	7,500	8,000	12.2%
% of Total Chip Set Solutions	25.7%	26.5%	26.5%	25.8%	24.6%	23.8%	23.4%	22.8%	
Merchant Chip Set Shipments	3,174	8,041	12,450	15,798	18,982	21,800	24,600	27,100	16.8%
Growth Rate	NA	153.3%	54.8%	26.9%	20.2%	14.8%	12.8%	10.2%	
Percent of Total Chip Set Solutions	74.3%	73.5%	73.5%	74.2%	75.4%	76.2%	76.6%	77.2%	
Chip Set ASP	$44.98	$44.56	$39.68	$35.59	$35.73	$34.87	$34.47	$33.41	(3.4%)
Growth Rate	NA	(0.9%)	(10.9%)	(10.3%)	0.4%	(2.4%)	(1.1%)	(3.1%)	
Chip Set Revenue ($K)	$142,755	$358,269	$494,061	$562,313	$678,245	$760,075	$848,077	$905,473	13.0%
Chip Set Revenue Growth	NA	151.0%	37.9%	13.8%	20.6%	12.1%	11.6%	6.8%	

NA = Not applicable
*As a function of DOS PCs
Source: Dataquest (June 1990)

Captive/Proprietary Markets Grow

Discrete solutions continue to be displaced by chip sets. The captive/proprietary chip set market should continue to grow at a CAGR of 12.2 percent. This growth marks a strengthening over Dataquest's earlier forecast. Dataquest believes that captive and proprietary chip set solutions will increase in popularity as PC vendors struggle to maintain product differentiation.

Declining ASP

Average selling prices (ASPs) will continue to decline throughout the forecast period. The ASP for 1989 dropped 10.9 percent to $39.68, influenced by fierce competition, especially in the 80286 segment. Dataquest believes that the ASP will continue its decline and level off at approximately $33.00 by 1994. Because AT-based PCs will continue to dominate the midrange PC market, AT chip set pricing will have a dominant effect on the aggregate ASP. Sales of XT-based machines will revive as a result of the popularity of the portable PC market early in the period. At the high end, MCA and EISA have yet to make a significant impact on the marketplace.

Continued Growth for PC AT

Figure 2 illustrates the continued growth expected in the PC AT market. Dataquest estimates that the PC AT segment will grow at a CAGR of 14.4 percent from 1989 through 1994. The PC AT bus is the midrange bus that has gained wide market acceptance and should continue to dominate through the forecast period. The PC AT bus will be the popular choice for the new PC growth markets, such as portable notebook and laptop PCs. The PC XT bus is considered the low-end bus and will continue to decline in the forecast period as the switch from PC XT to PC AT is made. Both MCA and EISA are considered high-end buses, and Dataquest does not expect to see either in the portable notebook or laptop markets.

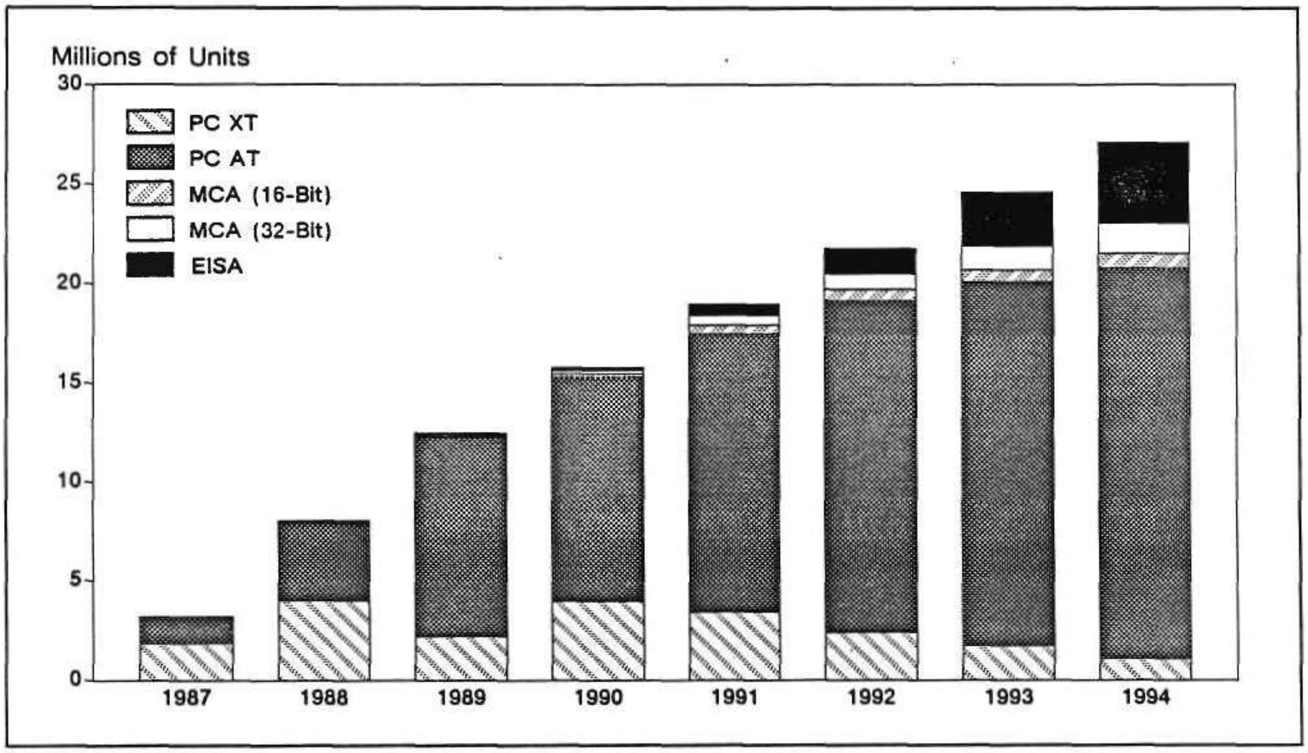
Market Share Rankings

Chips & Technologies ranked number one based on units shipped in the overall PC logic chip set market for the second consecutive year (see Figure 3). VLSI Technology and Texas Instruments followed, holding the number two and three spots, respectively.

In the PC AT segment, based on units, Chips & Technologies, VLSI Technology, and ZyMOS maintain their first, second, and third positions, respectively, for the second consecutive year (see Figure 4). Chips holds 39.1 percent, VLSI holds 18.7 percent, and ZyMOS holds 10.9 percent of the PC AT market.

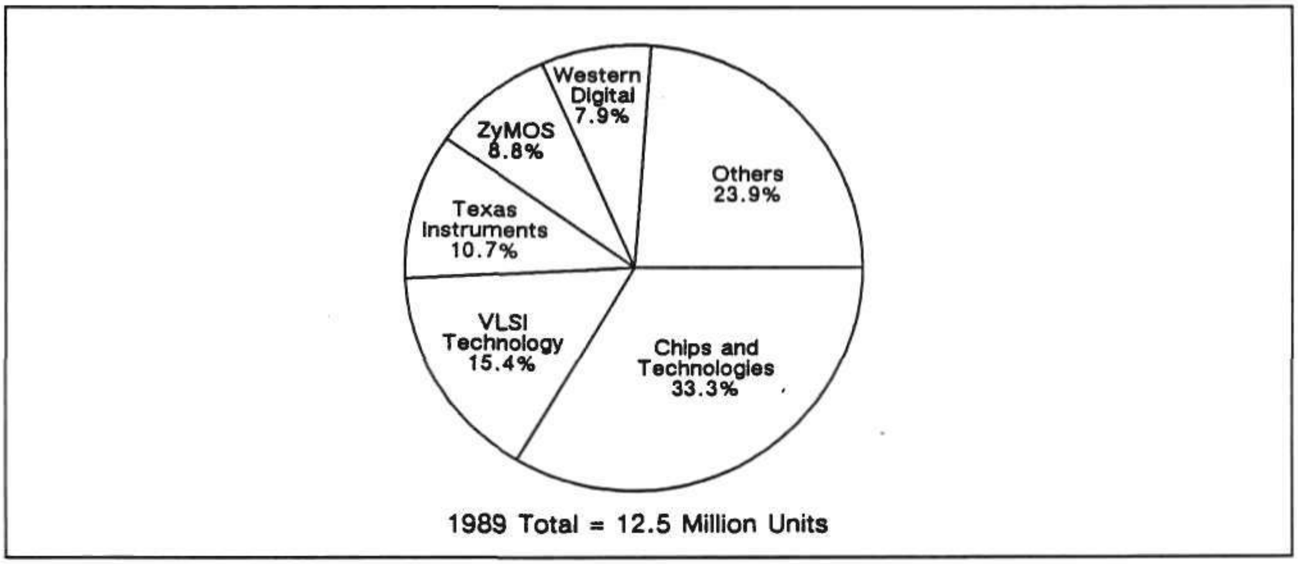
Lori Kulwin

Figure 2
Worldwide PC Logic Chip Set Forecast by Bus Architecture



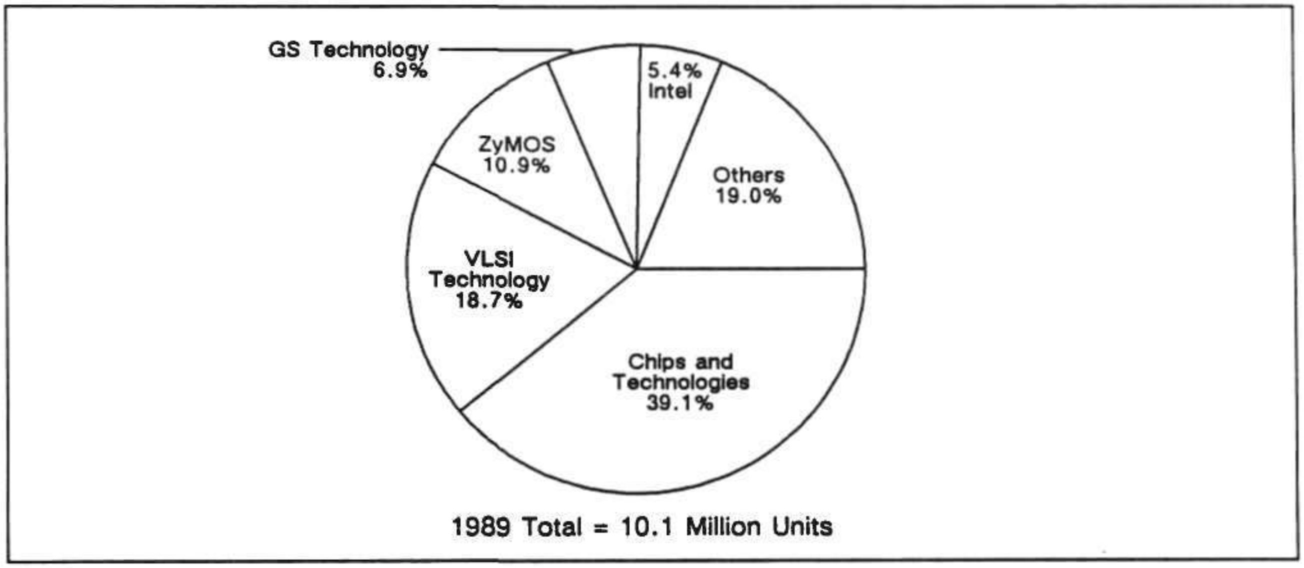
Source: Dataquest (June 1990)

Figure 3
Total Estimated PC Logic Chip Set Unit Market Share by Manufacturer



Source: Dataquest (June 1990)

FIGURE 4
Estimated PC Logic Chip Set Unit Market Share by Manufacturer by PC AT Bus



Source: Dataquest (June 1990)

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Research Newsletter

LASER PRINTERS: A HIGH-VISIBILITY EMBEDDED MARKET

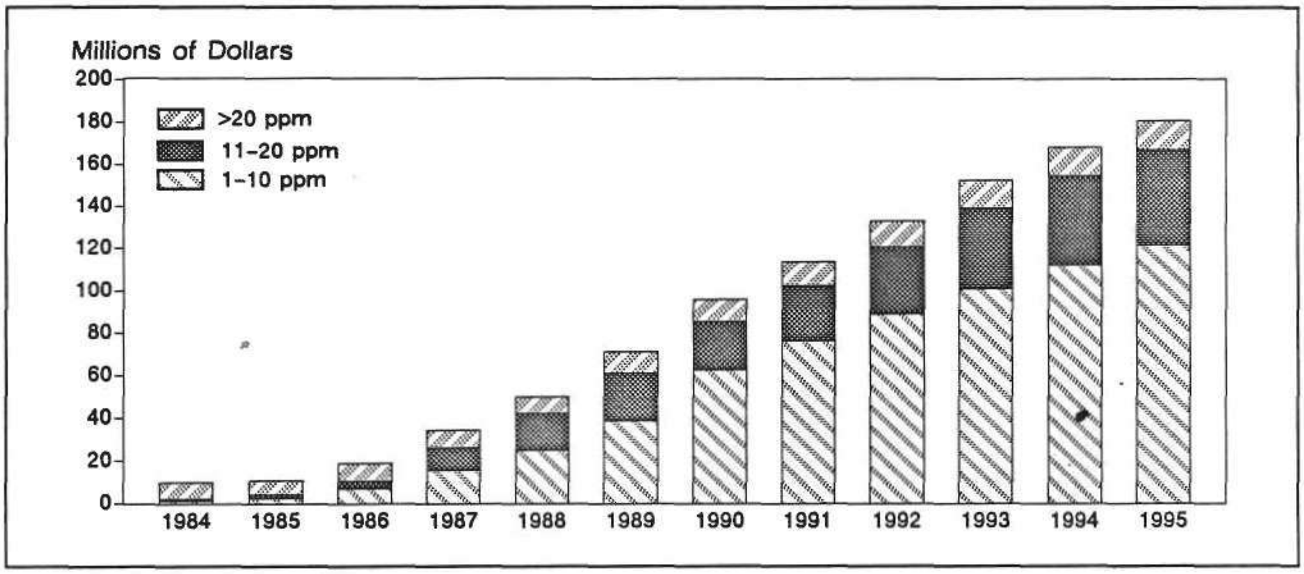
SUMMARY

The page printer (laser printer) market has experienced rapid expansion over the last several years and will continue to offer attractive growth rates through the mid- to late 1990s. The worldwide unit forecast for 1995 is close to 10 million units, approximately one-fourth the size of the forecast 1995 worldwide PC market. This market represents a high-visibility, high-volume embedded application that offers opportunities for semiconductor manufacturers. Successful chip suppliers will need to provide a product line of performance-enhancing, imaging-dedicated (application-specific) microprocessors or microcontrollers with a broad price/performance range, as well as systems expertise, easing entry barriers for new systems manufacturers. Figure 1 presents Dataquest's forecast of worldwide laser printer embedded controller opportunities. Dataquest estimated that the 1989 market was $71.3 million and will grow 35 percent this year to $95.9 million.

BACKGROUND

PC users have long been able to create more detailed and attractive documents and images on their screens than could adequately be reproduced by desktop dot-matrix or line printers. With the increased popularity of desktop publishing applications, the laser printer now is becoming an integral office peripheral for any organization doing desktop publishing ranging from simple correspondence

FIGURE 1
Estimated Worldwide Page Printer Controller Revenue



Source: Dataquest (June 1990)

SIS Newsletters 1990 Micro

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Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398 / (408) 437-8000 / Telex 171973 / Fax (408) 437-0292

to complex presentations and marketing collateral. Laser printers offer increased productivity and independence from outside printing and publishing functions. Because of these factors, the laser printer market had a compound annual growth rate (CAGR) of 97.5 percent in unit volume between 1984 and 1989. Dataquest forecasts 64.8 percent unit growth in 1990 and a 1989 to 1995 CAGR of 24.8 percent (see Table 1).

GENERAL-PURPOSE VERSUS APPLICATION-SPECIFIC PROCESSORS

Imaging functions and processing have been implemented in two ways for laser printer control designs. One method is to design around a general-purpose microprocessor, using the raw power of the processor for speed while implementing specific imaging functions, features, and logic in software or ASICs. The second method is to use application-specific processors that have built-in imaging functionality and logic.

The important success factors for design wins for most embedded applications are as follows:

- Familiarity of the product to the designers
- Price
- Design tools and development support
- Performance and features

Because of these factors, the use of general-purpose microprocessors has been extensive in laser printer designs. In fact, the Motorola M68XXX family of processors are the most commonly used devices, capturing between 75 and 90 percent of all laser printer design wins during the 1984 to 1989 time frame. The three leading vendors use M68XXX—Hewlett-Packard in its LaserJet products, Apple Computer in its LaserWriter products, and IBM in its laser printer products.

Because the M68XXX family is used in PC and workstation products, the production volume of

TABLE 1
Worldwide Page Printer and Printer Controller Forecast
Printer Units X 1,000
Microprocessor Revenue X 1,000

	1989	1990	1995	CAGR 1984-1995	CAGR 1989-1995
1-6 ppm					
Printer Units	1,140.8	2,590.1	6,973.2	97.5%	35.2%
MPU ASP	$11.85	$12.76	$12.39	(1.0%)	0.7%
Revenue	$13,514	$33,050	$86,374	95.6%	36.2%
7-10 ppm					
Printer Units	1,251.6	1,440.4	1,980.0	37.8%	7.9%
MPU ASP	$20.31	$20.51	$18.02	(0.4%)	(2.0%)
Revenue	$25,420	$29,543	$35,671	37.2%	5.8%
11-20ppm					
PrinterUnits	169.1	201.6	730.2	42.1%	27.6%
MPUASP	$132.01	$113.91	$61.87	(0.8%)	(11.9%)
Revenue	$22,323	$22,963	$45,176	41.0%	12.5%
>20 ppm					
Printer Units	21.8	27.3	76.0	21.9%	23.1%
MPU ASP	$460.80	$378.81	$178.20	(13.8%)	(14.6%)
Revenue	$10,045	$10,342	$13,548	5.0%	5.1%
Total Units	2,583.3	4,259.4	9,759.5	53.8%	24.8%
MPU ASP	$27.60	$22.51	$18.52	(15.4%)	(6.4%)
Total Revenue	$71,319	$95,898	$180,769	30.0%	16.8%

Source: Dataquest (June 1990)

these products allow for lower pricing structures. Systems designers are familiar with the product design parameters and development tools. A range of price/performance options exists within the family, as does a clear product growth path. Additional features may be added through the use of proprietary ASICs that complement the microprocessor, allowing further system differentiation. Other general-purpose processors that have been popular for laser printer designs for similar reasons are the Intel 80C186, 80286, and, recently, the 80960.

The second method of implementing laser printer control, the use of application-specific microprocessors, offers better opportunities for semiconductor vendors. Examples of application-specific microprocessors are the Weitek XL82XX family and the National Semiconductor 32CG, 32FX, and 32GX families of imaging-specific microprocessors. These products are not as familiar as the general-purpose processors, may cost between two and five times more, and offer less ability to differentiate the end product. However, the total controller cost is comparable when considering the additional costs of adding logic and proprietary features to the general-purpose processor design. Application-specific products also save board space and may lower overall manufacturing costs.

The Trend toward Imaging-Specific Products

Dataquest believes that the trend in laser printer control is toward imaging-specific microprocessor implementations. The high growth rates in the laser printer equipment market will continue to attract new suppliers. These laser-printer-specific products will facilitate entry into this market by lowering technical entry barriers. As barriers are lowered, competition increases, system prices decline, and unit volumes go up. These factors, in turn, raise unit volumes, causing processor and system prices to decline further.

An analagous model of this enabling phenomenon is the effect that the introduction of system logic chip sets had on the PC clone industry. The availability of PC logic chip sets, combined with the system design expertise provided by chip set vendors, had a dramatic effect on the PC market. New systems vendors with low-cost manufacturing capability were able to enter the PC market more easily, which dramatically raised unit volumes while lowering prices. Of course, another result of lower entry barriers was to create a highly fragmented industry with chronically low margins. In turn, chip set suppliers have seen pricing declines and margin pressures passed on to them by their customers.

THE LASER PRINTER CONTROLLER FORECAST

Dataquest presents its forecast of estimated worldwide revenue for microprocessors used in page printer applications in Figure 1. A detailed segment breakout by page-per-minute (ppm) categories is shown in Table 1.

Forecast Methodology and Assumptions

Dataquest's page printer controller revenue forecast is based on the page printer unit forecast generated by Dataquest's Electronic Printer Industry Service (EPIS). The market is segmented by speed, which is measured in pages printed per minute.

The basic assumptions in the laser printer controller revenue forecast model are as follows:

- One or more processors per printer are sold.
- A given processor will be applicable to certain ppm segments.
- The mix over time will begin to favor imaging-specific processors over general-purpose processors.
- The number of vendors that offer imaging-specific processors will increase.

Unit Volumes

No one-to-one unit relationship exists between the number of laser printers shipped and the number of laser printer controllers shipped. In some cases, vendors use two or more processors for higher-ppm systems. For example, vendors have used multiple M68000s, M68020s, and 80286s or combinations of these products with RISC or proprietary processors. However, the overall ratio of processors to printers is not high because the multiple processor products are the higher-end products in the lowest unit/volume segments. Therefore, the ratio of processors to printers for a given ppm segment could be as high as three to one, but the contribution of these segments in terms of total units is quite small. The overall ratio of processors to printers is most heavily influenced by single-processor, low-end products and is estimated to be about 1.03. This ratio has come down from over 1.1 in the 1984 to 1985 time frame as the segment mix has begun to favor the low-end segments.

Pricing

For the historical portion of the forecast model, an attempt was made to reconstruct the processor usage in printers based on the estimated market shares of printer vendors and knowing which processors were used by these vendors. The majority of products have been based on the Motorola 68XXX, which made up about 90 percent of the market in 1984 and approximately 75 percent in 1989. The average selling price (ASP) for each segment reflects a blending of products and ASPs.

The weighted average ASP for all processors declines through the forecast period. However, low-end segment ASPs actually increased in the 1986 to 1990 time frame because of changes in product mix and the increasing availability of the higher-priced imaging-specific products. In the 1989 to 1995 period, low-end ASPs are forecast to decline again to reflect the increase in the number of imaging-specific processor vendors and unit volume efficiencies.

Some Limitations

A problem with the ppm-segmentation method is the difficulty in defining and measuring ppm speeds. The speed for a given processor/printer engine combination depends on the information being printed. Typically, simple text is generated more rapidly than complex bit-mapped images, and different processors are more efficient at some operations than others. The ppm ratings used here are average speeds that are reported by the manufacturer. In reality, processor/print engine combinations often are compared relative to one another for a specific type of output generation.

Another issue that could have an effect on the forecast deals with the introduction of multifunction systems. The basic hardware and functionality of imaging devices such as printers, copiers, facsimile, and scanners are remarkably similar. We already have seen the introduction of the first so-called "hydra" systems, which combine several of these functions into one product, with a single processor to control all functions. This combination of functions could lead to some interesting pricing decisions for systems vendors, but it is less likely to affect processor pricing. It is more likely to affect the unit volumes of laser printers and, subsequently, the unit volumes of laser printer controllers. No attempt has been made to incorporate the advent of multifunction systems into the forecast model.

Critical Success Factors

The two key success factors for processor vendors in this market are the ability to offer a broad product line with a range of price/performance and systems expertise.

Systems vendors need to be able to offer products that range from the low to high end, and they need to be able to leverage their design resources by working within a single architecture. For processor vendors, this necessity translates into a product line that is based on a single architecture with proven design tools and that has a range of performance and price points. Processor vendors must also be able to demonstrate their capability and commitment to a product growth path.

Returning to the concept of enabling technologies, systems vendors also will require processor vendors to demonstrate system design and support expertise. Successful processor vendors will be able to facilitate the entry of new systems vendors by supplying whole solutions. In essence, systems vendors will be looking for development partners, not just processor suppliers.

Dataquest Conclusions

Dataquest believes that the laser printer market is undergoing rapid expansion and represents a high-volume and high-visibility embedded application. The trend in laser printer control is moving away from general-purpose microprocessor implementations toward imaging-specific products. Microcomponent suppliers have an opportunity to offer enabling technologies that can have a significant impact on the development of the laser printer market. Successful suppliers will have a broad product line based on a single architecture and demonstrated systems expertise.

Ken Pearlman

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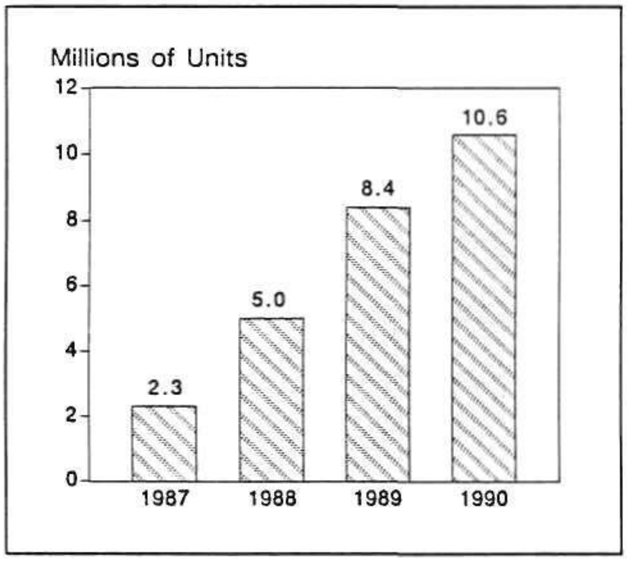
Research Newsletter

PRELIMINARY GRAPHICS CHIP SET FORECAST SHOWS REVENUE DECLINE

SUMMARY

Dataquest is expecting substantial growth in the DOS PC market as a result of high growth in the notebook and hand-held computer segments. This equates to an improved market for PC graphics chip sets. Based on survey results, Dataquest estimates the size of the merchant chip set market to be 8.4 million units in 1989, increasing to 10.6 million units in 1990 (see Figure 1). This market had 12 vendors in 1989, and the number is growing; therefore, Dataquest anticipates intense competition, coupled with declining prices and profit margins. VGA will become the dominant graphics standard in the low-end market as HGA, CGA, and EGA become obsolete.

FIGURE 1
Total Low-End Merchant PC Graphics Chip Sets Estimated Worldwide History and Forecast (Units)



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Source: Dataquest May 1990

THE FORECAST

Volume Up, Revenue Down

Based on preliminary forecasts from Dataquest's Personal Computer Group, we derived the total low-end graphics chip set solution forecast through 1990 (see Table 1). The merchant chip set market is expected to continue its growth to 10.6 million units in 1990, up 25.8 percent over 1989. Average selling prices (ASPs) took a dramatic drop as a direct result of competition and fell 18.4 percent to $19.50 in 1989. Merchant chip set revenue increased 36.1 percent to $163.8 million but is expected to decline slightly in 1990 as rising unit shipments are unable to offset falling ASPs.

VGA Dominates with 65 Percent of the Market

Figure 2 depicts the graphics survey results by graphics standard. As discussed, VGA is the dominant standard in the low-end market. Dataquest believes that over time HGA, CGA, and EGA will become obsolete as VGA prices decline. VGA and SVGA (super VGA) will be the key PC graphics solutions through the mid-1990s.

We expect to see a new graphics standard begin to erode VGA growth in the long term; however, the shift to a new standard will not occur as rapidly as it has in the past. Dataquest believes that the IBM 8514/A will be the eventual successor to VGA in the mainstream PC market.

As the PC market grows, Dataquest predicts that almost every PC produced will have a graphics chip set by the mid-1990s. As the portable notebook and laptop markets take off, we can expect VGA to be a standard item found on these PCs.

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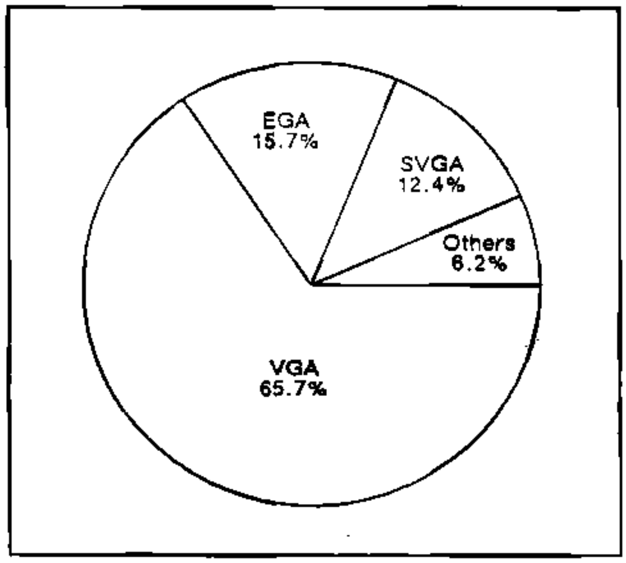
TABLE 1
Merchant Graphics Chip Set Market—Estimated Worldwide History and Forecast (Millions of Units)

	1987	1988	1989	1990
Total DOS PC Shipments	10.6	13.7	16.5	18.8
Growth Rate		29.2%	20.4%	13.9%
Low-End Graphics Chip Sets	5.0	8.7	11.9	14.5
Growth Rate		75.7%	36.6%	21.9%
Saturation[1]	46.7%	63.5%	72.0%	77.0%
Merchant Graphics Chip Sets	2.3	5.0	8.4	10.6
Growth Rate		116.5%	66.7%	25.8%
Saturation[2]	47.0%	57.9%	70.7%	73.0%
Merchant Graphics Chip Set ASP	$26.1	$23.9	$19.5	$15.0
Growth Rate		(8.6%)	(18.4%)	(23.1%)
Merchant Graphics Chip Set Revenue ($M)	$60.8	$120.3	$163.8	$158.5
Growth Rate		98.0%	36.1%	(3.2%)

[1]As a function of DOS PCs
[2]As a function of low-end graphics chip sets

Source: Dataquest
May 1990

FIGURE 2
1989 PC Graphics Survey Results
Shipments by Solution Type



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Source: Dataquest
May 1990

WHO ARE THE PLAYERS?

Table 2 represents the product matrix for the 13 vendors in the PC graphics chip set market. Notice that all 13 vendors offer VGA products. The top three merchant vendors—Western Digital, Tseng Labs, and Cirrus Logic—accounted for 56.8 percent of the merchant revenue in 1989. In comparison, in 1988, the top three vendors—Western Digital, Chips & Technologies, and Cirrus Logic—accounted for approximately 75.0 percent (see Figure 3). Market shares will continue to shift among vendors as more chip set vendors enter the market. Major semiconductor manufacturers will begin to enter the market. As the business shifts from add-in boards to motherboard implementations, an extended product line including mass storage, communication solutions, and system logic will be a key success factor in this market.

Western Digital

Western Digital emerged from the lethargic times following the Faraday acquisition to become a streamlined, highly focused operation. The company is one in a handful that offers an extended product line including core logic, storage, data communications, and video chip sets. With this broad product offering, Western Digital is able to service multiple segments as well as offer a full-system solution.

Tseng Labs

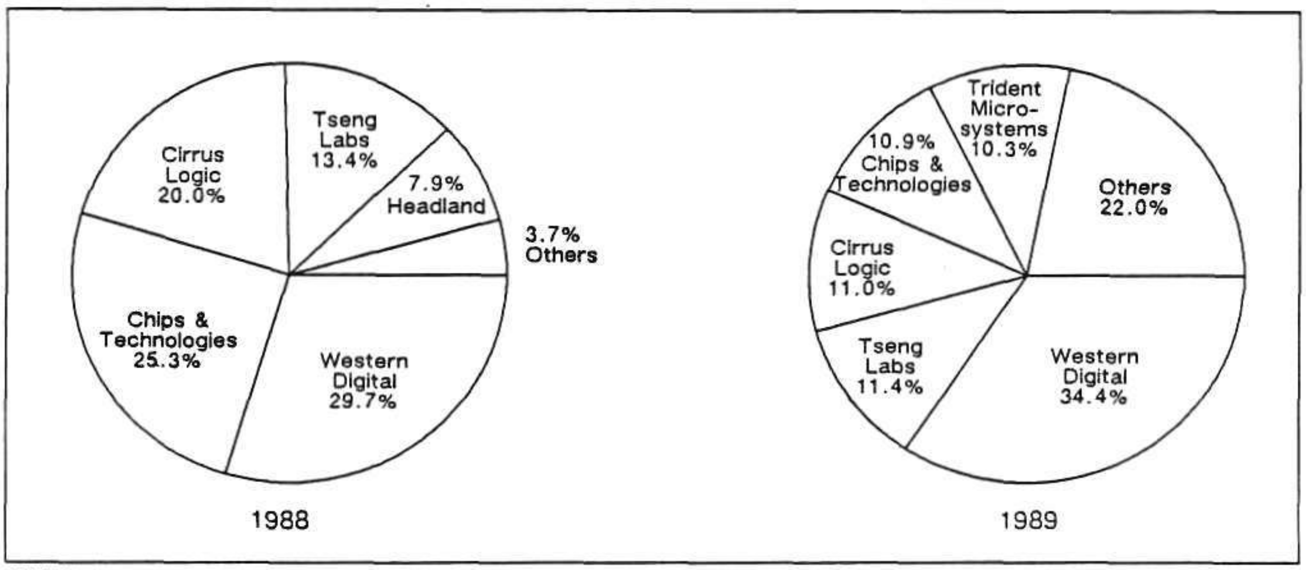
Founded seven years ago, Tseng Labs has emerged as the number two player in the PC

TABLE 2
Vendor Product Matrix

Vendor	SVGA	VGA	EGA	CGA	8514/A	TIGA
Chips & Technologies	X	X	X	X	X	
Cirrus Logic		X				
Genoa		X				
Headland		X	X			
Intel		X				
NSI Logic	X	X	X			
Oak Technology	X					
Renaissance GRX	X	X				X
Texas Instruments						X
Trident Microsystems		X				
Tseng Labs		X	X			
Western Digital		X	X	X	X	
ZyMOS	X					

Source: Dataquest
May 1990

FIGURE 3
1988 and Preliminary 1989 Low-End PC Graphics Merchant Chip Set Revenue Market Share by Manufacturer



0006859-3

Source: Dataquest
May 1990

graphics chip set market. Employing 36 people and based in Newtown, Pennsylvania, the company uses outside foundries to make its chips. As a small company, Tseng is better equipped to take advantage of technological changes. Following standards announced by IBM, Tseng offers both EGA and VGA solutions, selling the boards to large computer makers and the chips to graphics board makers.

Cirrus Logic

Founded in 1984, Cirrus Logic offers a growing product portfolio including mass storage, display graphics, data communications, and print graphics solutions. The company was the first to offer a product that brought VGA quality to liquid crystal display (LCD) panels. Capitalizing on its display graphics capabilities, Cirrus is targeting the portable PC market.

ZyMOS/Renaissance

ZyMOS recently acquired Renaissance GRX, a manufacturer of TIGA graphics boards. In acquiring Renaissance, ZyMOS will enter the high-end graphics chip set market by offering devices that support Texas Instruments' (TI's) TIGA standard. ZyMOS apparently believes that it can carve out a niche for itself in this high-end market by supporting TIGA. Dataquest believes that this is probably a sound strategy for a small chip set company. In choosing TIGA, ZyMOS will not have to compete with the likes of Chips & Technologies, Headland, and Western Digital, all of which have committed to adopt the IBM 8514/A graphics standard. In the long run, if TIGA is to move down the product curve and penetrate the mainstream PC market, the TIGA solution will likely have to be implemented on the motherboard, suggesting a one- or two-chip solution.

DATAQUEST CONCLUSIONS

Dataquest believes that VGA will be the dominant PC graphics standard through the mid-1990s as the market moves along the product life cycle to maturity. In the high-end graphics chip set market, the 8514/A standard will begin its path along the product life cycle. Dataquest believes that extended product lines and complete solutions will be factors to success for companies wishing to compete in the volatile PC graphics chip set market. We can expect to see those vendors that have had success focusing on graphics begin to enter the systems logic market if they have not already done so, and vice versa.

Lori Kulwin

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Research Newsletter

OUTLOOK FOR PC LOGIC CHIP SETS AND PRELIMINARY FORECAST

SUMMARY

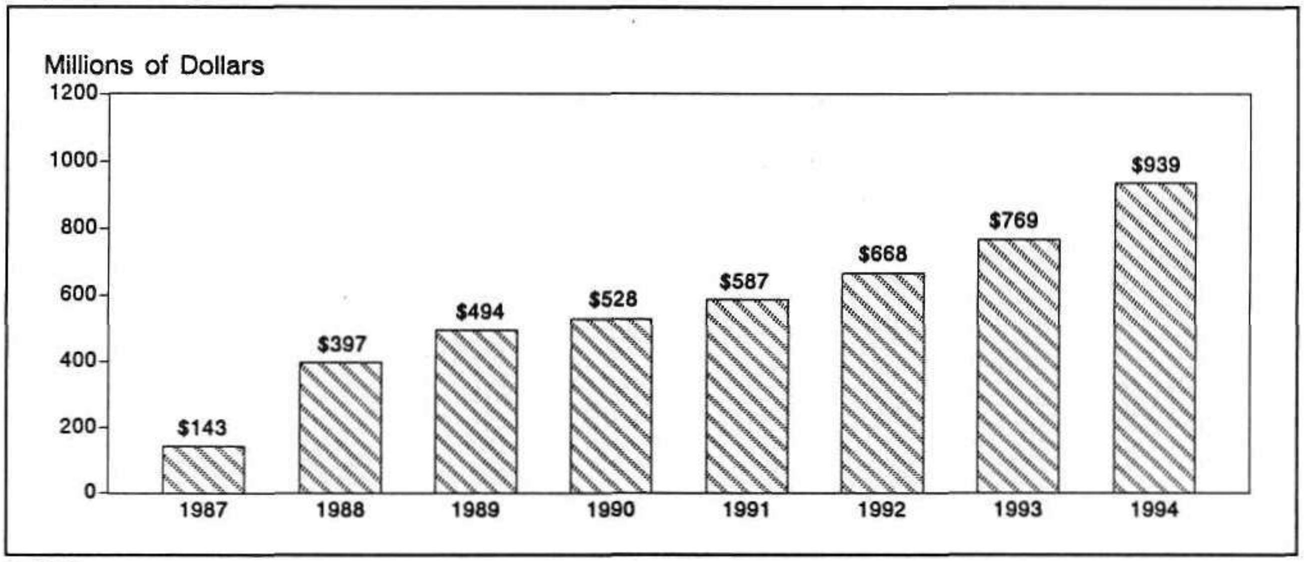
The PC logic chip set market continues its upward trend, based on the continued growth of the DOS PC market and displacement of discrete solutions by chip sets. Although merchant PC logic chip set revenue will grow through 1994, as illustrated by Figure 1, the 1990s will prove to be challenging for chip set vendors as overcapacity, price cutting, and reduced profit margins characterize the market. As the trend toward full integration on the motherboard evolves, product extension will be key. As competition intensifies, we will begin to see consolidation. Some vendors will form alliances or merge; others, not so fortunate, will drop out of the market altogether. We can also expect to see more of the major semiconductor manufacturers utilize their resources efficiently in the chip set market.

THE PC LOGIC CHIP SET MARKET

Aggressive Pricing Continues

Aggressive pricing and intense competition dominate the PC logic chip set market. In the early days of the chip set market, new product announcements were few and far between; as we embark on the 1990s, however, chip set announcements are a dime a dozen. From 6 vendors in 1987 to more than 30 vendors in 1990, the market has increased

FIGURE 1
Estimated Worldwide Merchant PC Chip Set Market Forecast



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Source: Dataquest
May 1990

SIS Newsletters 1990 Microcomponents

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to the point where the PC logic chip set is now a commodity product, winning sales based largely on price and service. Gone are the days of the boutique chip set vendor. A broad product line is necessary for survival.

Broad-Line Semiconductor Suppliers Enter the Market

Major semiconductor manufacturers such as Motorola and Texas Instruments are taking the plunge. Although National Semiconductor does not have a logic chip set product at this time, we expect National to enter the market. Major semiconductor manufacturers will not want to miss out on chip set opportunities as discrete components are displaced by chip sets. As high volumes dominate the PC DOS market, chip set volumes will increase. Major semiconductor manufacturers are better equipped to take advantage of the cost efficiencies that result from production in large volumes.

1990 and Beyond

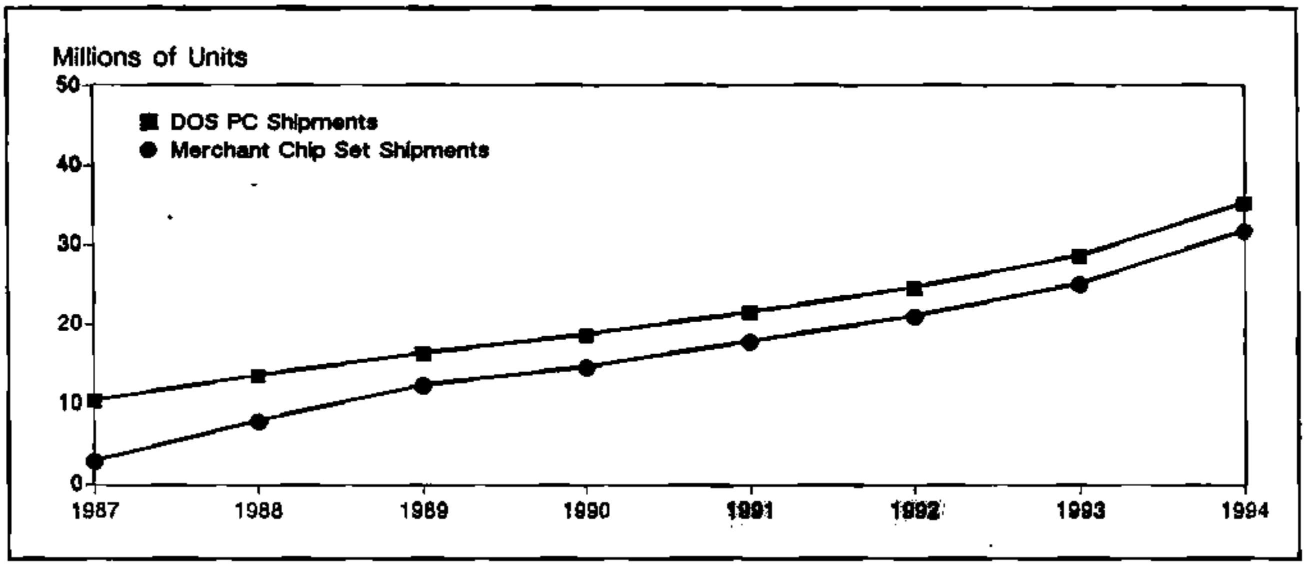
The PC logic chip set business fared well in 1989, with revenue climbing by 24 percent over 1988 to $494 million. Dataquest estimates that PC logic chip set revenue will grow at a compound annual growth rate (CAGR) of 13.7 percent through 1994.

Based on the DOS PC consumption forecast, Figure 2 presents Dataquest's forecast for merchant PC logic chip set shipments. Merchant chip set shipments follow the DOS PC shipment forecast closely; however, Dataquest expects a portion of the total available chip set market to remain captive. In Figure 2, the gap between DOS PC shipments and merchant chip set shipments consists of the captive and non-chip set portions of the solutions. Dataquest believes that this trend will continue over time as a basis for remaining competitive. In the PC market, using captive chip sets or discrete solutions in a PC design can help both in differentiating the system product and in securing a nonclonable product.

FORECAST METHODOLOGY AND ASSUMPTIONS

The PC chip set forecast is derived from Dataquest's preliminary Personal Computer Industry Service PC forecast and from a survey of worldwide chip set vendors. Each year, Dataquest forecasts worldwide shipments of personal computers. Table 1 presents our preliminary worldwide

FIGURE 2
Estimated Worldwide Merchant PC Logic Chip Set Forecast Compared with DOS PC Forecast



0006838-2

Source: Dataquest
May 1990

TABLE 1
Preliminary Estimated Worldwide PC Logic Chip Set Market Forecast (Millions of Units)

	1987	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
DOS PC Shipments	10.6	13.7	16.5	18.8	21.6	24.7	28.7	35.4	16.49%
Growth Rate		29%	20%	14%	15%	14%	16%	23%	
Total Chip Set Solutions	3.5	8.9	14.4	16.9	19.9	23.2	27.6	34.5	19.18%
Saturation*	33%	65%	87%	90%	92%	94%	96%	98%	
Non-Chip Set Solutions	7.10	4.80	2.14	1.88	1.73	1.48	1.15	0.88	(16.23%)
Percent of DOS PCs	67%	35%	13%	10%	8%	6%	4%	2%	
Merchant Chip Set Shipments	3.1	8.0	12.5	14.7	17.9	21.1	25.2	31.9	20.63%
Growth Rate		158%	56%	18%	21%	18%	19%	27%	
Percent of Total Chip Set Solutions	89%	90%	87%	87%	90%	91%	92%	93%	
Captive Chip Sets	0.40	0.90	1.86	2.20	1.99	2.09	2.34	2.59	6.89%
Percent of Total Chip Set Solutions	11%	10%	13%	13%	10%	9%	8%	7%	
Chip Set ASP	$46.13	$49.66	$39.53	$35.90	$32.80	$31.60	$30.50	$29.40	(5.75%)
Growth Rate		7.7%	(20.4%)	(9.2%)	(8.6%)	(3.7%)	(3.5%)	(3.6%)	
Chip Set Revenue ($M)	$143	$397	$494	$528	$587	$668	$769	$939	13.69%
Chip Set Revenue Growth		177.8%	24.4%	6.9%	11.0%	13.8%	15.2%	22.1%	

*As a function of DOS PCs

Source: Dataquest May 1990

shipment forecast for DOS PCs. The preliminary chip set forecast for 1990 through 1994 is derived as a function of saturation of the DOS market. The estimates for 1987, 1988, and 1989 are based on the chip set vendor survey and on Dataquest analysis.

DATAQUEST ANALYSIS

A Growing Market

Dataquest expects the PC DOS market to grow at a CAGR of 16.5 percent through 1994. Displacement of discrete implementations to logic chips will continue. Additionally, 100.0 percent saturation will not be reached during this time period because captive and discrete implementations are still present in the marketplace. Finally, as competition increases, average selling prices (ASPs) will decline.

We believe that the high growth through the 1990s will result from evolution of the markets for portable notebooks, laptops, and pocket PCs. The portable market is just beginning; this market will be in full swing by 1994, which will account for the continued growth through 1994. As the DOS PC market grows and matures, the merchant chip set market will flourish also, at a CAGR of 20.6 percent through 1994.

Declining ASPs

ASPs will continue to fall throughout the forecast period. The ASP for 1989 dropped 20 percent to $39.53 as a result of fierce competition, especially in the 80286 segment. Dataquest believes that the ASP will continue its decline and level off at approximately $30.00 by 1994. Because AT-based PCs will continue to dominate the midrange PC market, AT chip set pricing will have a dominant effect on the aggregate ASP. Sales of XT-based machines will revive as a result of the popularity of the portable PC market early in the period. At the high end, MCA and EISA have yet to make an impact on the marketplace.

The Dominant Microprocessors

As the portable PC market grows, Dataquest believes that the 80286 will be the dominant microprocessor for this market, squeezing out the 8088/86. The 80386SX will be the dominant midrange microprocessor, with growing opportunities in the notebook PC market. EISA- and

MCA-based PCs primarily will use 80486s and high-end 30386DXs.

The Next Logical Step

As the PC logic chip set market matures, chip set vendors must address the next logical step in their product portfolio: mass storage controllers and communication chip sets (e.g., LAN, modem, and fax). As individual markets, the mass storage and communication chip set markets probably are doomed to the same fate as the PC logic chip set market—intense competition and price cutting. However, companies hoping to compete in the chip set market cannot ignore these areas. Full integration will be the key in the 1990s. The broader your product line, the better your chances are for success.

Lori Kulwin

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Research *Newsletter*

THE HITACHI/MOTOROLA DECISION: AN OBJECT LESSON IN "IMPROVIDENT" LITIGATION

PANIC IN SILICON VALLEY

The decision by Federal Judge Lucius Bunton in the patent dispute between Hitachi Ltd. and Motorola, Inc., touched off a maelstrom of apocalyptic musings in press circles and sent Motorola customers scurrying to count their inventory of 68030 microprocessors. If ICs are the "crude oil" of the electronics industry, Judge Bunton's injunction against Motorola's U.S. shipments of its flagship microprocessor is the industry equivalent of an oil embargo to certain systems companies.

Ironically, the implications of the March 29 decision, reached in a U.S. District Court in Austin, Texas (the site of Motorola's Microprocessor Products Group), may be more profound, although less immediately dramatic, than initial media reaction might imply. Of greatest immediate importance to Motorola and its clients is that as of March 30 the company was granted a stay of the injunction against the M68030, which permits Motorola to conduct business as usual pending an appeal—or an out-of-court settlement.

THE DECISION

Judge Bunton basically decided in Motorola's favor, saying that Hitachi's H8 microcontroller was not licensed under the parties' 1986 Patent License Agreement; consequently, Hitachi committed patent infringement on three of Motorola's patents. Hitachi therefore was ordered to cease selling the H8 for the life of the affected patents and to compensate Motorola in the amount of $1.9 million. The judge also ruled that Motorola infringed on an Hitachi patent and therefore was barred from marketing or selling its 68030 microprocessor for the duration of that patent; Motorola thus was required to pay Hitachi $500,000 in damages.

A CHRONOLOGY

As the following chronology reveals, the Hitachi/Motorola case opened a legal Pandora's box that has had severe and unanticipated consequences for Motorola. It may be instructive at this point to briefly review the following events, which led to the March 29 decision:

- In January 1989, Motorola filed a lawsuit against Hitachi charging patent infringement and unfair competition that Motorola claimed began after it had granted Hitachi a patent license for certain devices in 1986. Motorola's position was that Hitachi's new H8 microcontroller series infringed on at least four Motorola patents.
- Approximately one week after Motorola's charges, Hitachi responded by filing a patent infringement suit against Motorola. Hitachi alleged infringement of one of its patents by Motorola's 68HC11 8-bit microcontroller and countered that not only did its H8 *not* infringe on any Motorola patent but that the device was covered by a patent license. Hitachi described itself as "greatly surprised" by Motorola's action in filing the lawsuit.
- In April, Motorola switched its legal venue and withdrew its lawsuit from the Federal District Court in Chicago, Illinois, to refile the charges in Austin, Texas.
- In June, Hitachi filed an amendment to its pending lawsuit against Motorola to include allegations of patent infringement by Motorola's 68030 microprocessor. In what has since proved to be a poetic use of foreshadowing, a spokesperson from Hitachi described Motorola's original lawsuit as "improvident" in that it caused Hitachi to "reexamine its patent portfolio."

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- In August, Hitachi submitted its claims to the U.S. Patent Office for resolution, hoping for a speedier outcome on the infringement issues. In the meantime, the courtroom trial was scheduled for October 23, 1989.

An Embarrassing Setback for Motorola

At the outset of the litigation, the legal battle was over two 8-bit microcontroller products. As events unfolded, both Motorola's 68030 and 88000 microprocessors were dragged into the legal fray because of their incorporation of a content addressable memory (CAM) used as an on-chip cache, which Hitachi claimed to be in violation of its patent rights.

To the undoubted shock and embarrassment of Motorola's legal department, Judge Bunton's decision has proved painfully "asymmetrical" in its impact on the Hitachi and Motorola devices in question. Although the decision may seem quite severe, Dataquest believes that the ruling was deliberately intended to force the two parties to settle their differences out of court. Quoting from the judgment, Judge Bunton notes that "What is more perplexing to this Court is these two parties have dealt personally with each other for years...Yet suddenly they left behind their prior relationship and expected this Court to ferret out the wrongdoings of which each is accused."

Good Reasons for a Quick Settlement

Clearly, the irate judge sent a powerful signal to Hitachi and Motorola that they had chosen the wrong method to resolve their problems. The fact that the judge readily granted Motorola's request for a stay of injunction may indicate that he is not blind to the consequences of his initial decision on Motorola's customers. At this point, both parties have 30 days either to appeal...or to take Judge Bunton's suggestion of a negotiated peace.

Both Hitachi and Motorola have good reasons for seeking a resolution to their litigation. In Motorola's case, the threat of injunction hangs over a product that Dataquest believes garnered revenue in the $120 million to $150 million range in 1989. Of greater long-term significance, stopping the flow of 68030s represents a serious hardship that would be inflicted on Motorola's customers. Companies such as Apple Computer, Hewlett-Packard, and NCR Corporation are dependent on the 68030 as the sole-source heart of significant portions of their systems sales. Clearly, Motorola's motivation to resolve this dilemma is paramount.

Hitachi also is motivated to resolve this problem. Although the U.S. sales of its H8 product may not be as monetarily significant as the 68030, sales of the device in Japan would be jeopardized if the final destination of domestic equipment was the United States. As has been demonstrated by Intel and Texas Instruments, invoking the powers of the International Trade Commission (ITC) in defense of one's intellectual property can empower customs to seize imports of equipment that contain an offending product. Consequently, many of Hitachi's customers also hope for a hasty resolution of the issue.

Broader Implications for Japan

In the initial hoopla over the 68030 injunction order, what seems to be overlooked is that Motorola scored a significant win in terms of the court's decision that Hitachi was in breach of a basic Patent License Agreement covering a broad range of microprocessor devices (including microcontrollers and microperipherals). Given the fundamental nature of the patents involved, upholding Motorola's patent position could have profound implications for all Japanese microdevices shipped to the U.S. market.

Lingering Questions

Given the stakes involved for both Hitachi and Motorola, Dataquest anticipates a fairly speedy settlement and an end to the jitters currently felt by 68030 customers. The settlement may cost Motorola the millions of dollars that it might have hoped to gain from Hitachi when Motorola first pressed its lawsuit more than one year ago. The nature of such a settlement raises some interesting questions, such as the following:

- Would a cross-license deal, as part of a settlement, imply access to selected technologies or the outright second-sourcing of the 68030?
- If the 68030 were to be second-sourced to Hitachi, how would this affect Motorola's agreement with Toshiba, with which it has a DRAM/microprocessor joint venture?
- How will a settlement of the current Hitachi/Motorola litigation affect the renegotiation of their 1986 microprocessor license agreements, which will take place in 1991?

This last conjecture may shed some light on Motorola's underlying intent in filing its lawsuit in the first place. Aside from the potential royalty income, Motorola may have hoped to strengthen its bargaining position in the 1991 renegotiation of its patent licenses with Hitachi through a successful legal battle over the H8.

A MORAL VICTORY FOR HITACHI

Although it must now contend with an unfavorable ruling concerning its violation of patent license agreements, Hitachi has won a moral victory of sorts through its litigation with Motorola. In our brief review of the complaints filed by Motorola against Hitachi, we noted a level of invective that may well have stung and surprised Hitachi, coming as it did from a "supposed" business partner. By digging into its own bag of patent tricks and pulling out a rabbit that could force an injunction against Motorola's 68030, Hitachi must certainly have shocked Motorola into realizing that it is dealing with an equal.

DATAQUEST CONCLUSIONS

Beyond a settlement based on cash and technology licensing, it is doubtful that Hitachi will want to inflict any greater damage on Motorola. Judge Bunton's actions seem to have given Hitachi a strong negotiating position, but it is not likely that Hitachi will want to exploit this position to the extent that it injures the business interests of U.S. systems companies. Nervous 68030 users should keep in mind that many of Motorola's customers are Hitachi's customers as well.

Currently, the lesson that emerges from Judge Bunton's decision is that U.S. semiconductor companies must approach patent license issues with their Japanese competitors differently in the '90s than they may have in the '70s or '80s. If the legal departments of U.S. chipmakers are working from an outdated model of "copycat" Japan, they will likely walk into an ambush in court when faced with Japanese companies that have become formidable competitors in the field of intellectual property. Dataquest believes that in the new decade of U.S./Japan relations, the use of litigation as a "preemptive first strike" against a competitor's market thrust is more likely to lead to the equivalent of "mutually assured destruction." From this point of view, Hitachi and Motorola now must move to a speedy settlement of their legal differences and give their customers some peace.

Michael Boss
Patricia Galligan

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Research *Bulletin*

CHIPS AND TECHNOLOGIES PRODUCT EXPANDS BEYOND PC BOUNDARY

SUMMARY

Chips and Technologies, Inc., recently introduced a new chip set product—the Multi-Processor Architecture Extension (MPAX). MPAX is a modular system architecture (MSA) standard that is designed to allow system OEMs to easily implement multiple-processor computer products based on PC platforms. The introduction of a new standard is a departure from the typical Chips strategy of bringing to market products based on established standards. For the MPAX to be successful, system OEMs must be convinced of its viability as an MSA standard that will gain broad acceptance. If successful, Chips is likely to see a change in its customer base that will reflect the different distribution channels and greater technical support required for these products as compared with single-user PC or workstation products.

THE CHANGING CUSTOMER BASE

Chips is well known for its role in pioneering the PC chip set market, offering VLSI implementations of PC system logic that have enabled systems manufacturers to reduce costs, speed design time, and decrease time to market. It has been argued also that chip sets have accelerated the rate at which leading-edge technologies and products are brought within reach of the mainstream end user.

The MPAX product continues the Chips tradition of facilitating systems design and introduction, but the systems we are now talking about are not single-user PC products. Multiprocessor systems, which are typically multiuser, multitasking environments, are the domain of the mainframe and superminicomputer vendors, and selling into this segment requires more sophistication and support than might be expected from some of Chips' current PC chip set customers. Because of this, Chips is likely to see a whole new type of customer—mainframe and superminicomputer vendors.

OPPORTUNITIES AND POSSIBLE ALLIANCES

For PC vendors, a product like the MPAX offers the opportunity to build minicomputer products using familiar PC architectures, enabling them to expand into higher-performance markets. To accomplish this expansion, PC vendors will require increased technical support from Chips, and they will need to restructure their support and distribution channels.

Viewed from the mainframe and superminicomputer vendor position, this is an opportunity to expand into the departmental computing market. These vendors have the incentive to produce such a product and the distribution channels and support capabilities to bring it to market.

It is probable that MPAX and similar products that are likely to be introduced will spawn alliances between some of the PC vendors and mainframe or minicomputer vendors. PC vendors offer PC platform manufacturing expertise and capacity, and mainframe and minicomputer vendors offer access to distribution channels and technical support.

STANDARDS

The MPAX represents a proposal by Chips for a new computing standard, a modular system architecture. Thus, MPAX represents a departure from the typical Chips strategy of offering only products based on established standards. From the proliferation of computing standards proposed by system vendors, it would be difficult to guess that

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in survey work and focus groups the system end users have been pleading for fewer standards and more compatibility. If one looks at just the IBM PC-compatible arena alone, end users (translates to "paying customers") have to decide between bus architectures (XT, AT, MCA, EISA); microprocessors (8086, 80286, 80386SX, 80386DX, 80486); speed grades (4, 8, 10, 12, 16, 20, 25, 33, 40 MHz); and graphics platforms (EGA, VGA, 8514/A, TIGA).

The fact is that end users don't care what is on the inside of the computer. They don't care whose standard it is or what it is called. They only care about whether or not the box will adequately perform the intended function and application, if it is compatible with their current investment in hardware and software, if it will be upgradable and compatible with their future investments in hardware and software, and if there is a sufficient support organization to back them up now and in the future.

Because MPAX would allow multiprocessor systems to be built based on a PC platform, an MPAX system would be 100 percent DOS-PC compatible but could also run UNIX and have a combination of RISC and CISC processors. The benefit of the MPAX is that it allows complete backward compatibility (in terms of hardware, software, and connectivity) to the PC environment while implementing UNIX without any loss in performance. The ability to build multiprocessor systems that are compatible with and can be connected to existing PCs could be a key competitive advantage. Current multiprocessor systems typically do not allow mixed processors and run DOS through emulation. The loss of performance associated with the DOS emulation may not be acceptable to users.

DATAQUEST CONCLUSIONS

It is difficult to achieve technical progress without occasionally having to generate new standards. But standardization issues are the prime concern of customers, and customers confused by these issues will put off making buying decisions or may not buy at all. This is the environment in which Chips must work, and the job is to convince both the system OEM and the end user that the MPAX is an acceptable solution.

Ken Pearlman

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Research Newsletter

START-UPS THREATEN INTEL DOMINANCE: FIRST VOLLEYS IN THE COPROCESSOR WAR

SUMMARY

Dataquest believes that the PC math coprocessor market is ripe for competition and that the number of suppliers to this market is likely to double or triple in the next two years. This will drive prices down at a rate much faster than in the past. Along with trends in hardware and software, this increased competition and resulting price drop will have the effect of increasing the penetration of coprocessors into available sockets.

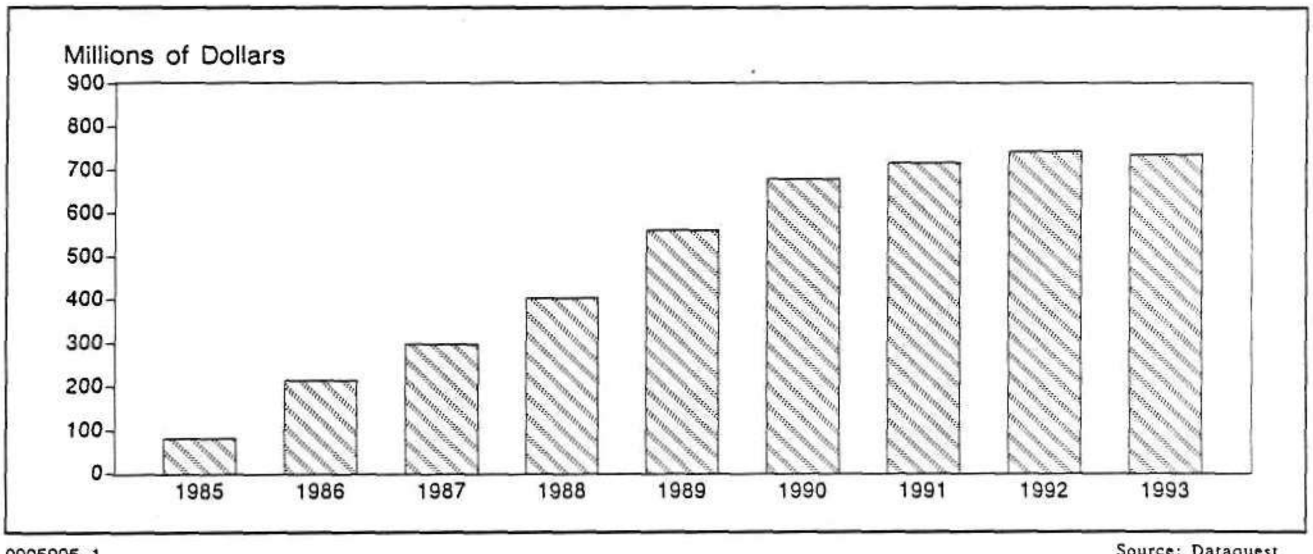
For suppliers choosing to enter this market, the challenge will be not only to sell products and gain market share, but to make a profit. In the last two years we have witnessed a large number of vendors entering the PC logic and graphics chip set markets, resulting in intense competition, rapidly falling prices and margins, and shrinking profits. The potential for a repeat of this scenario in the coprocessor market is very real.

The Dataquest revenue forecast for the PC and workstation math coprocessor market is shown in Figure 1.

PC MATH COPROCESSOR MARKET HEATING UP

Evidence of the first skirmishes in the floating-point coprocessor war already has appeared in the industry press. Intel, the company that has owned the DOS PC math coprocessor

FIGURE 1
PC and Workstation Math Coprocessor Revenue Worldwide History and Forecast



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market, has publicly announced the errors and incompatibility problems it has found in evaluating competitor Integrated Information Technology's (IIT's) 80287 plug-compatible device, the IIT 2C87. Intel claims that this device does not meet the ANSI/IEEE standard specifications for floating-point arithmetic. IIT claims that Intel tested a preproduction part and that the problems discovered have been fixed in the production version.

It is not unusual for chip manufacturers to offer information about potential problems with competitor parts during sales calls, but these issues are not usually made public. Intel's public criticism of IIT is an indication of the serious impact this product and others may have on Intel's near monopoly of the PC floating-point coprocessor market.

The PC math coprocessor market historically has been favored by high prices and margins, maintaining the perception that these products will sell into the high-end PC and workstation segments only. This fact has kept unit volumes low, and consequently, the penetration of these products into the total available sockets has been quite low. The result is a glaring invitation to talented chip designers and chip set vendors facing tough competition and saturated markets for PC-related chips and chip sets. Assuming that entry barriers are surmountable, the PC coprocessor market is ripe for competition. This means lower prices for coprocessors and higher penetration into PCs.

THE STAKES ARE HIGH

Dataquest divides the PC math coprocessor market into 80X87 (Intel) compatible and 68XXX (Motorola) compatible. Until recently, there were no 100 percent pin-compatible Intel 80X87 clones available, and Intel owned the DOS PC math coprocessor market. Motorola owned the 68XXX-based PC math coprocessor market except for a few specialty ASIC parts that are implemented as add-in boards. The workstation market, which is considered separately, comprises Motorola math coprocessors and other specialty high-end products.

The Dataquest revenue forecast for PC and workstation coprocessors is shown in Table 1. Intel's 80X87 products are believed to make up approximately 60 percent of the market in terms of revenue and about 55 percent in terms of units. Motorola's 68XXX products have approximately 25 percent of the revenue with about 30 percent of the units. These estimates are based on survey work that has been correlated with the Dataquest PC and workstation forecasts. The bottom line is that according to Dataquest estimates, math coprocessors make up approximately 10 percent of Intel's revenue.

FORECAST METHODOLOGY AND ASSUMPTIONS

The Dataquest PC math coprocessor forecast is derived from the Dataquest worldwide PC and technical workstation forecasts. The forecast for each type is derived from the Dataquest PC by microprocessor forecast. Historical data come from Dataquest survey work. The forecast unit shipment numbers are derived from assumptions of sales into the installed base, sales into new systems, and total saturation by coprocessor type. For the technical workstation segment, it is assumed that penetration is 100 percent.

The basic underlying assumptions of the Dataquest forecast are that the number of vendors in this market is going to increase, that this increase will drive prices down more rapidly than in the past, and that penetration into PCs will be higher than in the past. These assumptions are based on the following reasons and analysis.

Barriers to Entry

There do not appear to be any insurmountable technical or legal barriers to entry into this market. As long as new products are not direct copies, there is not likely to be any legal recourse for Intel. The argument for technical barriers is de facto. These products exist now, and there is every reason to believe that the talent and resources necessary to design and produce them are available to other potential entrants. This is not to trivialize the technical aspects of these products, but again, these aspects are surmountable.

Competition

There are currently four vendors in the Intel-compatible market: Cyrix (produces a pin-compatible 80387 clone), IIT (produces pin-compatible 80287 and 80387 clones), Intel itself, and Weitek (no pin-compatible products). Because of the saturation and strong competition in the PC logic and graphics chip set market and a softening of the domestic PC market, Dataquest believes that there is great incentive for some of the chip set

TABLE 1
PC and Workstation Math Coprocessor Market
Worldwide Forecast

	History			
	1985	1986	1987	1988
Unit Shipments (Thousands)	353	973.0	1,385.0	2,141.0
Growth Rate (%)		175.6	42.3	54.6
Weighted ASP	$232.29	$220.91	$215.73	$188.94
Growth Rate (%)		(4.9)	(2.3)	(12.4)
Revenue ($M)	$ 82	$ 215	$ 299	$ 405
Growth Rate (%)		162.1	39.0	35.4
Penetration (%)	10.3	15.3	15.3	15.9

	Forecast					CAGR	CAGR
	1989	1990	1991	1992	1993	1985-1993	1989-1993
Unit Shipments (Thousands)	2,830.0	4,156.6	5,929.9	7,922.8	9,541.2	51.0%	35.5%
Growth Rate (%)	32.2	46.9	42.7	33.6	20.4		
Weighted ASP	$198.51	$163.61	$121.17	$ 93.88	$77.29	(12.9%)	(21.0%)
Growth Rate (%)	5.1	(17.6)	(25.9)	(22.5)	(17.7)		
Revenue ($M)	$ 562	$ 680	$ 719	$ 744	$ 738	31.6%	7.0%
Growth Rate (%)	38.9	21.1	5.7	3.5	(0.9%)		
Penetration (%)	17.8	20.6	24.4	29.0	33.6		

Source: Dataquest
January 1990

manufacturers, as well as for other semiconductor houses, to consider entering this market. Companies with the incentive and the resources to produce a coprocessor product for the PC market include Acer, AMD, Chips and Technologies, Headland Technology, National Semiconductor, Texas Instruments, Trident, VLSI Technology, and Western Digital. These 9 companies, together with the 4 mentioned previously, make a total of 13 potential suppliers to this market.

In addition to having the incentive to enter this market, the chip set companies are especially well equipped to service it. These companies have capitalized on the trends of very large scale integration of logic and peripheral functions and the trend toward motherboard implementation of these functions. They have experience selling to motherboard and systems manufacturers and are in position to establish a trend toward increasing volumes by lowering prices and offering OEM motherboard and system vendors a means of differentiating their products.

Pricing

The model for the coprocessor forecast assumes that there will be between 6 and 12 vendors, with the new vendors entering in the next two years. Under this scenario, prices for each product type are forecast to drop at a compound annual growth rate (CAGR) of approximately negative 25 percent, giving a weighted average of negative 21 percent for the 1989 through 1993 period. This negative growth can be compared with the price declines of 30 to 40 percent that have been seen in the PC logic and graphics chip set markets or with the typical Intel pricing curve for microprocessors, which declines at a 30 to 32 percent CAGR.

Unit Volumes

For each compatible coprocessor type, assumptions are made as to unit sales into the installed base of PCs and unit sales into new PC shipments. These assumptions differ depending on the historical penetration levels of the product, the age of the product (where it is in the product life cycle), and the degree to which the product can be used effectively as an upgrade path. In all cases, the price decline assumptions lead to significantly higher penetration levels than have been seen historically.

Technology Drivers

Perhaps partly because of the potential threat to its coprocessor sales, Intel has brought the floating-point unit (FPU) on-chip with the new 80486 microprocessor. This fact may or may not prevent competitors from selling an 80487-type product, but it could induce software developers to develop programs that use the floating-point capabilities of the 80486. This possibility could accelerate the sales of coprocessors into the installed base of 80286 and 80386 systems as users upgrade to take advantage of new software. Just as memory upgrades have become mandatory for some PC users in order to effectively utilize new software products, coprocessor upgrades will become increasingly more common. As the rate of change in PC performance and technology increases, the role of performance upgrade products becomes more important.

DATAQUEST ANALYSIS

For potential entrants to the compatible coprocessor market, the current low level of penetration of these products into sockets, combined with artificially high prices and margins, is an attractive inducement to entry. Given certain assumptions regarding the hardware and software environments and pricing structures, the opportunity may exist to increase the saturation level of coprocessors in the PC market. This opportunity increases the potential for the market to support multiple suppliers.

The result of the forecast model, presented in Table 2, is that the penetration of math coprocessors into PCs almost doubles, from approximately 18 percent in 1989 to approximately 34 percent in 1993. Although overall unit shipments are expected to grow at a 35.5 percent CAGR for 1989 through 1993, overall revenue should grow at only 7.0 percent for the period. In fact, revenue is forecast to level off in 1992 and turn down slightly in 1993.

So what's the problem? The high growth rates and increased penetration are predicated on pricing assumptions. The average selling price (ASP) should decline at a 21 percent CAGR for the period (see Table 1). The ability of the rising volumes to offset these price declines should reach a crossover point in the 1993 time frame, partly because of the assumption that no new higher-priced product types will come into the market during the forecast period. The introduction of new products would slow the ASP decline and avert the flattening effect on revenue. An example of a new product that might extend the industry's revenue growth cycle would be a standalone 80487-type product.

With the first real competition just coming on-line and with the potential still existing for many technical, marketing, and legal barriers to appear, it is difficult to predict this market's future. The math coprocessor forecast model incorporates assumptions regarding technology, expected number of vendors, pricing curves, demand elasticities, market segmentation, and market saturation levels. These assumptions are based on historical data and trends for these and similar products and markets.

The high prices and margins on PC math coprocessors are an anomaly in the PC-related semiconductor business. This situation is not sustainable, and a number of vendors are both capable and motivated to expand the competition in this market. Unlike the logic and graphics chip set products, which are nearing saturation usage levels in PCs, the coprocessor market is far from saturated. This open field offers a tremendous near-term opportunity for the positioning of new entrants, but the potential exists for intense competition and oversupply if too many vendors elect to capitalize on the opportunity.

Ken Pearlman

TABLE 2
PC and Workstation Math Coprocessors by Type: Worldwide Forecast
(Revenue in Millions of Dollars, Units in Thousands)

	History					Forecast				CAGR	CAGR
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1985-1993	1989-1993
8087 and Compatibles (Units)	240.0	430.0	320.0	315.0	260.0	225.0	200.0	185.0	160.0	(3.7%)	(11.4%)
ASP	$140	$ 130	$ 120	$ 110	$ 95	$ 72	$ 52	$ 41	$ 35	(16.1%)	(22.1%)
Revenue	$33.6	$ 55.9	$ 38.4	$ 34.7	$ 24.7	$ 16.2	$ 10.4	$ 7.6	$ 5.6	(19.2%)	(31.0%)
Penetration (%)	11.6	15.5	13.7	12.8	13.3	14.2	15.5	17.3	20.1		
80287 and Compatibles (Units)	90.0	420.0	600.0	600.0	775.0	985.0	1,230.0	1,410.0	1,450.0	41.5%	17.0%
ASP	$350	$ 300	$ 250	$ 200	$ 180	$ 135	$ 95	$ 70	$ 60	(19.8%)	(24.0%)
Revenue	$31.5	$126.0	$150.0	$120.0	$139.5	$133.0	$116.9	$ 98.7	$ 87.0	13.5%	(11.1%)
Penetration (%)	10.9	19.9	16.6	14.0	14.2	15.5	17.8	20.7	23.7		
80387SX and Compatibles (Units)	0	0	0	5.0	75.0	440.0	1,090.0	1,945.0	2,750.0	105.5%	146.1%
ASP	-	-	-	$ 300	$ 253	$ 195	$ 135	$ 100	$ 80	(20.6%)	(25.0%)
Revenue	0	0	0	$ 1.5	$ 19.0	$ 85.8	$147.2	$194.5	$220.0	63.2%	84.5%
Penetration (%)	0	0	0	5.4	6.0	12.4	18.0	23.3	27.3		
80387 and Compatibles (Units)	0	0	77.0	335.0	715.0	1,145.0	1,510.0	1,900.0	2,100.0	73.5%	30.9%
ASP	-	-	$ 425	$ 375	$ 310	$ 235	$ 165	$ 125	$ 100	(21.4%)	(24.6%)
Revenue	0	0	$ 32.7	$125.6	$221.7	$269.1	$249.2	$237.5	$210.0	36.3%	(1.3%)
Penetration (%)	0	0	26.9	29.4	29.4	32.6	37.1	42.9	48.1		
68XXX and Compatibles (Units)	10.1	50.0	247.0	500.0	702.0	895.0	1,200.0	1,540.0	1,865.0	92.0%	27.7%
ASP	$225	$ 190	$ 160	$ 140	$ 120	$ 95	$ 75	$ 60	$ 50	(17.1%)	(19.7%)
Revenue	$2.3	$ 9.5	$ 39.5	$ 70.0	$ 84.2	$ 85.0	$ 90.0	$ 92.4	$ 93.3	59.1%	2.6%
Penetration (%)	1.5	3.6	9.9	17.4	23.6	28.6	33.6	38.8	43.7		
Technical Workstations (Units)	32.5	62.8	119.2	191.8	303.0	466.6	699.9	942.8	1,216.2	57.3%	41.5%
ASP	$450	$ 375	$ 320	$ 275	$ 240	$ 195	$ 150	$ 120	$ 100	(17.1%)	(19.7%)
Revenue	$14.6	$23.6	$ 38.1	$ 52.7	$ 72.7	$ 91.0	$105.0	$113.1	$121.6	30.3%	13.7%
Penetration (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		

Source: Dataquest
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Research *Bulletin*

U.S. SEMICONDUCTOR BOOK-TO-BILL REPORT AND ANALYSIS—NOVEMBER 1990

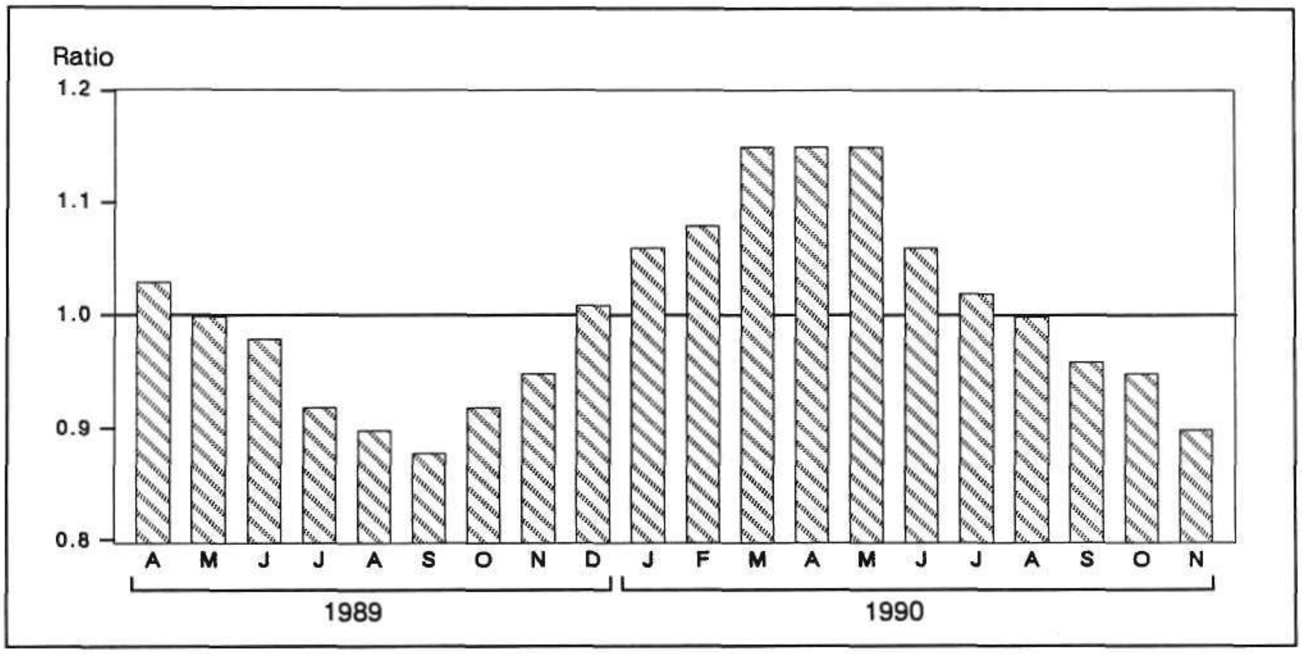
BOOK-TO-BILL RATIO

The levels of orders booked and shipments billed to the U.S. semiconductor market for November fell 6.0 percent and 1.5 percent, respectively, compared with the previous month. As a result, the book-to-bill ratio for November fell from 0.95 in October to 0.90 in November, according to the World Semiconductor Trade Statistics (WSTS) Flash Report (see Figure 1).

On a three-month moving average, orders booked to the U.S. semiconductor market in November decreased 6.0 percent to $1,121.5 million from October's $1,193.6 million (see Figure 2). November orders are 8.1 percent lower than August's $1,220.1 million (the last mid-quarter month). In addition, November 1990 bookings are 5.4 percent lower than November 1989's $1,185.6 million level.

Actual billings to the U.S. semiconductor market in November were $1,206.9 million—a 2.1 percent increase from October. However, November billings are 1.8 percent lower than August's $1,229.2 million and 0.1 percent lower than November 1989's $1,208.2 million.

FIGURE 1
U.S. Market Book-to-Bill Ratio
April 1989 to November 1990



Source: WSTS, Dataquest (December 1990)

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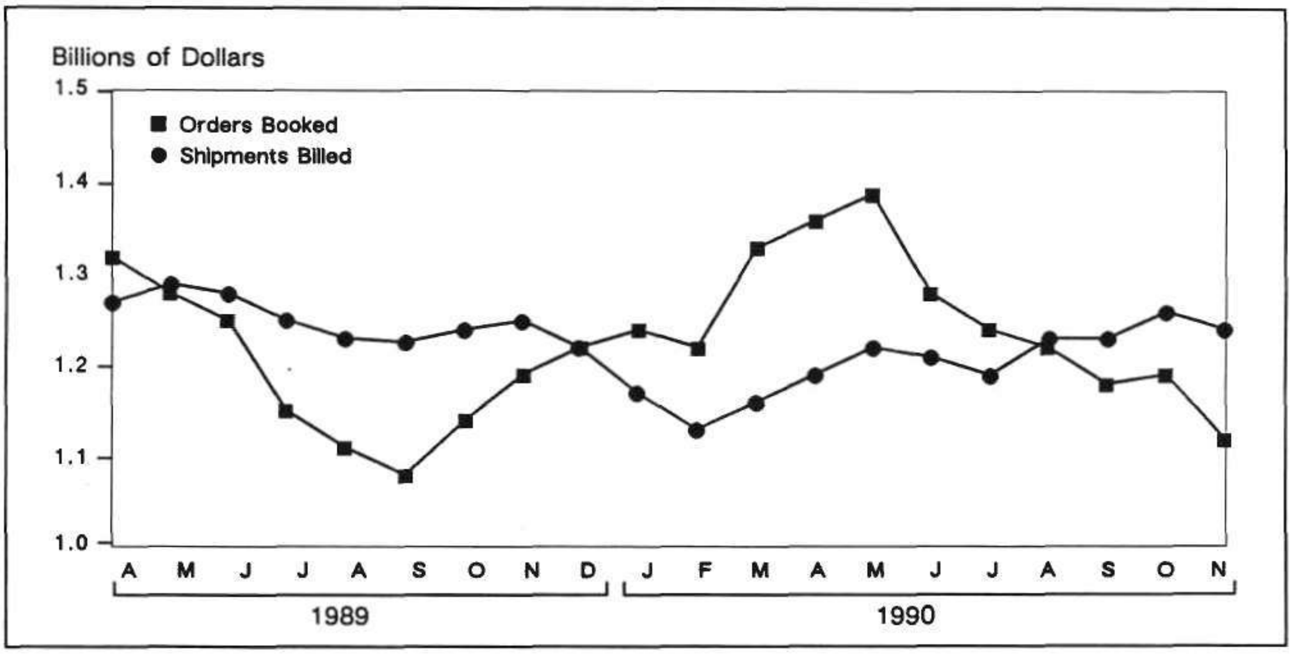
FIGURE 2
Three-Month Average Orders and Shipments
April 1989 to November 1990



Source: WSTS, Dataquest (December 1990)

END-USE OUTLOOK

Looking ahead, the procurement survey conducted this month by Dataquest's Semiconductor User Information Service (SUIS) indicates that target and actual inventory levels for semiconductor devices declined from last month's levels to 28 and 19 days, respectively. The decline in inventories is in line with last month's Dataquest prediction that target and actual inventory levels would fall in November from 35 and 22 days, respectively, in October. Semiconductor buyers maintain a positive growth outlook for system sales. Buyers predict an average 4.1 percent growth over the next six months, up from last month's 3.0 percent indication. This forecast represents the reversal of a declining growth rate trend that began in June. Despite the sharp decline in the level of bookings in November, semiconductor procurement managers expect the semiconductor order rate to increase by 30.0 percent in December.

According to a recent Department of Commerce (DOC) report, on a three-month moving average, both shipments and bookings of computers and office equipment rose in October over September. However, actual billings of computers and office equipment for October fell 29.0 percent from September and rose 29.0 percent over July (the last beginning-quarter month). Actual bookings fell 38.0 percent from September's level, but rose 3.0 percent over July. In addition, the three-month average growth rate for bookings of computers and office equipment rose to 5.0 percent from 4.8 percent in September.

DATAQUEST CONCLUSIONS

Dataquest believes that the softness that has affected the general economy in recent months is beginning to ripple through the semiconductor industry. October shipments and bookings of computers and office equipment are disappointing; even the positive three-month average growth is the result of exceptionally low July shipments and billings. According to the DOC, three-month average shipments and bookings of communications equipment also rose, although actual shipments and bookings each were down more than 14 percent on a month-to-month basis. Despite the multitude of negative indicators, however, semiconductor buyers maintain a positive growth outlook. Should this optimism prove warranted, the lower inventory levels discussed earlier will allow increased systems business to translate more easily into semiconductor growth.

Phil Mosakowski

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Research *Newsletter*

NEW KID ON THE BLOCK: MATSUSHITA ACQUIRES U.S. FAB

INTRODUCTION

On November 21, 1990, Matsushita announced that it had signed a letter of intent with National Semiconductor to purchase National's Puyallup, Washington, fabrication facility. Under the terms of the agreement, which is expected to close in the first quarter of 1991, Matsushita will pay National approximately $86 million in cash for the facility, including the assumption of certain financial liabilities associated with the plant. Matsushita will also acquire certain manufacturing equipment from National. The purchase will not include the transfer of any technologies, products, or processes.

As part of its restructuring program unveiled in August, National announced the closure of its Bipolar 2 fab line, a 6-inch line used for the production of BiCMOS SRAMs. At the same time, the company announced that its Bipolar 1 4-inch line would remain in operation. National had been courting possible purchasers since the August announcement. After much rumor and speculation, the company agreed to sell the whole facility, including both the 4-inch and the 6-inch lines, to Matsushita.

Matsushita has announced that it plans to manufacture DRAMs and MOS logic components in the Puyallup facility. The acquired fab represents Matsushita's first front-end fab outside Japan. The company is one of the last first-tier Japanese semiconductor manufacturers to obtain a fab facility in North America. Fujitsu, Hitachi, Mitsubishi, and NEC have already established fab facilities in the United States.

Matsushita has long been a strong player in the electronic equipment industry. In 1989, the company was the world's third largest supplier to the $11 billion consumer electronics market, capturing 9.9 percent market share. Recently, Matsushita has taken actions to strengthen its position in the worldwide semiconductor market. The company's acquisition of National's Puyallup fab is the latest in a series of strategic actions taken by Matsushita. This newsletter highlights the company's other recent activity in the semiconductor industry.

STRONG SEMICONDUCTOR R&D SPENDING

Matsushita's intention to gain semiconductor market share by establishing state-of-the-art technologies in-house is evident in its high R&D-to-revenue ratio. Although Hitachi and Toshiba are in a class by themselves in terms of their absolute monetary investments in semiconductor R&D, among Japanese suppliers, Matsushita trails only Sony in its R&D-to-sales ratio. In 1989, Matsushita had an R&D-to-sales ratio of 17.5 percent, while Sony posted a 21.9 percent ratio. In 1989, the Japanese industry average R&D-to-sales ratio was only 12.9 percent, while the top ten companies' average was 14.0 percent.

ALLIANCES

During 1990, Matsushita announced the creation of or the results of a number of strategic partnerships.

In February 1990, Matsushita and Intel announced their intention to team up in the areas of semiconductor production and marketing. Matsushita will market Intel's EPROM products in Japan; Intel will provide Matsushita with its MPU technology. Intel plans to use Matsushita's large marketing network in Japan to reinforce sales of its chips. In turn, Matsushita regards the relationship as an opportunity to increase the sales of imported

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ICs, in compliance with the U.S./Japan Semiconductor Trade Arrangement.

Also in February, Matsushita announced that it had developed a 64-bit RISC MPU jointly with Solbourne Computer. The MN10501 integrates a central processing unit (CPU), floating point unit (FPU), memory management unit (MMU), instruction cache unit (ICU), data cache unit (DCU), and bus control unit (BCU) on one chip. The device is used in Solbourne's recently introduced S4000 64-bit workstation. Matsushita is a major equity shareholder in Solbourne.

In July, the company announced a deal with National Semiconductor whereby the two companies will jointly develop automotive ICs for Toyota. National plans to produce 1 million ICs and supply them to Toyota through Matsushita.

DATAQUEST ANALYSIS

As the semiconductor industry continues to assume a more global nature, Dataquest believes that successful semiconductor manufacturers will have to maintain a worldwide manufacturing presence. Several large Japanese suppliers, including Fujitsu, Hitachi, NEC, and Toshiba, have manufacturing facilities in Japan, North America, and Europe. In addition to several facilities in Japan and one in Singapore, Matsushita now has a semiconductor manufacturing center in the United States. Its new Puyallup facility is a state-of-the-art manufacturing center capable of producing BiCMOS devices with 1.0-micron geometries on 6-inch wafers.

Long a leader in the market for consumer electronics products, Matsushita's recent activity is characterized by its intention to improve its position in the global semiconductor market. In addition to the acquisition of a North American manufacturing facility, the company has entered several strategic partnerships in the past year and has continued a very high rate of R&D spending. As a vertically integrated manufacturer of electronics equipment, Matsushita has the luxury of a large captive market for its semiconductor products. The company's new challenge is to become a successful player in the merchant market.

Phil Mosakowski
Junko Matsubara

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Research *Newsletter*

AT&T TARGETS HIGH-GROWTH MERCHANT OPPORTUNITIES

INTRODUCTION

During the week of November 5, 1990, AT&T Microelectronics made two announcements that hopefully will lead the company to greater fortune in the merchant semiconductor market. On November 6, the company announced the availability of its first field-programmable gate arrays (FPGAs) based on designs licensed from Xilinx Corporation of San Jose, California. AT&T announced availability of its 2,000-gate FPGA with performance speeds of 125, 100, and 75 MHz; in addition, the company is sampling 4,200-gate and 9,000-gate devices.

On November 7, AT&T announced its entry into the SRAM market with the availability of a 10ns very fast SRAM, manufactured under a product-rights agreement with Logic Devices. Targeted applications for the high-performance SRAMs include cache memory, high-performance RISC and CISC computers, digital signal processing (DSP), and data communications.

These two announcements are the latest in a series of steps taken in the last two years by AT&T to enhance its position in the merchant semiconductor market. This newsletter examines AT&T's merchant strategy and discusses some of the company's actions designed to address its merchant market opportunities.

CORPORATE STRATEGY

As early as 1988 it was apparent that, as part of its strategy to survive in nonregulated business areas, AT&T began encouraging its equipment manufacturing groups to obtain components from the best available source. By doing so, the company hoped to make its equipment more competitive in the marketplace. For the captive semiconductor operation at AT&T, this policy represented a business challenge. No longer would there be a guaranteed market inside the company for its semiconductors. As the semiconductor operation strove to make its products more competitive, it seemed only logical that AT&T would try to pursue more business in the merchant semiconductor market.

In July 1989, AT&T announced its intention to balance the percentage of semiconductor production that was used for captive consumption and merchant sales. The company also indicated that it would be targeting fast SRAMs and microcontrollers in future strategic agreements and product development. AT&T achieved great success in the merchant marketing of its cell-based IC (CBIC) products; in fact, the company was the leading worldwide supplier of CBICs in 1989. AT&T's strategic agreements in the past two years have helped it expand its product portfolio into other markets, where its production expertise may be best utilized.

ALLIANCES

Table 1 lists the major alliances that AT&T entered in 1989 and 1990. The company has gained access to several new markets—including FPGAs, gate arrays, microcontrollers, and fast SRAMs—through these alliances. Concomitant with the corporate goals stated in July 1989, many of AT&T's recent agreements pertain to fast SRAMs. In January 1989, AT&T entered a foundry relationship with Logic Devices. Under terms of the agreement, AT&T provides finished wafers to Logic Devices. Since the signing of the initial agreement, AT&T and Logic Devices have entered a licensing agreement whereby AT&T is licensed to manufacture and market SRAMs designed by Logic Devices. In turn, Logic Devices receives foundry services from AT&T. AT&T's most recent SRAM product announcement is a result of the pact with Logic Devices.

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TABLE 1
AT&T Semiconductor Alliances—1989-1990

Company	Date	Product(s)
Logic Devices	January 1989	Wafer foundry
Paradigm	August 1989	SRAMs
Xilinx	December 1989	FPGAs
Mitsubishi	February 1990	SRAMs
NEC	March 1990	ASICs, MCUs
M/A-COM	May 1990	GaAs MMICs
Logic Devices	August 1990	SRAMs
Mitsubishi	September 1990	Bipolar IC assembly

Source: Dataquest (December 1990)

AT&T also has licensed fast SRAM capability from Paradigm Technology. In August 1989, the two companies signed a five-year agreement to codevelop fast SRAMs, under which AT&T provides Paradigm with equity and codevelopment funding and Paradigm gains access to AT&T's worldwide foundry capabilities. To date, AT&T has not announced products based on this licensed technology.

In another agreement to gain fast SRAM technology, AT&T and Mitsubishi signed a five-year agreement in February 1990 that provides AT&T access to Mitsubishi's SRAM design and process technology, beginning with the 256K SRAM. In addition, AT&T gains worldwide manufacturing and marketing rights to all Mitsubishi SRAM products. In return, AT&T will manufacture current and future SRAM products for Mitsubishi.

In December 1989, AT&T signed an agreement with Xilinx to manufacture and market Xilinx's 3000 and 4000 families of FPGAs. Xilinx gains access to AT&T's worldwide fab capability, including European capacity, through AT&T's fab in Madrid, Spain. On November 6, 1990, AT&T introduced the first products that resulted from this agreement.

In addition to fast SRAMs and FPGAs, AT&T also gained access to microcontroller and gate array technology through its March agreement with NEC. Under the terms of the five-year relationship, AT&T will be licensed to design, manufacture, and market NEC's gate array products, starting with NEC's most advanced CMOS gate array family. In return, NEC will receive AT&T's sophisticated CAD tools for ASICs. The relationship also calls for AT&T to provide manufacturing support for NEC's 4-bit microcontrollers.

DATAQUEST ANALYSIS

AT&T's pursuit of strategic partnerships appears to be driven by three goals, the first of which is filling its fab capacity. At one time, AT&T had more excess leading-edge fab capacity than any company in the world. In the last two years, the company has signed numerous foundry agreements in an attempt to better utilize its capacity. Second, these alliances are serving as a cornerstone of a more extensive product portfolio. As mentioned earlier, AT&T has gained licensing or manufacturing rights to products in the gate array, PLD, microcontroller, memory, and GaAs MMIC markets. Finally, by strengthening its position in these new product markets, AT&T is attempting to improve its position in the merchant semiconductor market in general.

In the past year, a number of companies—including AMD, National Semiconductor, Philips, Saratoga Semiconductor, and VLSI Technology—have exited the SRAM business. As the market experiences consolidation, it seems an odd time for AT&T to be entering this market. However, AT&T is positioning itself in the very fast segment of the SRAM market. Dataquest considers devices with access times of less than 25ns to be very fast SRAMs. AT&T's new products, with access times of 10, 12, and 15ns, will be competing with products by the likes of Cypress, IDT, Motorola, NEC, and Sony in the very fast SRAM market. Dataquest predicts a compound annual growth rate of 88.6 percent in the very fast SRAM market between 1990 and 1994. By 1994, we expect the market to be nearly $1.8 billion.

In choosing new markets for the company's merchant entry, AT&T has done a fine job. The very fast SRAM market has excellent growth expectations, and Dataquest believes that the FPGA segment of the PLD market also is ripe for significant growth and can support numerous suppliers. With extensive leading-edge fab capacity in North America and Europe, AT&T also is well positioned for an extensive merchant operation from a manufacturing technology standpoint. While some companies choose to hire additional engineering expertise to penetrate new markets, AT&T has chosen a strategy of well-planned strategic partnerships. As the decade unfolds, Dataquest expects to see AT&T further strengthen its position in the merchant semiconductor market. The company appears to be off to a fine start.

Phil Mosakowski

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Research Newsletter

NEC: DOMINANCE THROUGH DIVERSIFICATION

INTRODUCTION

This monthly newsletter is the first in a series focusing on the semiconductor operations of leading semiconductor suppliers. Additional corporate financial information is provided in Dataquest's forthcoming NEC company backgrounder.

THE COMPANY

This newsletter discusses NEC Corporation, a leading global supplier of communications systems, computer and electronic systems, electronic devices, consumer electronics, and information services. NEC has been the world's leading semiconductor supplier since 1985. The company's recent activities are likely to allow it to maintain its strong market position.

In the past year, NEC has announced several strategic actions. In March 1990, it signed a licensing agreement with AT&T, granting AT&T a license to design, manufacture, and market NEC gate arrays. In return, NEC received AT&T's sophisticated CAD tools for ASICs. In April, NEC announced an investment of $48 million in its facility in Livingston, Scotland, to upgrade the facility for 4Mb DRAM production. NEC now has 4Mb production capacity on three continents: in Japan, in the United States (Roseville, California), and in the United Kingdom (Livingston).

In September, the company announced a joint venture with Shoudu Iron & Steel to manufacture ICs in China. NEC's earlier plans to invest in China were canceled when Japan froze all investment in China following the Tiananmen Square massacres. In November, NEC announced that it will limit DRAM production to no more than 30 percent of semiconductor shipments. At the same time, the company announced that it will be increasing 4Mb DRAM production.

Tables 1 and 2 and Figures 1 through 4 detail NEC's product segmentation, revenue growth, and capital spending history.

PRODUCTS

ASICs

Most of NEC's total ASIC revenue comes from gate array sales. Of those sales, a great majority are in MOS gate arrays. In 1989, NEC was the number 2 supplier of MOS gate arrays worldwide, trailing only LSI Logic in market share. In addition, NEC was the number 2 supplier of bipolar gate arrays in 1989, trailing Fujitsu. NEC also is the market leader in the small, although growing, market for BiCMOS gate arrays. Most of NEC's ASIC product development is driven by internal applications in personal computers and mainframes. The company's MOS gate arrays, for instance, are designed for use in its personal computer systems and later sold in the merchant market. In the same manner, NEC designs bipolar ECL gate arrays for applications in its mainframe computers, later selling the semiconductors in the merchant market. The company's BiCMOS gate arrays were successfully introduced into PC applications and now are being sold as merchant products.

Dataquest expects NEC to continue to focus on product development for internal consumption, bringing these products to the merchant market after successful internal application. Traditionally, NEC has dominated the low-complexity, high-volume gate array market. Employing advanced CAD tools, the company now is positioning itself to become a high-end player, focusing on high-density, high-margin products. In addition, NEC has taken steps to regionalize its product development, with regional product design and development teams tailoring products for specific local markets.

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TABLE 1
NEC Semiconductor Revenue by Product Segment
(Millions of Dollars)

	1988	1989	% Change	World Market % Change
Semiconductor	4,543	5,015	10	12
IC	3,884	4,321	11	14
Bipolar digital	292	302	3	(13)
Total MOS	3,123	3,604	15	22
Memory	1,490	1,739	17	40
Micro	790	937	5	15
Logic	843	928	10	4
Analog	469	415	(12)	6
Discrete	571	574	1	1
Optoelectronics	88	120	36	21
Exchange Rate (Yen/US$1)	130	138		

Source: Dataquest (November 1990)

TABLE 2
Estimated NEC Semiconductor Capital Spending Compared with Total Revenue—Calendar Year
(Millions of Dollars)

	1985	1986	1987	1988	1989
Revenue	1,984	2,598	3,368	4,543	5,015
Semiconductor Capital Spending	517	179	208	423	580
Growth Rate of Capital Spending (%)	(5)	(65)	17	103	37
Revenue (%)	26	7	6	9	12
Exchange Rate (Yen/US$1)	238	168	144	130	138

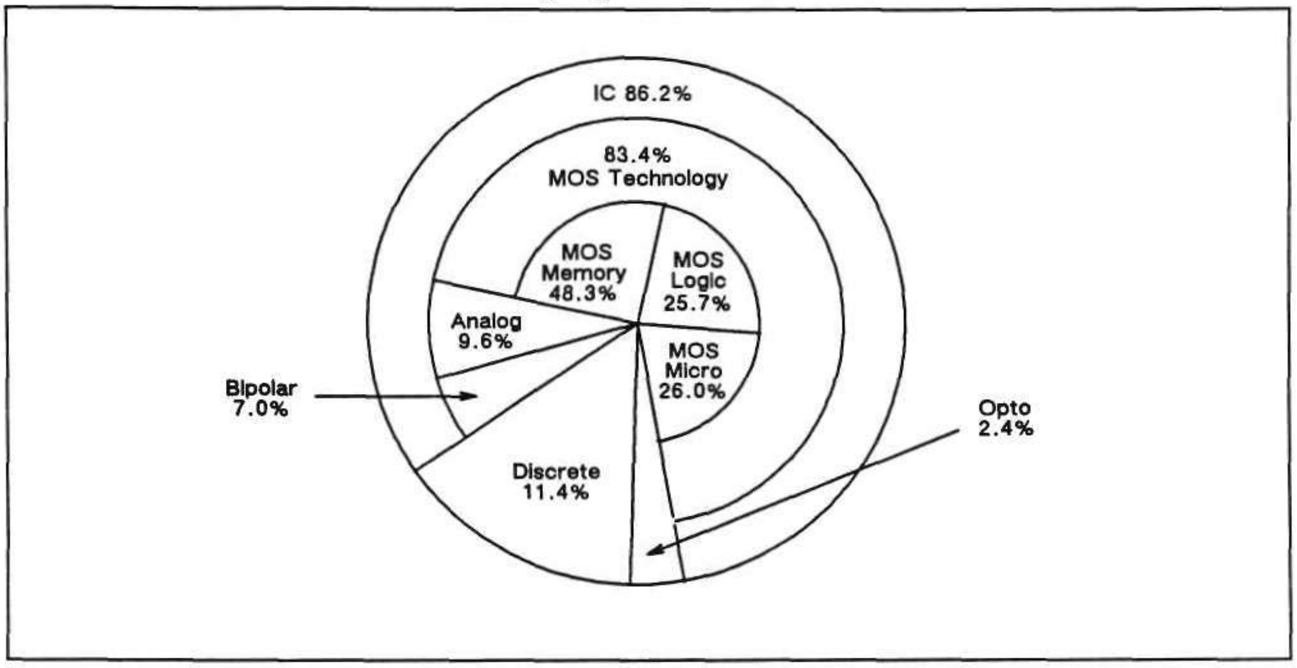
Source: Dataquest (November 1990)

Memory

NEC has been a market leader in DRAMs since the early 1980s and was number 2 (behind Toshiba) in market share in 1988 and 1989. Recently, NEC announced that engineering samples of the 16Mb DRAM will be available in late 1990 or early 1991. With the announcement, NEC joins Hitachi, Samsung, Texas Instruments, and Toshiba as companies that have announced 16Mb sampling. In 1989, NEC was the third largest supplier (behind Hitachi and Fujitsu) to the worldwide SRAM market. In both the SRAM and DRAM markets, NEC tends to focus more on the domestic Japanese market, whereas other suppliers such as Toshiba have taken a more global marketing approach.

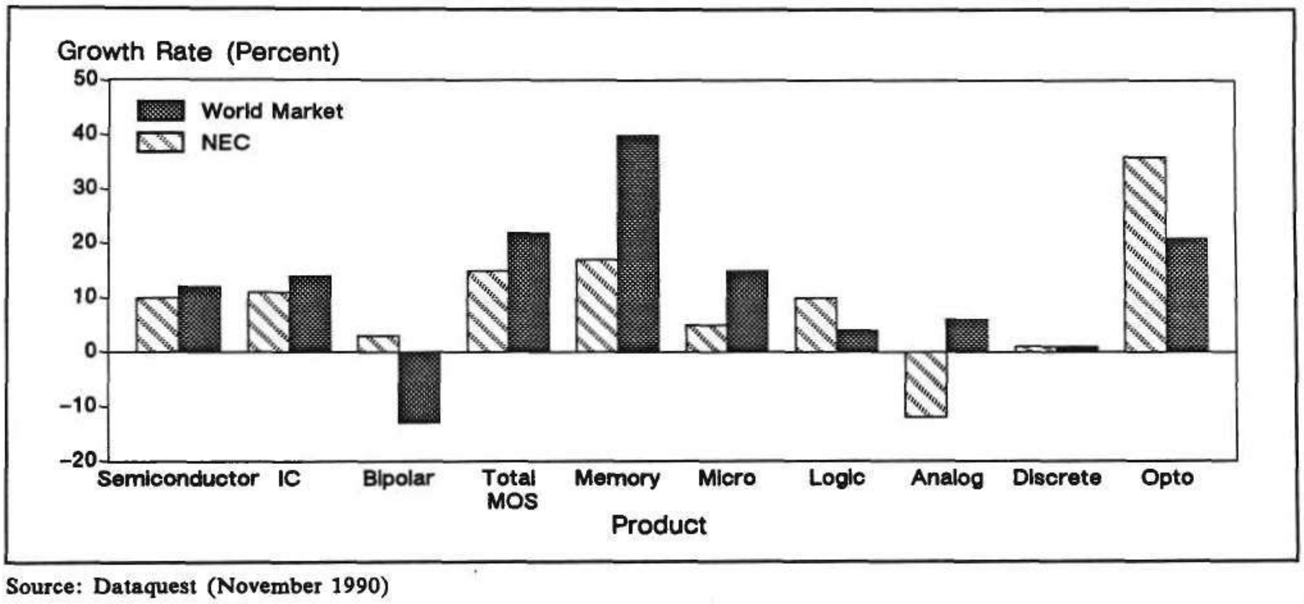
NEC is the second largest supplier to the worldwide nonvolatile memory market. The company supplies 1Mb and 2Mb EPROMs and is the world's leading supplier of 4Mb EPROMs. In addition, NEC held 22 percent market share in the mask ROM market in 1989. Unlike other ROM vendors such as Seiko-Epson and Sharp that target office automation products, NEC has chosen to target consumer applications such as electronic typewriters and electronic games with its mask ROM products. NEC was the first to announce a 32Mb ROM and is targeting software storage applications in electronic instruments and musical instruments with the new device. Dataquest anticipates NEC's entry into the burgeoning Flash

FIGURE 1
1989 NEC Semiconductor Revenue Percentage by Product



Source: Dataquest (November 1990)

FIGURE 2
NEC Growth Rate Compared with Worldwide Market



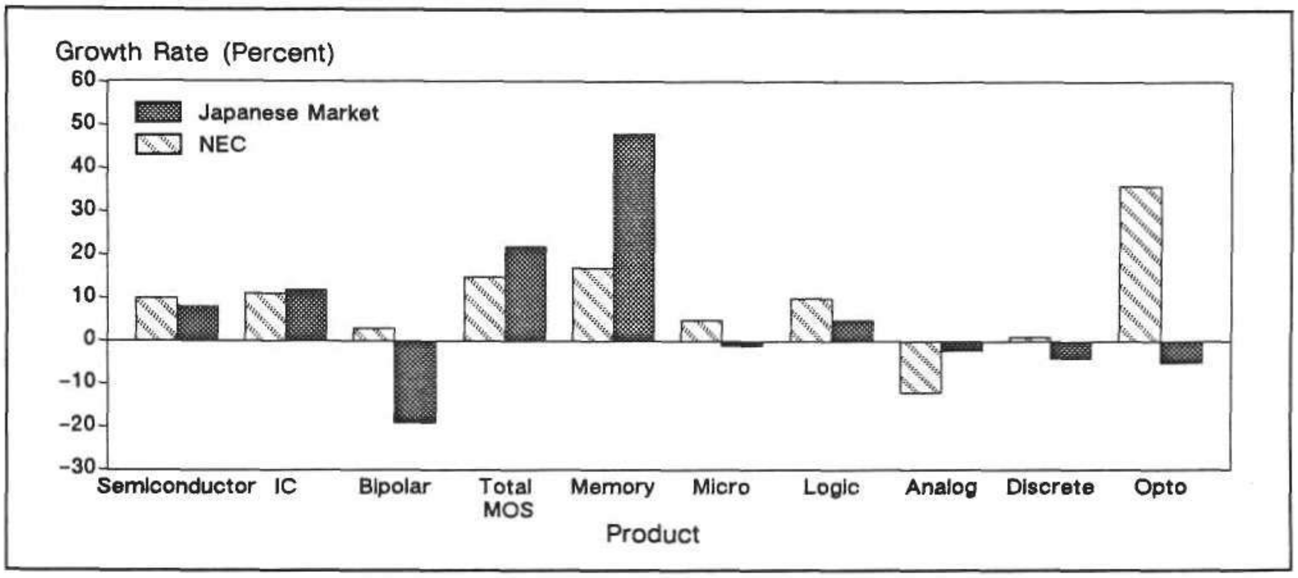
Source: Dataquest (November 1990)

memory market in the near future as a logical extension of its memory activity.

Microcomponents

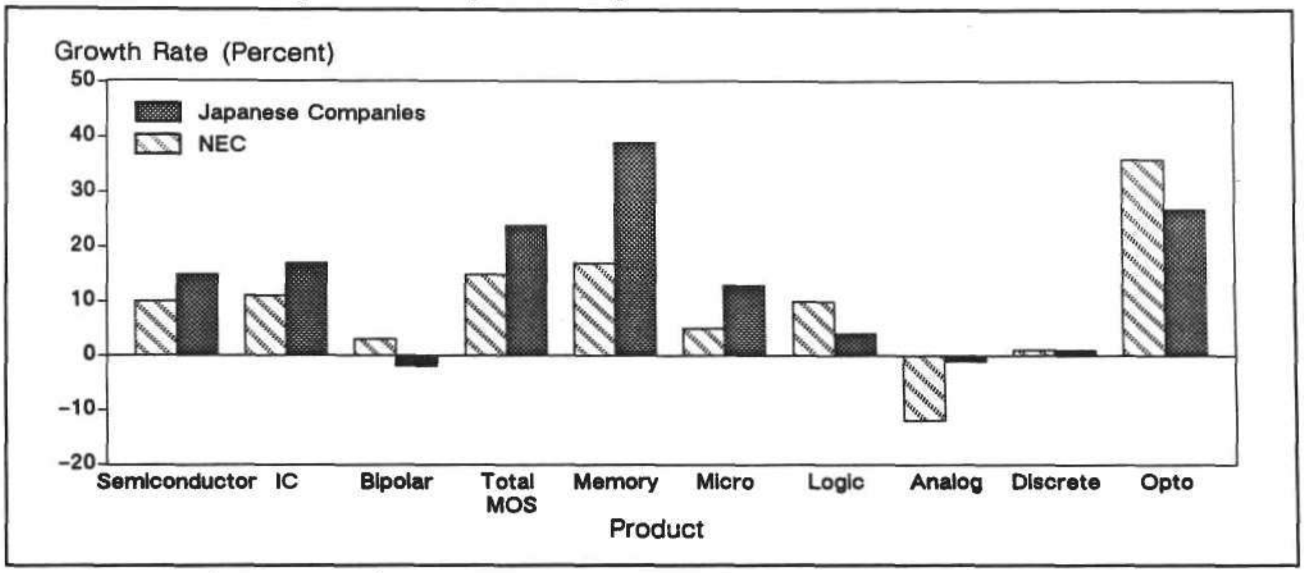
In 1989, NEC was the second largest supplier of microcomponent products worldwide, trailing only Intel. The company posted revenue growth of 19 percent in this product segment. In general, NEC focuses on proprietary products, de-emphasizing second-source products. In microprocessor production, NEC ranked fourth behind Intel, Motorola, and Advanced Micro Devices. NEC wants to be a dominant player in the design of new microprocessor architectures involved in the standards process. In terms of microprocessor design, Dataquest believes that

FIGURE 3
NEC Growth Rate Compared with Japanese Market



Source: Dataquest (November 1990)

FIGURE 4
NEC Growth Rate Compared with Japanese Companies



Source: Dataquest (November 1990)

NEC is the most advanced Japanese semiconductor manufacturer. A large portion of NEC's microprocessors are used in the production of its own personal computer and office automation equipment. In addition, NEC is a leading supplier of microprocessors to the merchant office automation market, supplying components for use in personal computers, facsimile machines, and page printers.

NEC is the leading worldwide producer of microcontrollers and the number three producer worldwide (behind Intel and Chips & Technologies) of microperipherals. The company also is a licensed manufacturer of MIPS-based microprocessors. Dataquest expects NEC to be a significant player in the RISC microprocessor market. As with all of NEC's semiconductor products, a large portion of demand is driven by internal applications, although a great deal of investment is made in product development for the merchant market. All of the company's products employ application-driven designs.

DATAQUEST ANALYSIS

NEC Corporation's degree of vertical integration is perhaps the main ingredient in the success of its semiconductor operation. During fiscal year 1990, 44 percent of the corporation's revenue came from the sale of computers and industrial electronic systems. As a leading supplier of computers, industrial electronic systems, communications systems and equipment, and home electronics products, NEC has a substantial end market for its semiconductor products within its own organization. With revenue of $21.8 billion in 1990, the company has enough resources to support significant investment in its semiconductor development program. NEC's semiconductor capital spending remains strong (see Table 2), with growth rates of 103 and 37 percent, respectively, in 1988 and 1989. In addition, capital spending also climbed above 10 percent of revenue in 1989.

NEC also is a well-diversified semiconductor supplier (see Figure 1). Although the company's 10 percent growth rate in 1989 was below the industry average of 12 percent, the only market segment that showed significantly slower growth was MOS memory, which recorded an industry-wide growth rate of 40 percent. Had the company achieved 25 percent growth in its MOS memory business segment, its overall growth would have been 19 percent. Because semiconductor memory has come to play such an important role in semiconductor revenue, and because NEC has decided to limit its production of memory products, Dataquest believes that NEC's continued success in the overall semiconductor market depends on its ability to capitalize on new opportunities in other product segments such as microcomponents and ASICs.

With facilities in North America, Europe, and Asia, NEC has established a well-diversified manufacturing base. NEC has production capacity for 4Mb DRAMs on three continents. In addition, the company has set up regional ASIC design centers to address region-specific design problems. Dataquest believes that memory prices will continue to be a major strategic issue, and memory products will remain a very volatile component in a company's business. NEC's announcement earlier this month to put a cap on DRAM production, in terms of percentage of total company shipments, is a significant strategic decision and should help insulate the company from wild swings in memory prices.

NEC's combination of technology leadership, worldwide manufacturing presence, product diversification, and strong internal demand put it in a position to be a semiconductor industry leader for many years to come. With challengers such as Toshiba ready to take the top spot with memory dominance, NEC will have to concentrate on foreign market penetration and its strong position in the ASIC market to maintain its position as the number one semiconductor supplier.

Phil Mosakowski

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Research *Bulletin*

US SEMICONDUCTOR BOOK-TO-BILL REPORT AND ANALYSIS—OCTOBER 1990

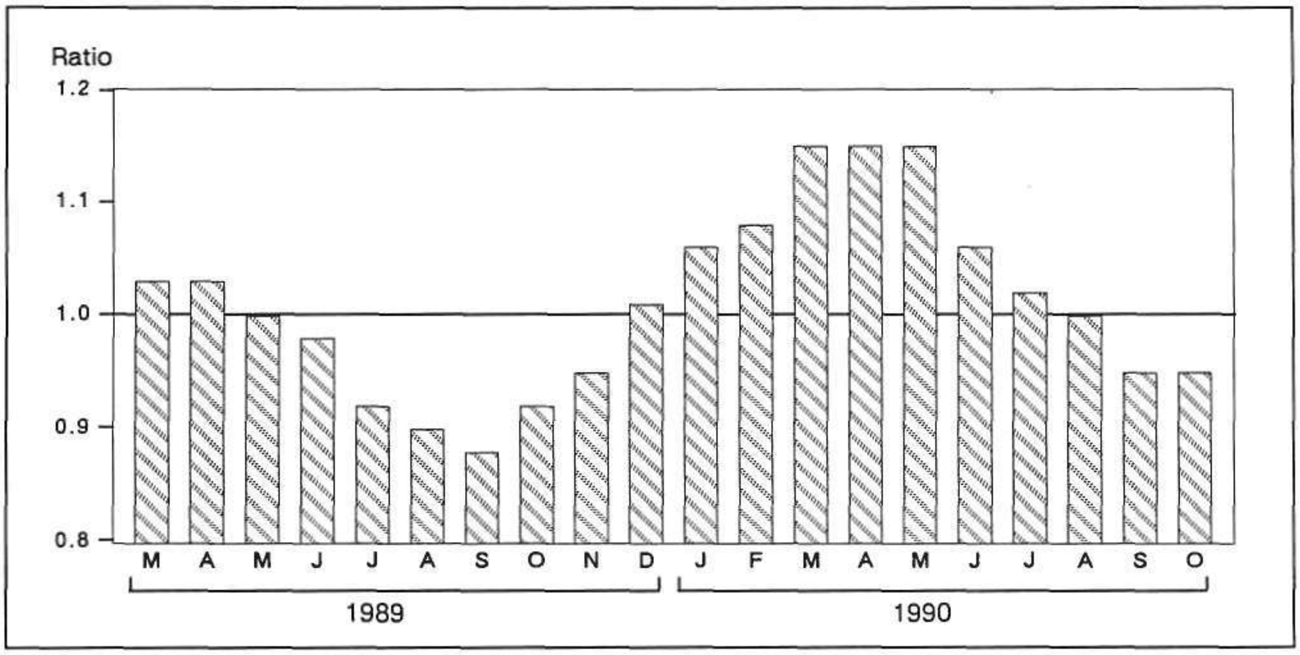
BOOK-TO-BILL RATIO

The levels of orders booked and shipments billed to the US semiconductor market for the month of October each rose less than 1 percent compared with the previous month. As a result, the book-to-bill ratio for October remained unchanged from September at 0.95, according to the World Semiconductor Trade Statistics (WSTS) Flash Report (see Figure 1).

On a three-month moving average, orders booked to the US semiconductor market in October increased 0.4 percent to $1,193.6 million from September's $1,188.5 million (see Figure 2). In line with expectations of a declining market, October orders are 4.0 percent lower than July's $1,243.4 million (the last beginning-quarter month). On the brighter side, October 1990 bookings were 5.1 percent higher than October 1989's $1,135.8 million level.

Actual billings to the US semiconductor market in October were $1,181.6 million—a 14.0 percent drop from September. This decline is normal for a transition from a five-week month to a four-week month. October billings are also 0.5 percent lower than October 1989's $1,187.8 million. However, October billings are 4.5 percent higher than July's $1,130.8 million.

FIGURE 1
US Market Book-to-Bill Ratio
March 1989 to October 1990



Source: WSTS, Dataquest (November 1990)

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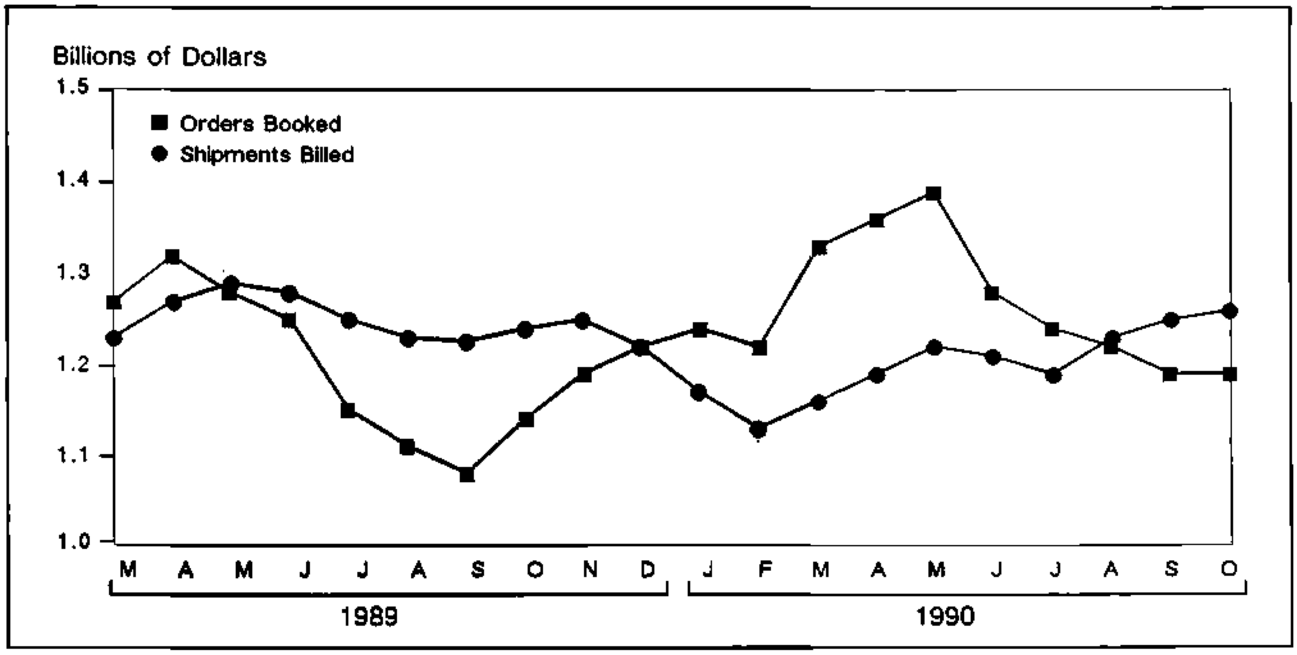
FIGURE 2
Three-Month Average Orders and Shipments
March 1989 to October 1990



Source: WSTS, Dataquest (November 1990)

END-USE OUTLOOK

Looking ahead, the procurement survey conducted this month by Dataquest's Semiconductor User Information Service indicates that target and actual inventory levels for semiconductor devices rose slightly to 35 and 22 days, respectively. Despite the slight increase, inventory levels remain quite manageable. Dataquest expects the target and actual inventory levels to be corrected next month. In addition, semiconductor buyers maintain a positive growth outlook for system sales. Buyers predict an average 3.0 percent growth over the next six months, down slightly from last month's 3.4 percent indication, although still positive. Computer system billings fell 3.0 percent on a month-to-month basis in October, yet the semiconductor order rate is expected to rise slightly over last month.

According to a recent Department of Commerce (DOC) report, on a three-month moving average, both shipments and bookings of computers and office equipment rose in September over August. Actual billings of computers and office equipment for the month of September rose 52.0 percent over August and 0.3 percent over June (the last ending-quarter month). Actual bookings rose 80.0 percent over August and 18.0 percent over June. In addition, the three-month average growth rate for computers and office equipment rose to 4.3 percent from 0.3 percent in August.

DATAQUEST CONCLUSIONS

It is as yet unclear how the general economic softness will affect the semiconductor industry in the long run. During the 1982 recession, the electronics industry was not affected. The Middle East crisis remains another element of uncertainty. Despite the cry of recession from some industry observers, strong system sales and the optimistic procurement outlook indicate that the sky is not falling.

Phil Mosakowski

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Research Newsletter

PACKAGING TECHNOLOGY: FROM AFTERTHOUGHT TO ENABLER

SUMMARY

Over the next decade, the demands of high-performance electronics systems will cause a dramatic shift in interconnect technology from the traditional dual in-line package (DIP) to advanced surface-mount technology (SMT) applications such as tape-automated bonding (TAB), flip-chip, and chip-on-board (COB). As the semiconductor industry approaches the 21st century, single-chip packaging solutions will increasingly give way to multichip modules (MCM) as the semiconductor industry enters an era of high-density interconnect (HDI).

During the next decade, the demands of the high-end ASIC business, particularly gate arrays, will have the biggest influence on the growth of SMT packaging. As we approach the year 2000, the technical workstation market, especially through its impact on microprocessor architectures, will play an increasingly important role in the advancement of MCM technology.

Given the necessary investments in developing an HDI infrastructure, the cost of penetrating a rapidly expanding packaging market will be enormous. As a result, industry participants that realize the critical performance factors necessary to high-performance system design will be forced to make investments in interconnect R&D similar to those made in semiconductor technology during the last decade. The high end of the data processing market of the 1990s could very well be dominated by the region that approaches the interconnect challenge in the most expedient fashion.

This newsletter looks at ASIC and reduced-instruction-set computer (RISC) trends as they affect worldwide packaging production over the next ten years. The anlaysis and data on which this newsletter is based are the result of an 18-month multiclient study conducted by Dataquest's Semiconductor Consulting Group, which culminated in the June 1990 publication of Dataquest's *VLSI Packaging Study*, a 400-page report on the future of the semiconductor packaging market.

FROM TH TO SMT: THE NEXT FIVE YEARS

Table 1 presents Dataquest's forecast for worldwide packaging production over the next five years, with a ten-year leap to the year 2000. The table describes the market as we believe it will act if the emerging interconnnect technologies or their enhancements are not superseded by others. Although the traditional through-hole (TH) packages will maintain a sizable but declining share of the market, as shown in Table 1, SMT is expected to reach a 71 percent share of worldwide packaging production by 1994.

THE ASIC IMPACT

Over the next five years, Dataquest believes that the transformation of electronics industry designs from standard ICs to ASICs will be the most significant force in changing package interconnect. This is true not only because of the trend in higher-pin-count devices, but because of the sheer pervasiveness of ASIC devices. Dataquest believes that from an $8.6 billion market in 1989, ASIC consumption will reach nearly $18.0 billion by 1994.

The largest segment of the worldwide ASIC market during this period will continue to be gate arrays, which will grow in revenue from just under $4 billion to almost $11 billion. Gate arrays will be the product area contributing most to both package proliferation and developments through the year 2000. The shift in gate array package production over the next decade from DIP, chip carrier, and PGA to SMT and MCM solutions is illustrated in Figures 1 and 2.

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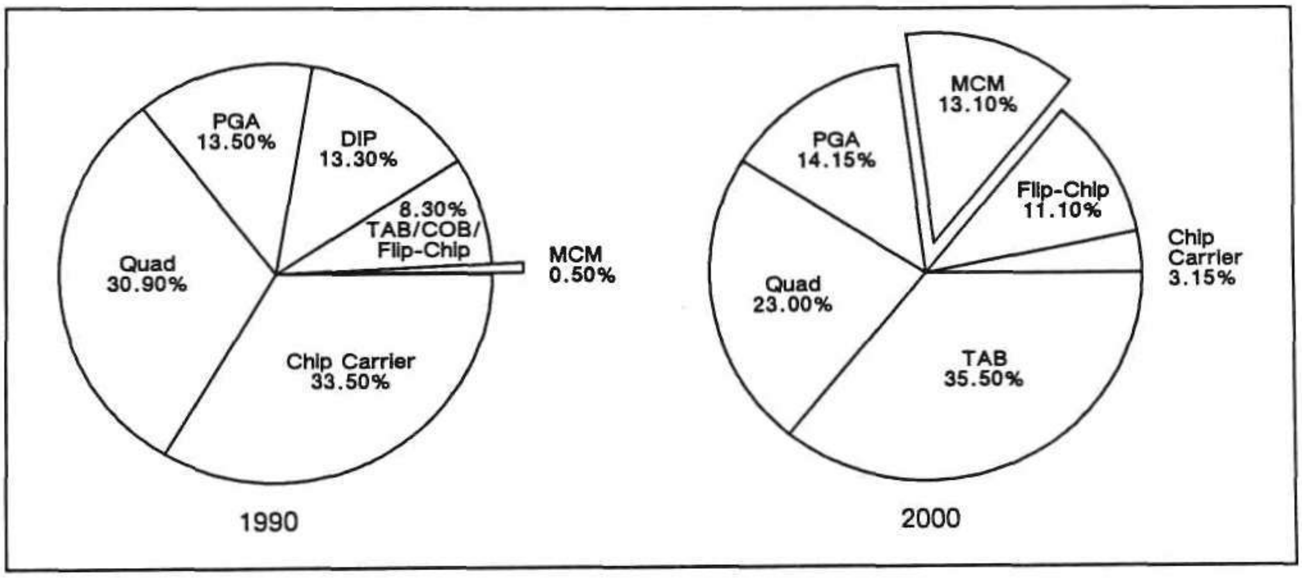
TABLE 1
Estimated Worldwide Package Production
(Millions of Units)

	1987	1988	1989	1990	1991	1992	1993	1994	2000
Plastic DIP	18,749	22,870	22,632	20,359	18,128	16,209	14,700	11,401	1,839
Ceramic DIP	3,479	3,958	3,583	3,251	3,206	3,039	2,922	2,621	1,327
QUAD	281	735	1,857	2,718	4,312	7,053	14,100	14,990	28,300
Ceramic Chip Carrier	138	191	246	270	302	405	431	387	160
Plastic Chip Carrier	203	332	425	466	623	809	899	804	341
SO	1,596	2,921	4,737	5,584	7,277	8,860	11,810	12,430	14,607
Ceramic PGA	49	137	181	256	410	641	807	862	482
Plastic PGA	11	34	85	147	248	554	770	904	587
TAB/COB/Flip-Chip	410	1,014	1,605	2,219	4,223	7,812	13,042	16,204	53,843
Total (Single Chip)	24,916	32,192	35,351	35,270	38,729	45,382	59,481	60,603	101,486
MCM (Units)	0	0	1	13	99	388	1,631	3,228	45,828

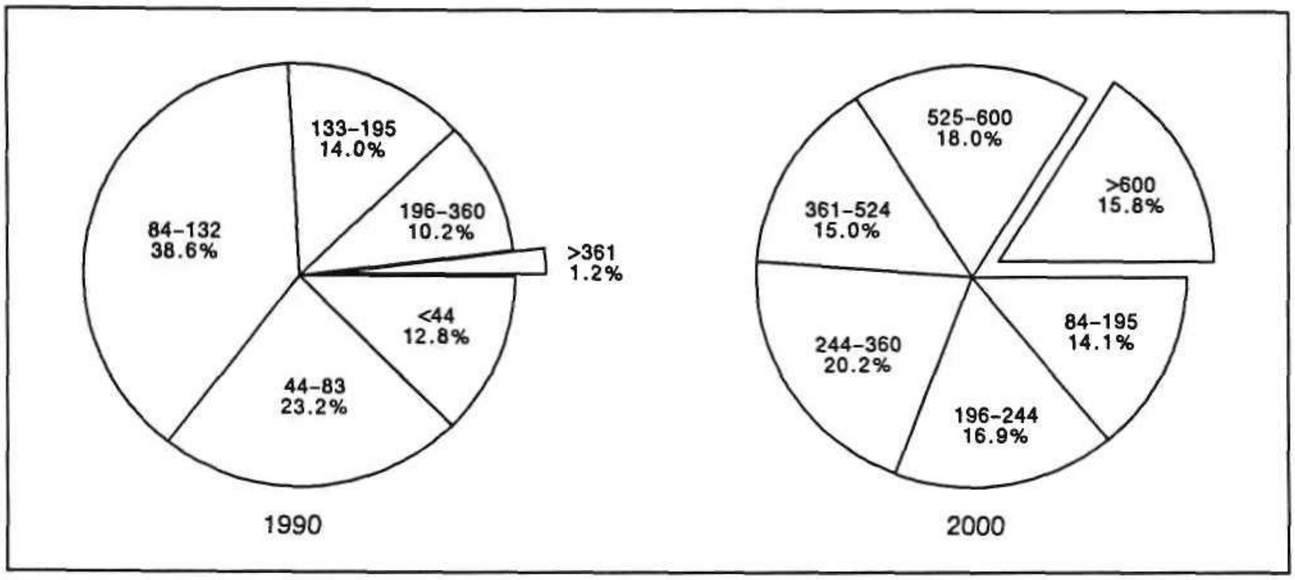
Note: MCM value = number of unit or chip demand.
Source: Dataquest (November 1990)

FIGURE 1
Estimated Worldwide Gate Array Package Production by Package Type
1990 versus 2000
(Percentage of Units)



Source: Dataquest (November 1990)

FIGURE 2
Estimated Worldwide Gate Array Package Production by Pin Count
1990 versus 2000
(Percentage of Units)



Source: Dataquest (November 1990)

THE WORKSTATION EXPLOSION

Although ASIC devices will be the technology driver for high-pin-count packages, the next generation of microprocessors (MPUs) will be the system performance drivers of MCM implementation—a trend owing to the continued growth of the technical workstation market. At a systems level, technical workstations are the electronic equipment products that will offer the greatest opportunity for change in process and packaging interconnect technology during the next decade.

According to Dataquest's Technical Computer Systems Industry Service (TCSIS), technical workstation industry revenue currently has a compound annual growth rate (CAGR) of 30.0 percent. In terms of architectural design, complex-instruction-set computing (CISC)-based workstations were the primary drivers of revenue growth in the technical workstation market of 1988. In the five years following 1988, however, TCSIS analysts expect RISC-based workstations to grow 57.5 percent in revenue and an impressive 89.9 percent in units. By 1993, as shown in Figure 3, RISC-based systems will account for 51.0 percent of workstation unit shipments, while CISC-based workstations will claim 49.0 percent.

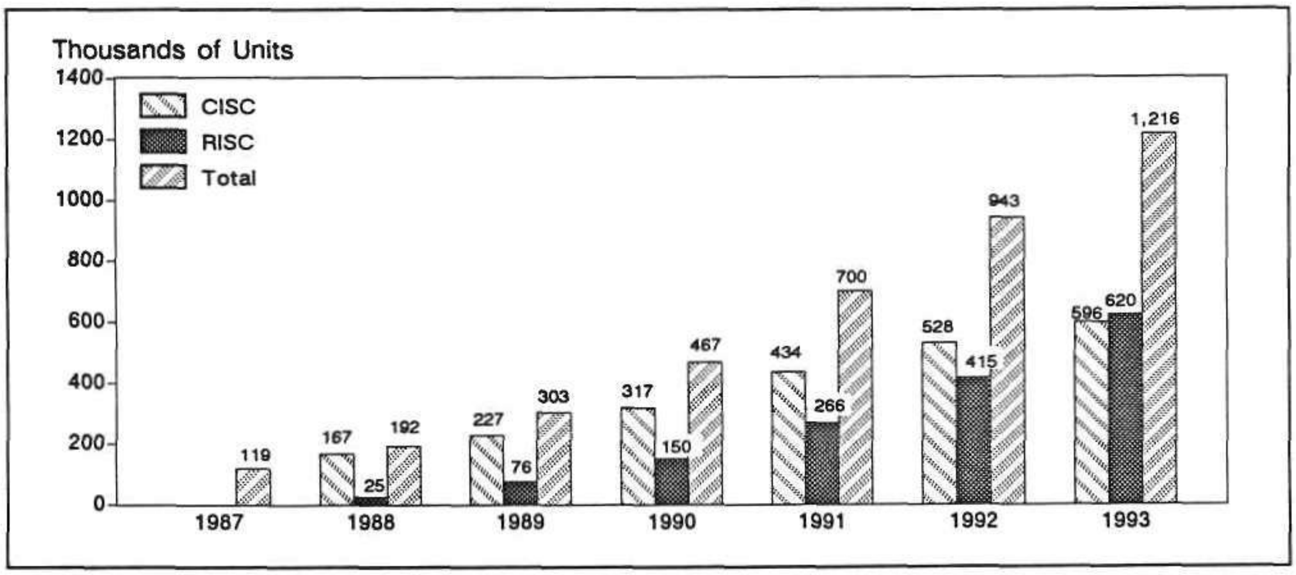
THE RISC IMPACT

Because most systems in the mid-1980s had relatively low, 10-MHz clock frequencies, interchip travel time was not a major concern of systems manufacturers. However, system clock frequencies currently are exceeding 30 MHz and are expected to reach 50 MHz by 1991 and 100 MHz by 1994—leaving only 20 and 10 nanosecond (ns) clock periods for calculation cycles. Currently available HDI technologies already have offered speed improvements of 15 percent or more at 50-MHz clock rates, with greater improvements at higher clock rates. HDI, just as much as developments in submicron manufacturing, will be critical to the continued improvement of high-performance MPUs.

HITCH YOUR WAGON TO A STAR

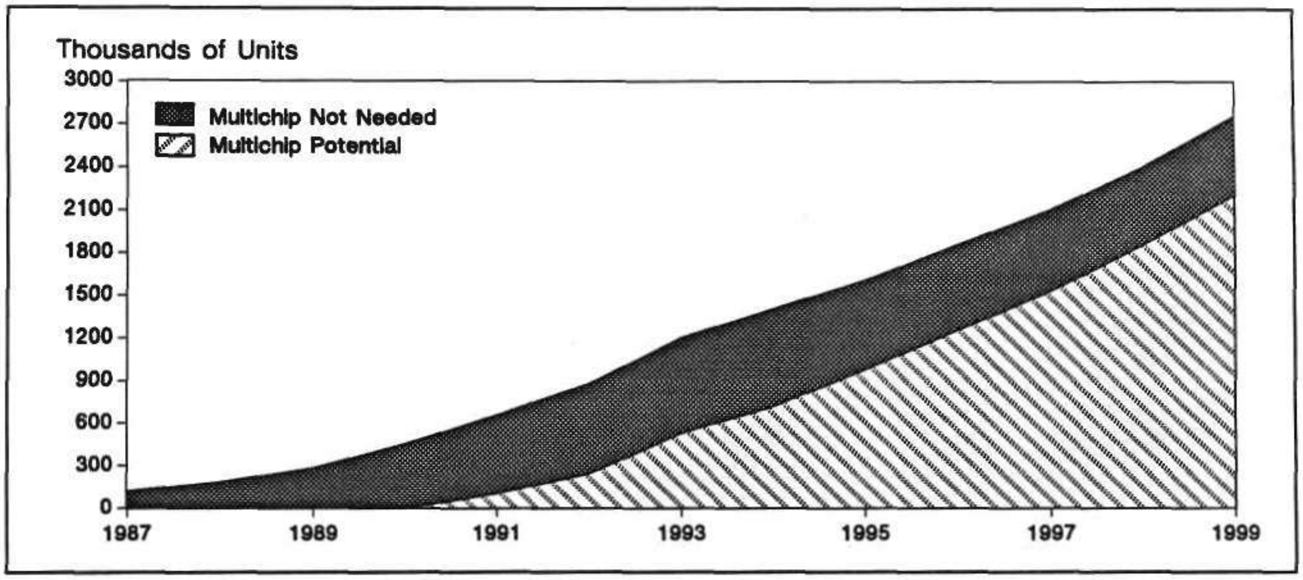
By the year 2000, workstations operating at 50 MHz and above will constitute 80 percent of the workstation market as measured in unit shipments. The increased penetration of RISC-based systems will in turn represent a tremendous opportunity for MCM producers. As illustrated in Figure 4, the number of workstations requiring MCM solutions will grow from approximately 70,000 units to over 2 million units during the next decade. This growth is significant not only in terms of numbers, but

FIGURE 3
Estimated Worldwide Technical Workstation Shipments
CISC versus RISC
1987-1993



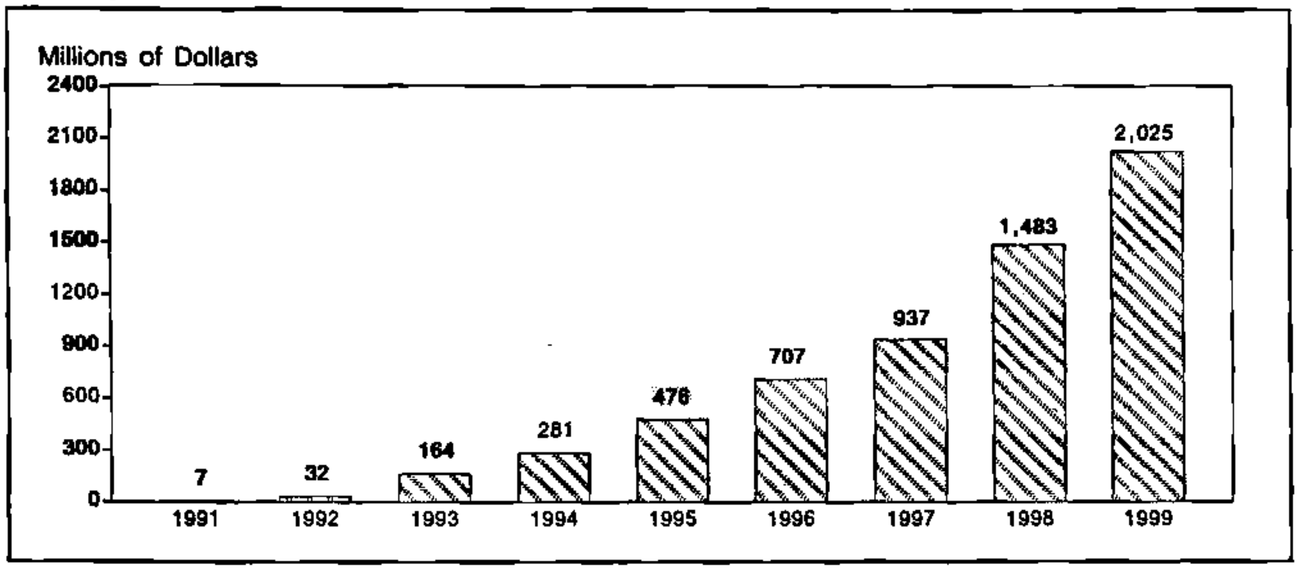
Source: Dataquest (November 1990)

FIGURE 4
Workstations Using Multichip Modules



Source: Dataquest (November 1990)

FIGURE 5
Multichip Module Revenue Potential in Workstations



Source: Dataquest (November 1990)

because of its relationship to high-margin products. The MCM requirements of future workstations will create a market that could potentially grow from only $7 million in 1991 to more than $2 billion by the turn of the century, as seen in Figure 5.

THE FUTURE LOOKS GREAT . . . BUT FOR WHOM?

The technical workstation market, and high-performance data processing and telecommunications applications in general, will offer numerous opportunities for SMT and HDI suppliers beyond those identified with MPU technology. As has been continually demonstrated in the electronics industry, new solutions create new problems that in turn engender new solutions. As RISC architectures answer the performance demands of next-generation technical workstations, increased CPU performance will in turn require new process and performance solutions in primary and secondary cache memory and the migration of main memory from fast SRAM/DRAM approaches to BiCMOS processes capable of operating in the 24 to 45ns range. Extended memory will, in turn, evolve from DRAM-based to solid disk-based technologies. The impact of all of these changes on memory, logic, and microcomponent package requirements will create high-growth markets for packaging technology.

The capital costs involved in making the transition to HDI will be huge, particularly given the priority that has historically been placed on process development in North American R&D spending. Increased emphasis on packaging solutions, however, is now a strategic necessity rather than a marketing afterthought. From its historic contributions to form-factor improvements in electronic systems to its more recent role in solving the pin-count challenges of increased logic integration, packaging is becoming an enabling technology in meeting the high-performance demands of 21st century data processing systems.

The interconnect requirements of the 1990s add yet another variable to the make-or-buy equation that worldwide systems companies must agonize over. Particularly in North America, systems companies must hope that their merchant IC suppliers not only keep pace in process and manufacturing technologies, but also find the resources to tackle the changes taking place in packaging. North American semiconductor suppliers have their work cut out for them: according to Dataquest's *VLSI Packaging Study*, MCM production by Japan and Europe will account for roughly 57 percent of units shipped worldwide in the year 2000.

Note: Contributors to the consulting study cited in this newsletter include Mary Olsson, Howard Bogert, and Mel Thomsen.

Michael J. Boss

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Research *Newsletter*

QUARTERLY SEMICONDUCTOR COMPANY RESULTS

INTRODUCTION

Dataquest regularly reports on semiconductor company financial results through its weekly on-line news service, *The DQ Monday Report*. As a service to SIS' Products, Markets, and Technology segment binderholders, a summary of this information is provided herein.

Table 1 summarizes the net sales and income disclosures of selected semiconductor companies based on data from quarterly report periods that ended during the August-through-October time frame. This information is compared with the corresponding 1989 time frame and is provided in millions of dollars unless otherwise indicated. Figures 1 and 2 show the percent change by quarter for aggregate company revenue and net income, respectively, from the third quarter of calendar 1989 through the third quarter of 1990. Descriptive summaries of quarterly performance highlights for the companies listed follow.

THE COMPANIES

Adaptec

Adaptec announced net income of $4.5 million on sales of $26.5 million for its second fiscal quarter, which ended September 28. Figures for revenue and net income represent increases of 33 and 47 percent, respectively, from the corresponding period a year ago. The company reports that revenue growth reflects Adaptec's ability to rapidly develop and market high-performance SCSI and AT I/O solutions to microcomputer and peripheral OEMs worldwide. Adaptec's investment in R&D has increased as the company continues to strengthen the breadth and depth of its product offerings. During the second quarter, the company began sampling its 7000 family of single-chip controllers for use in next-generation 2.5- and 3.5-inch embedded disk drives.

Advanced Micro Devices

AMD reported third-quarter revenue of $254.2 million, resulting in a net loss of $17.8 million for the quarter. The results reflect a 7.5 percent decline in sales from the third quarter of 1989, when AMD reported sales of $274.8 million and net income of $12.1 million. The company reported an increase of $15.0 million in CMOS sales over the prior quarter, to a record $96.0 million for the quarter. The CMOS growth was led by logic products such as PLDs. However, the company's low-density EPROMs remain under severe pricing pressure. In addition, weakening demand, particularly in Southeast Asia, for older products such as the NMOS 286 and bipolar PLDs more than offset the sales gains in CMOS. The company hopes to increase CMOS sales by more than 20 percent in the current quarter.

Altera

Altera Corporation reported net income of $3.4 million and revenue of $20.5 million for its third quarter, which ended September 30. These results reflect a 31 percent increase in sales and an 18 percent increase in net income over the corresponding period a year ago. Third-quarter operating income of $4.8 million increased by 35 percent over the same period in 1989. The company reports that demand for its new products continues to outstrip the company's ability to supply the devices. For this reason, Altera is working to bring additional wafer supply on-line through its investment in Cypress' Texas wafer fab.

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Table 1

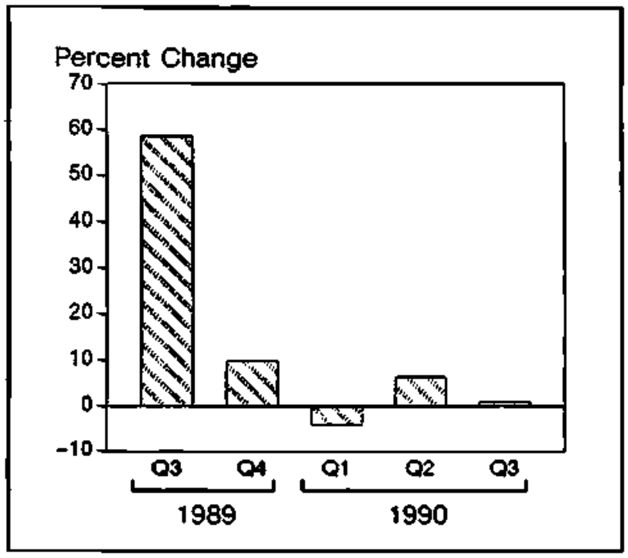
Quarterly Financial Summaries for Selected Semiconductor Companies (Millions of Dollars Unless Otherwise Indicated)

Company (Quarter End, Fiscal Quarter)	Latest Quarter Revenue	Percent Change*	Latest Quarter Income	Percent Change*
Adaptec (Sept. 28, Q2)	35.2	33	4.5	47
AMD (Sept. 30, Q3)	254.1	8	(17.8)	NM
Altera (Sept. 30, Q3)	20.5	31	3.4	18
Burr-Brown (Sept. 29, Q3)	43.7	5	800K	(29)
Chips & Technologies (Sept. 30, Q1)	59.5	(16)	700K	(92)
Cirrus Logic (Sept. 30, Q2)	34.6	92	4.4	29
Cypress Semiconductor (Oct. 1, Q3)	55.6	7	8.3	4
Dallas Semiconductor (Sept. 30, Q3)	25.2	9	3.5	7
IDT (Sept. 30, Q2)	49.5	(9)	250K	(96)
Intel (Sept. 29, Q3)	1,000.0	31	171.9	139
International Rectifier (Sept. 30, Q1)	58.4	18	1.1	NM
Lattice Semiconductor (Sept. 29, Q2)	18.0	114	3.3	151
Linear Technology (Sept. 30, Q1)	21.1	19	3.6	47
LSI Logic (Sept. 30, Q3)	172.5	29	4.2	NM
Maxim (Sept. 30, Q1)	17.3	41	2.3	36
Micron Technology (Aug. 30, Q4)	105.3	2	3.0	(81)
Motorola (Sept. 29, Q3)	2,700.0	12	102.0	15
National Semiconductor (Aug. 26, Q1)	442.7	11	(165.0)	NM
SEEQ Technology (Sept. 30, Q4)	11.1	10	(15.9)	NM
Siliconix (Sept. 9, Q3)	31.7	17	(3.1)	NM
Texas Instruments (Sept. 30, Q3)	1,680.0	7	(7.0)	NM
VLSI Technology (Sept. 29, Q3)	75.4	(2)	(18.8)	NM
Weitek (Sept. 29, Q3)	16.0	25	2.2	24
Western Digital (Sept. 30, Q1)	255.8	14	1.7	NM
Xilinx (Sept. 29, Q2)	23.1	103	3.7	102

*Compared with corresponding time one year ago.
NM = Not meaningful
K = Thousands
Source: Company Literature, Dataquest (November 1990)

FIGURE 1

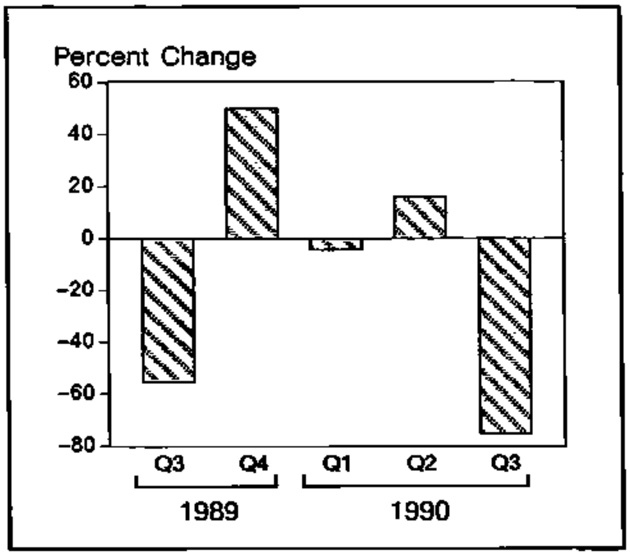
Aggregate Company Revenue



Source: Dataquest (November 1990)

FIGURE 2

Aggregate Company Net Income



Source: Dataquest (November 1990)

Burr-Brown

Burr-Brown announced sales of $43.7 million and net income of $0.8 million for its third fiscal quarter of 1990, which ended September 29. Revenue was up 4.7 percent from the third quarter of 1989. Operating income for the quarter was $1.5 million, down 54.9 percent from the preceding quarter. The low operating income was a result of a four-week shutdown in wafer fabrication caused by a process problem. Quarterly bookings were up 18.3 percent from the corresponding quarter of 1989.

Chips & Technologies

For the first fiscal quarter, which ended September 30, Chips & Technologies reported net sales of $59.5 million, a decline of 7 percent from net sales in the first quarter of 1990. The company also reported net income of $700,000, compared with net income of $9.1 million for the corresponding quarter a year ago. The company attributes the decline in net sales and net income to lower ASPs on some of the company's more mature products for PC AT compatible systems, a shift in product mix to chip sets with comparatively lower margins, and lower unit shipments because of a softening in overall PC market demand.

Cirrus Logic

For the second quarter, which ended September 30, Cirrus Logic reported revenue of $34.6 million and net income of $4.4 million, which represent increases of 92 and 29 percent, respectively, from the second quarter of 1990. The company reported record revenue for both mass storage and graphics products. Graphics revenue growth was driven by volume shipments of the company's LCD VGA controller to laptop and notebook computer suppliers. Mass-storage growth was a result of strength in the company's PC AT products and increased demand for the Cirrus' SCSI products.

Cypress Semiconductor

Cypress announced revenue of $55.6 million and net income of $8.3 million for its third fiscal quarter, which ended October 1. These figures represent increases of 7 and 4 percent, respectively, over those reported in the third quarter of 1989. The company reports record demand for its products, reflected by record revenue and the second best quarter ever in terms of bookings. Demand for fourth-quarter delivery was very strong for products from Cypress' Ross Technology and Aspen subsidiaries. Cypress still has not reached the increased wafer output goals in its Texas fab and, therefore, is not yet fully satisfying its customers' demands.

Dallas Semiconductor

Dallas Semiconductor reported that net sales for the third fiscal quarter, which that ended September 30, were $25.2 million, a 9 percent increase over the same period a year ago. Net income for the third quarter was $3.5 million, a 7 percent increase compared with $3.3 million during third quarter 1989. The company reports record bookings for a summer quarter. Sales of silicon-timed circuits, integrated battery backup, system extension, microcontrollers, and multiport memory products all were at record levels during the third quarter.

Integrated Device Technology

For its second fiscal quarter of 1991, which ended September 30, IDT reported revenue of $49.5 million and net income of $250,000. When compared with figures from the second quarter of 1990, these results reflect a 9 percent revenue decline and a 96 percent decline in net income. The company admits disappointment with its recent quarter financials. The poor results reflect two problems in the TTL SRAM area: severe price competition and delays in bringing new high-speed products to market. These new products are in various stages of completion, and the company expects to sample or ship limited quantities of most of these products during the December quarter.

Intel

Intel announced that third-quarter revenue exceeded the $1 billion level for the first time. Net income also set a new record. Revenue for the quarter that ended September 29 reached $1 billion, up 31 percent from $771 million for third quarter 1989. Net income was $172 million, a 139 percent increase from $72 million a year ago. The company reports that product demand remains strong and that it is making progress toward meeting the market's total needs for 386 and 486 products. The company expects to be back to a more balanced supply/demand situation by the end of the year.

International Rectifier

International Rectifier (IR) reported net income of $1.1 million on sales of $58.4 million for its first fiscal quarter, which ended September 30. First-quarter revenue is up 18.0 percent from that recorded in the first fiscal quarter of 1990. Gross margins rose 2.8 percent year-to-year, to 31.5 percent. Results reflect the year-to-year increase in production volume in the Electronic Products Division. At HEXFET America, the company's HEXFET power MOSFET manufacturing plant, wafer fab capacity utilization averaged 59.0 percent in the quarter, compared with 45.0 percent in the year-ago quarter.

Lattice Semiconductor

Lattice announced revenue of $18.0 million, an increase of 114 percent over the figure posted in the same quarter a year ago, for its second fiscal quarter, which ended September 29. The company also reported net income of $3.3 million, a 151 percent increase over net income reported in the second quarter of 1990. In July, Lattice raised $22.6 million in net proceeds through a public offering of common stock.

Linear Technology

Linear Technology reported net income of $3.6 million on sales of $21.1 million for the company's first fiscal quarter, which ended September 30. These figures represent increases of 47 and 19 percent, respectively, over net income and revenue figures from the corresponding period a year ago. During the quarter, the company's operating profit reached a record 23 percent of net sales. The company intends to continue emphasizing both consistent financial performance and aggressive new product introductions and positioning, despite the uncertain economy.

LSI Logic

LSI Logic reported revenue of $172.5 million and net income of $4.2 million in the third quarter, which ended September 30. Revenue in the third quarter rose 29 percent from revenue of $133.7 million in the same quarter last year. Third-quarter net income compared with a net loss of $35.7 million in the third quarter a year ago. The company's results compare favorably with the second quarter of 1990, despite a slowdown in the PC market that impacted chip set sales and factory utilization. The gross profit margin of 34.7 percent in the third quarter compared with 34.3 percent in the second quarter. During the quarter, LSI introduced its VHDL software and announced its C-MDE software. LSI also recently introduced several new RISC products, including chip sets that work with the company's SPARC and MIPS microprocessors. LSI's DSP group extended its product line during the quarter by adding a high-performance video compression chip set. The company also has sampled single-chip versions of its 286 and 80386SX chip sets.

Maxim Integrated Products

Maxim reported record sales of $17.3 million for the first quarter of fiscal 1991—a 41 percent increase over the $12.3 million during the same period a year ago. The company achieved net income of $2.3 million, a 36 percent gain over income reported a year ago. Maxim reports that 62 percent of the company's revenue came from markets outside the United States during the quarter.

Micron

Micron Technology reported net income of $4.9 million on sales of $333.3 million for fiscal year 1990, which ended August 30. These figures compare with net income of $106.1 million and net sales of $446.4 million for fiscal year 1989. For the fourth quarter, the company reported net sales of $105.3 million and net income of $3.0 million. Net sales increased 2.2 percent for the quarter when compared with the fourth quarter of 1989.

Motorola

For the third quarter, which ended September 29, Motorola's earnings totaled $102 million on sales of $2.7 billion. These figures represent increases of 15 and 12 percent, respectively, from year-ago figures. The company reported that its semiconductor business continued to do very well. Semiconductor sales increased 14 percent to reach an all-time record. Orders rose 9 percent, and the operating profit rose as a result of improved operations. Orders were up in all major regions, led by Asia/Pacific-ROW and Japan. Motorola reported higher order levels in bipolar and CMOS gate arrays, MPUs, MCUs, bipolar analog, and MOS digital analog products. Record orders were achieved for fast SRAMs, despite significant pricing pressure on DRAMs.

National Semiconductor

National announced a net loss of $165.5 million for the first quarter, which ended August 26. This figure compares with a net loss of $21.9 million for the comparable quarter a year ago. Results for the quarter include a pretax charge of $143.6 million in connection with the restructuring activity announced on August 21. Despite the large loss, the company enjoyed revenue growth of 11.3 percent, with first-quarter sales increasing to $442.7 million from $397.6 million a year ago. The company reports that operating performance was affected by several factors, including a seasonal slowing in shipments, pricing pressure in certain product areas, and operating losses in the product areas identified during recent restructuring activity.

SEEQ

SEEQ Technology reported that net revenue for its fiscal year that ended September 30 was $45.1 million compared with $55.1 million for the prior year. The company also reported a net loss for the year of $26.1 million, which compares with net income of $1.1 million for the prior year. For the fourth quarter, the company reported revenue of $11.1 million, compared with revenue of $10.1 million for the corresponding period a year ago. SEEQ also reported a net loss of $15.9 million for the quarter. This figure includes a restructuring charge of $11.4 million, related to the conversion of the fab from full production manufacturing to a preproduction and process development facility.

Siliconix

Siliconix announced that sales for the third fiscal quarter, which ended September 9, were $31.7 million with a net loss of $3.1 million. This compares with sales of $27.2 million and a net loss of $5.1 million for the third quarter of last year. The third-quarter loss was due primarily to the accrual of interest expense and Chapter 11-related expenses. The company was encouraged, however, by the continuing improvement in operating level results. The third quarter marks the first quarter since 1988 that Siliconix has been profitable at the operating level. In addition, quarterly bookings continued to be strong, with record bookings for a summer quarter.

Texas Instruments

Results for TI's third quarter include revenue of $1.7 billion and a net loss of $7 million. The revenue figure represents a 7 percent increase over revenue reported in the third quarter of 1989. Net income in last year's third quarter reached $65 million. TI cites losses in its semiconductor business, caused by sharply lower memory prices and substantially higher investments in new products and capacity, as major contributors to the unfavorable change from last year's third quarter. Third-quarter results were also impacted by the temporary disruption of business at the company's assembly and test operation in the Philippines following the July earthquake.

VLSI Technology

VLSI reported net revenue of $75.4 million and a net loss of $18.8 million for its third fiscal quarter, which ended September 29. Revenue fell 2 percent from year-ago levels, while earnings fell from $3.3 million in the third quarter of 1989. Included in the current quarter's operating loss was a pretax charge of $12.8 million in conjunction with the company's exit from the memory business. In addition to the company's exit from the SRAM market, VLSI cites demand softness for its 286 chip sets and slower software sales as contributing to the disappointing financial results.

Weitek

For its third quarter, which ended September 29, Weitek reported net income of $2.2 million on sales of $16.0 million. Compared with the third quarter of 1989, these results represent a 25 percent increase in revenue and a 24 percent increase in net income. For the first nine months of fiscal 1990, Weitek posted revenue of $47.2 million and net income of $6.6 million. Revenue in the first nine months of 1989 was $35.0 million and net income was $4.9 million.

Western Digital

Western Digital reported revenue of $255.8 million for its first fiscal quarter, which ended September 29. This figure represents a 14 percent increase over the revenue recorded in the first quarter of 1990. In addition, the company announced net income of $1.7 million, compared with a net loss of $2.7 million in the first quarter of 1990. The company reported that first-quarter results reflect the usual slowness of its markets in the summer months, as well as an accelerated decline in demand for several of its older board-level products in the reseller channel. Western Digital expects to be shipping key new products in the second half of its fiscal year, several of which are targeted at the rapidly growing portable computer market.

Xilinx

Xilinx reported record revenue, operating income, and net income for its second fiscal quarter, which ended September 29. The company reported net income of $3.7 million, an increase of 102 percent from $1.9 million in the second quarter of 1989. Revenue for the quarter was $23.1 million, an increase of 103 percent from $11.4 million in the comparable quarter last year. The company reports that sales of each of its nine FPGAs grew significantly over the preceding quarter, with 31 percent of the company's second-quarter sales coming from overseas.

Phil Mosakowski

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Research Newsletter

HUNGARY: BREAKING THE EAST/WEST BARRIERS

INTRODUCTION

Ever since the iron curtain was rent asunder in 1989, speculation about business opportunities in the Eastern European countries has been rampant. It is apparent now, nearly a year later, that there are no quick investment opportunities. Most of the Eastern European countries still are fumbling with the structural forms of their own governments. Building business relationships with the Eastern European countries will be a slow, laborious process. Economies are nearly bankrupt, currencies are virtually nonconvertible, and in some of the countries the concept of a "market economy" is unknown.

However, there are some bright spots. Hungary, one such bright spot, is very Western-focused and is making progressive changes (see Figure 1). It has thrown out its socialist republic government and has formed a parliamentary democracy. It is writing new laws to allow foreign investment and ownership, protect intellectual property, and transfer state-owned businesses to the private sector. And most important, it has a history of independence and a capitalistic outlook.

FIGURE 1
Hungary in Eastern Europe

Source: Dataquest (November 1990)

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THE BUSINESS ENVIRONMENT

The economic climate inside Hungary is similar to that of most of the Eastern European nations and the USSR. Massive budget cuts are hurting all sectors of the economy. The movement to a peaceful Europe has reduced the demand of most industries' primary customer, the military. The impact on the electronics industry, particularly electronics R&D, is disastrous. The Hungarian economy, however, is slightly better than that of its Eastern European neighbors because it has been building trade with the West, specifically Austria.

Table 1
Facts about Hungary

Population	10.6 million
Land Area	35,921 square miles
Language	Hungarian
Gross Domestic Product	$28 billion
GNP per Capita	$2,460
Growth Rate	5.1% annual average
Inflation Rate	6.4% per year
Government Spending	58% of GNP
Total External Debt	$17.5 billion
Balance of Payment	$386 million*
Interest Rates	
Lending	13%
Deposit	9%
Literacy	>95%
Largest Cities	Population
Budapest	2,060,000
Miskole	210,000
Debrecen	195,000
Szeged	175,000
Pecs	170,000
Gyor	125,000
Szekesfehervar	102,000

*World Bank estimate
Source: Dataquest (November 1990)

Although the consumer market inside Hungary is not large (10.6 million people), it is a very literate population with a relatively high technical competency. Hungary, as an Eastern European country, was part of the socialistic distributed manufacturing system and therefore has an Eastern marketing orientation. As a result, Hungarian businesses have existing relationships within the Eastern European countries and the USSR, which could prove advantageous for new joint ventures. Hungary has been a primary provider of telephones and switching systems for several of the Eastern European countries and the USSR.

Business enterprises fall into three categories: state-owned, cooperative, and privately owned. About 64 percent of the business are state-owned, 24 percent are cooperative, and 12 percent privately held. Between 60 and 70 percent of all exports still go to Eastern European countries and the USSR.

The principal export to the West is computer software. Estimates suggest that between 30,000 and 50,000 persons are engaged in producing and marketing software. Most of the software, however, is for custom applications.

The government is looking for investments from the West and is willing to offer incentives that include no income tax on new joint ventures for the first five years. However, the tax on profit currently is 60 percent and would be applied after the fifth year. Most of the investments being sought are for rebuilding the infrastructure.

Hungary is in debt, as are most of the Eastern European countries (see Table 1). It has borrowed a total of US$20.7 billion from multiple sources that include the World Bank, the International Monetary Fund, the Industrial Development Bank of Europe, South Korea, Japan, member countries of the European Community (EC), and private lenders. Some of this money is used to help make the Hungarian forint (currency) nearly convertible to Western currency. Some is being used to rebuild the infrastructure, and some is helping to keep the government afloat. The current external debt now is at US$17.5 billion, and the balance of payments is estimated by the World Bank to be US$389 million.

The World Bank has a commitment to help rebuild East European countries' infrastructures and now has US$13 billion allocated for this work. Much of the money will be allocated for projects in such areas as telecommunications and transportation.

Hungary is not waiting for overtures from Western companies, but is actively seeking joint ventures and business investments. Several joint ventures between US and Western European companies already are operational. Additionally, Hungary is pushing its currency toward convertibility to eliminate any stumbling blocks for trade with Western countries.

POLITICAL AND LEGAL CHANGES

With the exception of East Germany, now unified with West Germany as a single Germany, the governments of the Eastern European countries cannot be considered fully stable. Most still are debating state ownership versus privatization of industry. Hungary is one of the most progressive and capitalistically oriented countries, and therefore has a better opportunity to build trade with Western countries. It must be remembered, however, that stability for all of these governments depends on a growing and improving economy.

Hungary's parliament has passed three key pieces of legislation that position it close to a Western democracy: the right of private ownership, foreign investment liberalization, and transformation of state-owned businesses to the private sector. The government currently is working on a law to protect intellectual property and is reevaluating a 5 to 10 percent customs tax.

Under the private ownership laws, private companies may be organized in a variety of forms. These organizational forms include unlimited partnerships, limited partnerships, unions, joint enterprises, limited-liability companies, and companies limited by shares.

Three foreign investment provisions literally open the door to all foreign investment. One provision allows foreign investors to invest with an existing Hungarian company. The second provision enables foreign investors to start a company in Hungary that is 100 percent foreign owned. The third provision allows foreign investors to establish a Hungarian company with joint foreign and Hungarian ownership.

The transformation law allows the privatization of existing state-owned businesses. It allows a foreign investor to participate in a joint venture or buy the state-owned business outright. The law protects the capital investment and will suspend taxes on joint ventures for five years. One goal of this program is to have 50 to 60 percent of the state-owned businesses under private ownership within five years.

TECHNOLOGY BASE

Semiconductor/Component Production

One of Hungary's major assets is its people (see Table 2). Technically oriented, they manufacture computers, write software, and design and build communications systems. Hungary's university system is one of the few in Eastern Europe to offer courses in microelectronics. Hungarian political leaders express some fear that as Hungary makes stronger ties with the West, its technical leadership will be raided by Western companies.

Hungarian companies currently obtain most of their semiconductor components from the West. There is a limited production of semiconductor products using 4-inch wafers and 3-micron technology by Interbip Invest Microelectronics Company, Ltd., a private shareholding company.

A major Hungarian objective is to become as close to self-sufficient as possible in semiconductor production. It is likely that an upgraded Interbip fab and one other production facility could adequately supply the country's electronics companies.

TABLE 2
About the Hungarian People

Life Expectancy	70 years
Births per 1,000	12
Deaths per 1,000	13
Infant Mortality per 1,000	16
Maternal Mortality per 1,000	28
Childbearing-Age Women	48% of population
Physicians	1:310
Nurses	1:170
Daily Caloric Supply	3,569
Education:	
Literacy	>95%
Complete Primary	>97%
Female/Male Ratio	95:100
Complete Secondary	>70%
Female/Male Ratio	190:100
Complete Trade/College	15%
Teacher/Pupil Ratio	1:14

Source: Dataquest (November 1990)

Once there is an adequate indigenous semiconductor supply, Hungary hopes to become a major semiconductor supplier for the other Eastern European countries and the USSR.

Because of its existing telecommunications knowledge, expertise, product production, and marketing orientation, we believe that much of Hungary's semiconductor production will be oriented toward this application.

Computer Development

About five years ago, Hungarian companies began manufacturing computers. Slightly less than one-half of the nation's computer demand now is being met by Hungarian-manufactured computers. Estimates place the installed base at about $1 billion in PCs, minicomputers, and mainframes.

The two principal Hungarian producers, Muszertechnika and Videoton, make IBM-compatible systems. Computer production is mostly assembly, using motherboards purchased through Taiwan and Singapore. Other companies, such as Controll, sell and service computers partially built outside Hungary.

About 50 percent of the installed mainframes are from Hungary, the USSR, or East Germany and are IBM compatible. The other 50 percent of the mainframes are purchased from Western companies, with IBM having the largest share. More than 95 percent of the PCs are IBM compatible. Other computer manufacturers represented in Hungarian sales include Bull, Control Data, Hewlett-Packard, Honeywell, ICL, and Siemens. Most recently, Compaq announced that it signed agreements with four Hungarian companies to sell its computers in Hungary.

Telecommunications

It takes about ten years to get a telephone in Hungary, and this is without any population growth. Hungary has had nearly zero population growth for the past ten years. Currently, there are about 14 telephones per 100 people, considerably less than the 65 to 70 per 100 in Western Europe. The country is divided into 100 trunk lines, and some of the small rural communities have only switchboard-operated systems. As a result, Hungary's government has embarked on a ten-year, US$6.3 billion development program to bring Hungary's telephone system up to Western European standards.

The development plans include installing 3 million new telephone lines, reducing the wait time to one year, and providing digital transmission and switching, data transmission capabilities, optical fiber transmission, and ISDN capabilities. Most of the development will be completed by Hungarian companies, but with limited products and capabilities, the government will encourage joint ventures.

Today's public network is noisy, but data transmission at speeds of 1,000 to 2,400 baud is possible. A circuit-switching data network was imported from Japan in 1986 and is in use for some areas. Packet switching was barred from shipment to Hungary by Western companies for military reasons, but between 1975 and 1986 Hungarian communications specialists developed a packet-switching network for governmental use. Today, that network is available through the public-switched network used as a terminal.

Currently, more than 16 Hungarian companies are involved in telecommunications; many are planning to develop digital capabilities. Most of the joint ventures with Western companies involve communications. The joint ventures include the following:

- Northern Telecom (Canada)—Digital switching with data storage
- Siemens and Standard Elektric Lorans (an Alcatel-owned company) (Germany)—Digital microwave products
- Alcatel (France)—64 Kbit microwave system on cellular radio
- US West (United States)—Cellular radio development
- NCM Corp. (United States)—Bipolar semiconductor fabrication

The government also is looking for a company to participate in a joint venture to develop credit card pay telephones.

For anyone interested in exploring the opportunities of any developing economy, Dataquest has built computer models that will assist in evaluating the semiconductor usage and demand curves of a developing nation or region. The models can be fitted to different applications and evolving criteria.

DATAQUEST ANALYSIS

Each of the Eastern European countries will develop different political orientations with differing levels of affiliation to Western Europe. Hungary seems to be particularly focused on catching up to the capitalism of Western European countries. In evaluating any potential business opportunity, it is important to remember that the political stability depends greatly on the development of the economy. Although developing as separate nations, a situation in one Eastern European country can dramatically affect its neighbor nations.

Hungarian representatives will say that the best opportunities are in electronic product assembly and test for the Hungarian market, but Dataquest does not believe that this alone is a sufficient incentive for an investment. Dataquest believes that the real opportunities lie in using the already-established market connections to service a greater part of the Eastern European market from Hungary. It is likely that Hungary will be an economic driver in Eastern Europe.

There do appear to be opportunities to install a semiconductor fabrication facility, either as a joint venture or independent company. It seems that the most immediate market lies in telecommunications applications, especially because it appears that some funding is allocated for these applications.

Dataquest does not believe that Hungary, or any of the other Eastern European countries, will be accepted into the EC in the next several years. Two of the EC requirements are a Western-style government and capitalistic economy, both of which Hungary is building. It would be a severe economic hardship for the EC to try to assimilate Eastern European countries. A limited, associate-type, no-tariff affiliation would be possible in three to five years for countries such as Hungary that are completely focused on economic growth.

Marc Elliot

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Research Newsletter

TRIADS TOWARD ECONOMIC PROSPERITY

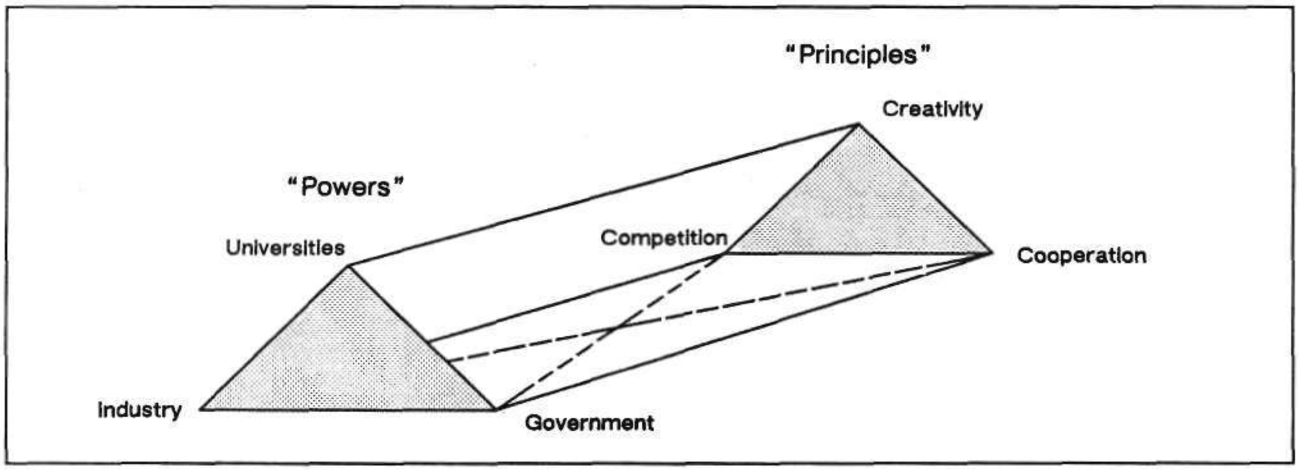
INTRODUCTION

The drama of trade negotiations between the United States and Japan has permeated the mass media for close to two decades. As has been observed during the past decade, the semiconductor industry highlights some of the trade tensions and issues that can arise between two staunch allies. Recently, the Structural Impediment Initiative (SII) negotiations have taken center stage. This latest series of negotiations has attempted to correct some infrastructural flaws that are believed to stymie economic growth and inhibit free trade between the United States and Japan. Through the SII negotiations, Japan basically is being asked to develop its domestic economy in order to de-emphasize its export drive economy. The United States, on the other hand, is being asked to reduce its federal deficit and create an environment conducive to increased savings and investment while de-emphasizing its consumption of goods. The SII actions are noble, and the efforts of those directly involved should be applauded. However, the underlying goal of these trade negotiations is to foster the growth of economic prosperity in both nations. Dataquest believes that the dynamics of economic prosperity go far beyond trade negotiations.

POWERS AND PRINCIPLES TRIADS

Prosperity will be driven by a country's ability to leverage all its resources and to nurture the "powers" and "principles" of economic success. "Powers" encompasses the interrelationship of three key infrastructural seats of influence: industry, government, and universities. "Principles" encompasses the interrelationship of three key intangible forces: cooperation, competition, and creativity. For advanced economies, powers and principles are highly interdependent. Figuratively, the interrelationship of all six elements can be represented by a prism, as shown in Figure 1.

FIGURE 1
Powers and Principles Prism



Source: Dataquest (September 1990)

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One end of the prism represents the industry, government, and university triad, while the other end of the prism represents the principles of competition, creativity, and cooperation. Although the power and influence of industry, government, and universities tends to vary over time and from country to country, the ultimate goal is for these seats of influence to strike a balance among themselves that is conducive to the growth of competition, creativity, and cooperation. Today, the strongest bonds typically are found between industry and competition, universities and creativity, and government and cooperation. As globalization becomes an economic necessity, these bonds will become stronger and more intricate. Although unheard of in the past, researchers from industry, universities, and government today work side by side in laboratories, sharing their ideas about emerging technologies. However, even with this cooperative spirit in the laboratories, industries are competing as hard as ever in the marketplace.

THE UNITED STATES

The United States is world-renowned for competitive, creative industries. The United States traditionally has set records for the world's firsts in science and technology. The United States also is recognized for a world-class university system that works and cooperates with industry and government. However, the infrastructural link that is strained appears at the cooperation level between government and industry. The country is lost in an internal struggle to define the role of government in industry. Battles continue to be waged over whether the government's role in industry should be that of planner, coordinator, facilitator, or investor. Some influential people are calling for an industrial policy, while others advocate a laissez-faire approach. Meanwhile, as government vacillates from one role to another, private industries are held hostage in the international trade marketplace. The tenuous status of government contributions to Sematech is only one of many examples where government vacillates between support and nonsupport of industry.

JAPAN

Japan, like the United States, also is world-renowned for its highly competitive products. In contrast, however, Japan has established a dynamic level of cooperation between government and industry. Japan's current economic prowess can be directly attributed to the efforts of industry in concert with the support and guidance of its governmental ministries. Again, in contrast with a key strength of the United States, Japan's infrastructural weakness appears at the creativity level between industry and university scientists. This weakness has compelled some key Japanese scientists to pursue their research outside of Japan because of the lack of a supportive environment from industry. However, Japan is taking steps both to strengthen and to compensate for any infrastructural weakness.

One step taken by Japan has been to organize consortia that bring researchers together from industry, academia, and government to develop basic technology. The recent creation of the Laboratory for International Fuzzy Engineering (LIFE) by the Ministry of International Trade and Industry (MITI) and over 48 participating companies is a good example. LIFE's charter is based on the development of fuzzy logic theory, its applications, and the promotion of research exchange between industry and academia. In an attempt to bring academia and industry together, the charter clearly spells out the inclusion of academia in the development of fuzzy theory and applications.

Another step taken by Japan has been to actively support the development of basic research at US universities. Universities have received support from Japanese companies in terms of funding university endowments and on-campus research and sending visiting scientists to university laboratories. Furthermore, Japanese companies have built company research and development centers near the major university laboratories that they have helped fund.

DATAQUEST CONCLUSIONS

The international order is changing in a dramatic way. Economic prowess rather than military prowess is quickly becoming the key measure of powerful nations. Globalization is rapidly becoming the avenue toward the attainment of economic prosperity, which will only come through recognizing and fostering the dynamics of change. To master the dynamics of change, industry, government, and universities need to work together in the spirit of cooperation, competition, and creativity. Ultimately, the society that recognizes and fosters this metamorphosis will stand in a position of economic strength.

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Len Hills

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Research Newsletter

ISRAEL: A BRIDGE TO EUROPE FOR UNITED STATES COMPANIES

INTRODUCTION

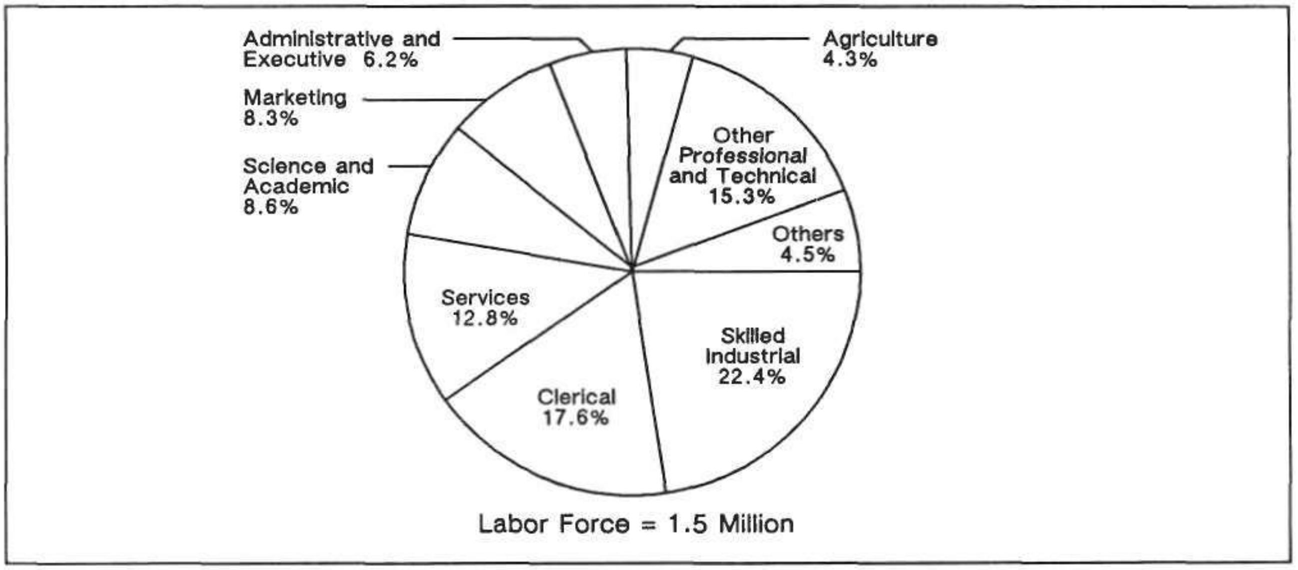
Access to the European electronics market is going to become difficult and expensive. As the investments in Europe increase, countries will no longer offer incentives to build new manufacturing facilities. Already there is growing industry concern of overcapacity; therefore, evaluating return on investment is even more critical as competition in Europe increases. The resulting tighter price constraints then force us to explore other options.

One option is Israel. Although not on the European continent, Israel, because of unique trade agreements, offers a nearly tariff-free, two-way bridge between the United States and Europe. It also has favorable trade arrangements with other countries.

Situated on the eastern shore of the Mediterranean Sea between Lebanon and Egypt, Israel is approximately the size of New Jersey and has a population approaching 4.5 million with a work force of 1.5 million (see Figure 1). But, although not part of the European continent, the flight time between Ben Gurion Airport near Tel Aviv and Heathrow in London is five hours—less than the flight time between San Francisco and New York. Also, from Tel Aviv to Paris or Rome takes less flight time than from Los Angeles to Chicago or Los Angeles to Denver, respectively.

Israel's climate is similar to that of southern California. With a nearly year-round growing season, it is ideal for agricultural production; however, two-thirds of its $11 billion in exports last year were industrial goods, many of which were high

FIGURE 1
Work Force by Type of Work



Source: Central Statistics Bureau of Israel, Igal Brightman & Co., CPAs tech. Israel has the highest percentage of persons with multiple degrees of any country in the world. Nearly one-half of them have technical degrees. This fact contributes to Israel's rapidly developing image as a high-tech producer nation.

Overwhelmingly outnumbered in personnel and arms by neighboring countries that have not yet resolved the 1967 or 1973 wars, Israel resorted to developing an electronic proficiency to balance the odds. This proficiency has led to world leadership in electronic detection, avoidance, targeting, and guidance. Israeli companies now hold contracts with US defense contractors and the Department of Defense (DOD) to develop US weapons systems.

In May 1989, Israel surprised the world by launching a low-level surveillance satellite that was developed and produced entirely within Israeli industry. This launch makes Israel one of the few countries possessing such highly sophisticated technology. In April 1990, Israel launched a second satellite for astronomy studies.

SUMMARY

Israel holds a unique position for value-added manufacturing for products being shipped to Europe. They are not subject to European Community (EC) tariffs. The country has similar agreements with the United States and tariff reduction agreements with 12 other countries. Israel also has strong relationships with the Eastern European countries, which already look to Israel for technical expertise.

The labor force in Israel has an extremely high proportion of technically skilled personnel. There is a higher proportion of engineers per capita in Israel than in either the United States or Japan. Although Hebrew is the official language, English is common, particularly among the technical personnel. Also, the fully burdened labor cost for engineering talent is lower than in most other developed nations.

To entice businesses to locate in Israel, the State of Israel offers attractive government assistance packages that include facility grants up to 38 percent of the capital investment, research and development (R&D) grants for technology development, and reduced tax rates. There are also private foundation grants for joint R&D projects between Israeli and non-Israeli companies.

In spite of the fact that an Israeli facility can provide an excellent return on investment, doing business in Israel can seriously challenge the fainthearted. Although they are not evident inside Israel, political problems include:

- A boycott of Israel has been maintained by Arab nations since the formation of the State of Israel in 1948, although the number of those nations honoring the boycott is declining substantially.
- A technical state of war still exists between Israel and neighboring nations Syria and Jordan, which have not signed peace agreements to end the 1967 or 1973 wars. The problem is further compounded by the territories Israel captured from Jordan in 1967 and still administers.
- There is periodic rioting and civil disobedience by Palestinians, living in the 1967 territories, who want self-determination.
- Neighboring Lebanon is enmeshed in civil war.
- The diversity of Israel's political government makes it difficult for the government to develop a cohesive plan to deal with the turmoil or to take a leadership role in bringing peace to the Middle East.

TRADE AGREEMENTS: CONTINENTAL BRIDGES

In 1975, Israel signed an agreement with the then six-member EC to eliminate tariffs on most products traded between Israel and the European member countries. Although the agreement does not make Israel a member of the EC, it gives the nation a status equal to that of an associate member. This agreement also covers the countries that have joined the EC since 1975. The agreement means that tariffs are not levied on Israeli-manufactured electronics. Such tariffs are applied to products from countries outside Europe, including US-manufactured products.

The agreement, however, rules out the operation of "screwdriver factories" in Israel with the rules of origin. The rules of origin apply the same as they do in any EC member nation—35 percent local content, including R&D costs. With the latest interpretation for semiconductors, processing must take place in an EC member nation, or Israel, to be considered a nontariff product. Semiconductor die imported from the United States to Europe currently are subjected to a 9 percent tariff, and packaged semiconductors or board products carry a 14 percent tariff.

The trade relationship with the United States started in 1951 with the signing of the Friendship, Commerce, and Navigation Agreement and the Most Favored Nation (MFN) agreement. In 1976, Israel joined the Generalized System of Preferences (GSP) program. Under MFN, about 55 percent of Israel's products have been duty-free to the United States since 1951. Joining the GSP program in 1976 brought this level to 90 percent.

In 1985, Israel and the United States signed an agreement forming a Free Trade Area (FTA) to gradually eliminate all remaining tariffs and trade restrictions between the two countries. With these agreements, it is possible to make products in Israel that can be sold in Europe at a lower point-of-sale cost than if they were imported directly from the United States or even produced in Europe.

Israel also has tariff reduction agreements with Australia, Austria, Brazil, Canada, Finland, Japan, Korea, New Zealand, Norway, Sweden, Switzerland, and Turkey. Ties also exist between Israel and the Eastern European countries. Diplomatic relations were established before the iron curtain came down, and some business relationships are already in place.

INDUSTRY, ECONOMICS, AND LIVING CONDITIONS

Experiencing a flat, if not recessionary, economy for more than two years, Israel is starting to see a turnaround. The estimated 1989 gross national product is $40 billion (see Figure 2) with exports of $11 billion and imports of $13 billion. Nearly one-half of the imports and one-quarter of the exports involve trade with the EC.

Israel has heavy defense obligations, which limit resources for economic development (see Table 1). However, Israel always has paid its foreign debt obligations. The defense spending, substantial social service commitments, and a dependency on imported raw materials have contributed to an annual inflation rate that was as high as 445 percent in 1984. Inflation has been contained at an annual rate of 16 percent since 1987.

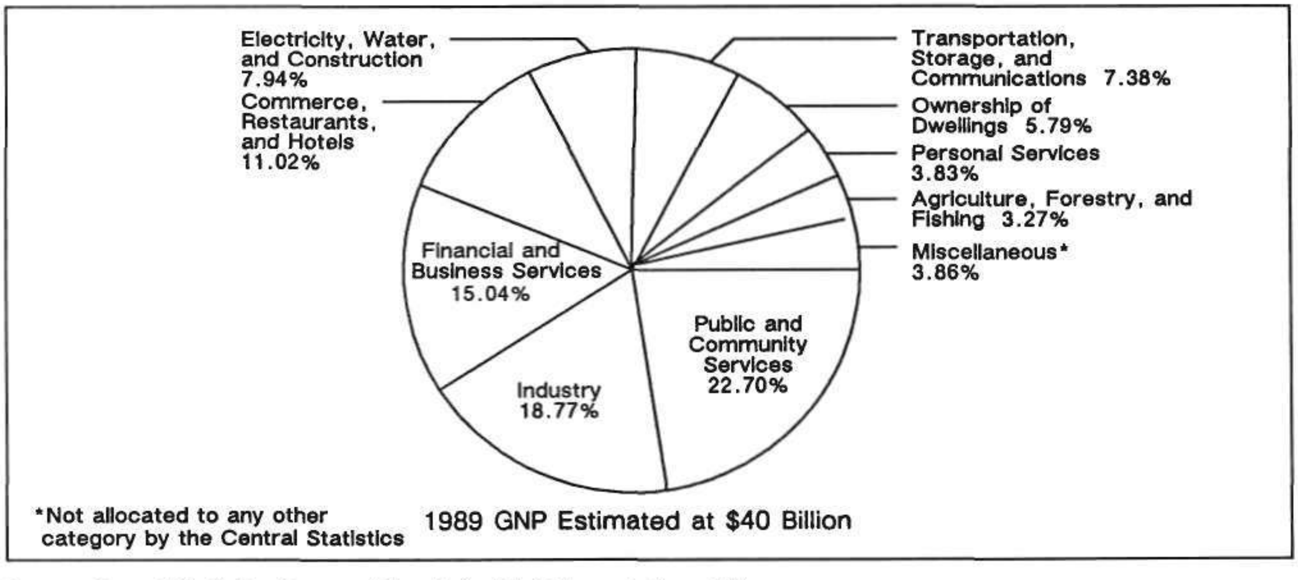
Exports are increasing (see Table 2). At 83.9 percent of imports in 1989, exports are up from 76.7 in 1988. Three free trade zones exist at

TABLE 1
Balance of Payments (Billions of US Dollars)

	1988	1980	1970
Total Deficit Account for Goods and Services	5.3	3.8	1.3
Deficit Less Defense Imports	3.3	2.1	0.6
Foreign Obligations	31.1	22.1	3.3
Foreign Assets	12.5	10.1	1.0

Source: Igal Brightman & Co., CPAs

FIGURE 2
GNP by Domestic Products



Source: Central Statistics Bureau of Israel, Igal Brightman & Co., CPAs

TABLE 2
Israel Foreign Trade (Billions of US Dollars)

	1989	1988	1980	1970
Net Imports	13.1*	12.3	7.8	1.4
Net Exports	11.0*	9.4	5.3	0.7
Excess Imports	2.1	2.8	2.5	0.7
Export as % of Import	83.9	76.7	67.2	51.2
Agricultural Exports	NA	0.5	0.5	0.1
Industrial Exports	NA	6.3	3.3	0.3
Diamond Exports	NA	2.8	1.6	0.2
Imports				
Consumer Goods	NA	1.4	0.5	0.1
Production Material	NA	9.5	6.5	0.9
Investment Goods	NA	1.9	0.9	0.3

NA = Not available
*Estimate
Source: Central Statistics Bureau of Israel/Igal Brightman & Co. CPAs

Israel's three seaports, Elat on the Red Sea and Haifa and Ashdod on the Mediterranean.

Although Israel was originally formed as a socialistic economy, the country now is rapidly moving toward a capitalistic, market-driven economy. The state currently is selling shares of the government-owned businesses, such as the airline and utilities. This policy change is planned to remove the government from industry ownership and to generate badly needed revenue.

Infrastructure

Israel has embarked on a concentrated effort to attract business and industry. In the process, the government is rebuilding and expanding the nation's infrastructure.

Near Ashkelon, a new, state-of-the-art electricity-generating plant will expand capacity by 25 percent of the nation's current demand. The plant is ahead of most environmental standards, removing 99.97 percent of all pollutants. Also, planning is complete to double the capacity of the Haderia plant, which is north of Tel Aviv.

Transportation and communication facilities are marginally adequate for the current load, but they need to be improved and expanded for long-term economic growth. Little was spent during the past three years on maintaining roads, but now the Ministry of Interior is releasing funds for road and communication improvements. Both maintenance/repair projects and expansion projects are planned.

Cost of Living

Inflation is being contained at 16 percent, and the currency exchange rate now is approximately two Israeli shekels for one US dollar. Locally grown fruits, vegetables, and poultry cost well below the US scale, but not the proportional one-third to one-half one would expect from the salary scale or the exchange rate. This inequality makes imported consumer goods increasingly expensive. In May, certain consumer items other than groceries appeared to be slightly more expensive than during May 1989.

Public transportation, which is government subsidized, is excellent and very inexpensive by US standards. Within cities, a single bus ride costs 60 to 75 cents, depending on the city. Discounted multiple-ride tickets and monthly passes are available through local shops. The cost for bus travel between towns also is quite reasonable, and most of the routes have frequent schedules. Even many remote locations of the country are served more than once a day.

Housing

Currently, with the large number of Russian immigrants, housing is in short supply. But new houses are being built all across the country. Although there are single family houses, they are significantly more expensive than apartment-style housing. The dominant construction is apartment or condominium-style housing units. The majority of the units are owner-occupied.

Prices for an average 1,000- to 1,500-square-foot apartment ranges from US$65,000 to US$85,000 in the outer suburbs of Tel Aviv to US$130,000 and more in Tel Aviv proper. The rent for an average two-bedroom apartment in Tel Aviv is between US$400 and US$1,000 depending on location and amenities.

LABOR FORCE

The size of the Israeli work force is about 1.5 million persons and represents 35.0 percent of the total population. About 40.0 percent of the work force are women. Unemployment was

8.6 percent in the last half of 1989, up from 6.4 percent in 1988. Much of the unemployment is attributed to the influx of immigrants, which also makes it unlikely that wages will increase appreciably in the near term (two to four years).

Wages for the average clerical worker are between US$700 and US$950 a month (see Table 3). The fully burdened rate (total overhead, including salary benefits and all company costs) for an engineer with five years of experience is about $40,000 a year.

Some industries are highly unionized, but these are mainly government-owned. In past years, when the labor party was in power, there were some potential problems in productivity and economic balance. There also are still periodic strikes in some industries, such as the socialized health care sector. However, the country is modernizing its employment laws. A law prohibiting discrimination was implemented in 1988, ensuring fairness in the workplace.

Today, with the growing government emphasis on privatization, union political influence is diminishing. There is little union impact on privately owned industries, especially now that the government is striving for economic development and growth.

Israelis are some of the most highly educated people in the world. On average, there are more college degrees and advanced degrees per capita than in any other country in the world. Between 1970 and 1988, about 182,000 students received university degrees in Israel, of which nearly 6,500 were Ph.D. degrees.

Although Hebrew is the official language, more than 70 languages and dialects are commonly spoken. Most Israelis speak multiple languages. The average Israeli reads 20 books a year, compared with 3 in the United States and 7 in most other highly read countries of the world.

GOVERNMENT INCENTIVES

The Israel government, competing with other nations of the world for industrial development, offers a variety of incentives to companies willing to work in Israel.

R&D Grants

Two forms of grants are available to companies willing to participate in Israel's development. The first is a government grant for R&D. The company ownership need not be Israeli, but the company must have a facility in Israel, and the R&D must be performed in Israel.

The second type of grant is from a private foundation for R&D projects performed in partnership between an Israeli company and a non-Israeli company. In this situation, the R&D must be performed in Israel, but the non-Israeli partner does not need an Israel location.

TABLE 3
Work Force by Economic Sector--Average Monthly Wages (US Dollars)

Economic Sector	1989 Monthly Wages	Employment Percentage
Agriculture, Forestry, and Fishing	651	4.6%
Industry (Including Mining)	1,205	22.3%
Electricity and Water	2,111	1.0%
Construction	916	5.1%
Commerce, Restaurants, and Hotels	947	14.3%
Transport, Storage, and Communication	1,572	6.6%
Financial and Business Services	1,162	10.2%
Public and Community Services (Government)	911	29.2%
Personal and Other Services	723	6.7%

Source: Central Statistics Bureau of Israel/Igal Brightman & Co., CPAs

Tax Benefits

The Israel government is willing to give several tax incentives to companies that wish to locate a facility in Israel. Income tax often is not charged during the first year or two of operation; after that, it remains at a reduced rate for some time. Also, income taxes are charged only on business transacted through the Israel facility to help eliminate double taxation.

Government Assistance

The Israel government will make direct incentive payments to companies willing to locate a facility in Israel. Up to 38 percent of a company's new facility costs (land, building, and facility equipment) may be paid by the government. In addition, the government will help a company find the location that is best for the company within the various industrial zones.

POLITICAL POSITION

Government Structure

Israel has a parliamentary democracy form of government that is similar to the British structure. The country is governed by a cabinet that is headed by a prime minister. The cabinet is responsible to the Kenesset (parliament) and is subject to a vote of confidence by the Kenesset.

There are 120 members in the Kenesset with the proportional number of seats for each party determined by a public election every four years. To form a cabinet, a party must have control over 61 seats of the Kenesset. Every five years, the Kenesset elects a president, whose duties are mainly ceremonial, as head of state.

1967 Territories

In 1967, Israel went to war with Egypt, Syria, and Jordan. Known as the Six-Day War, Israel captured territories that previously had been accorded to Jordan and Egypt when the British mandate administration ended in 1948.

On March 26, 1979, Israel signed a peace treaty with Egypt, which led to the reinstitution of diplomatic, economic, trade, financial, tourist, and industrial relations between the two countries. At that time, Israel returned the Sinai territory to Egypt.

Although there is no open conflict, Israel technically is at war with Syria and Jordan, so the remaining territories still are being administered by Israel. These territories are the areas in which Jordan and Egypt had settled the original Palestinian refugees from the Israel War of Independence in 1948.

It is in these territories that there have been Palestinian riots and demonstrations in an effort to gain self-determination. Although the violence is diminishing, it is unlikely that there will be a speedy settlement of the issues surrounding these territories. The situation is further confounded by Israelis settling in the territories.

Conservative Government

The current government, under Prime Minister Yitzhak Shamir, is a coalition of parties that is considered to be on the conservative side of Israel's political spectrum. What this means is a continuing movement away from socialistic economic policies and more emphasis on market-driven free enterprise policies. The privatization of government-owned industries is one such example. The encouragement of industry growth and enticement of foreign investment are other illustrations.

These policies are most likely to continue in the short term (two years or more). Long-term continuation will depend on the economic improvement gained over the next two to four years.

The installation of a conservative government also means less likelihood of an early peace settlement involving the 1967 Territories. Many Israeli people believe that the country needs this conservatism, that it represents the position of strength necessary to get a peaceful settlement with its neighbors. Although it is not comfortable to know that there is a potential for violence nearby, there is far less violence inside Israel's borders than in most major US cities on any given day.

DATAQUEST CONCLUSIONS

Companies that are considering establishing an offshore production facility for access to Europe, Eastern Europe, and the USSR should consider Israel. Although there are risks, the positive aspects could outweigh those risks.

Dataquest believes that the best opportunities lie in establishing research, design, and development centers. Establishing an assembly or packaging plant also is a very practical approach, but the rules of origin eliminate screwdriver plants for European access.

A major asset for Israel is the high talent level of the work force. The cost for this talent is substantially less than in the United States or even in Europe. The government, pushing for a stronger economy, offers enticing incentives for companies to locate at least part of their business there.

Although the rapport between the Bush administration and the Shamir government is diminishing, the Israel government will remain strategically very close to the United States. It provides one of the few fully secured military access points to the Middle East for the United States—a position that the United States may need with the pull-back of US forces from Europe. If the United States were to withdraw its $3 billion a year in aid to Israel, the impact would hurt but not devastate Israel's economy.

Marc Elliot

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Research *Bulletin*

BOOK-TO-BILL FIGURES SHOW RECOVERY IS UNDER WAY

The May World Semiconductor Trade Statistics (WSTS) book-to-bill ratio shows a return to a strong semiconductor ordering position, surprising many market watchers. And although the book-to-bill ratio is only one indicator, the semiconductor market actually is growing stronger, living up to an earlier Dataquest forecast.

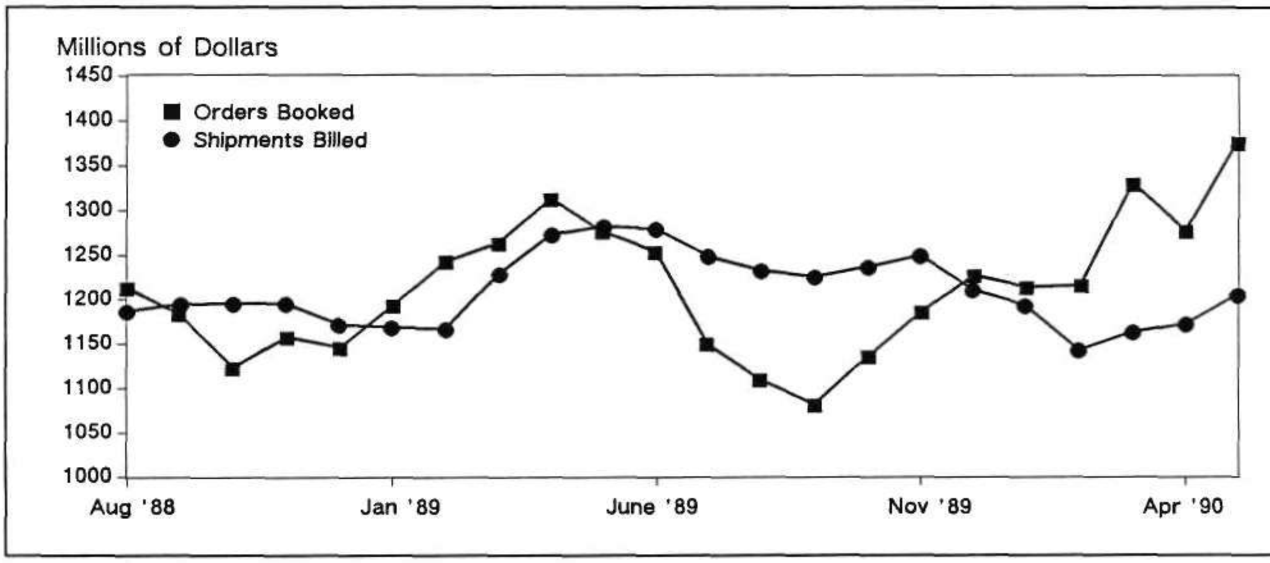
The May US three-month moving average bookings hit an all-time high of $1,379.6 million, up 7.8 percent from April's $1,279.3 million (see Figure 1). Bookings are also up 13.2 percent from the $1,218.2 million reported in February, the last midquarter month, and up 8.0 percent from a year ago. May US billings are $1,177.6 million, up 5.7 percent from April's $1,114.0 million and 6.3 percent from February's $1,107.7 million. Compared with last May's $1,233.7 million, however, May billings are down 4.5 percent.

In Europe, the book-to-bill ratio is steady at 1.17, indicating continuing growth. However, bookings are the same as last month at $940.0 million, and billings have slipped slightly from $771.5 million in April to $745.7 million in May.

Traditionally, May is the last growth month before semiconductor sales flatten out for the summer slump. However, this year the US indicators point to a stronger-than-average market well into summer. Europe appears to be following the more traditional pattern.

One indicator of continuous growth is that May is the third consecutive month average weekly US billings and bookings have increased. This fact is important because after a brief respite, most semiconductor prices are continuing to decline. This means that there must be progressively stronger unit growth to be able to increase dollar

FIGURE 1
Three-Month US Average Orders and Shipments



Source: WSTS

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growth—an unusual condition for a market about to enter the summer doldrums.

Dataquest expects prices for memory products and standard microprocessors to continue to decline through the end of the year. Overall prices on logic products should remain flat, with some price decline in the older-technology products and price increases in new-technology products.

A second indicator of continued growth is that component buyers say they are increasing June semiconductor purchases over May's procurement level by as much as 20 percent. This semiconductor growth appears to be driven by moderate systems growth rather than by inventory building, say buyers.

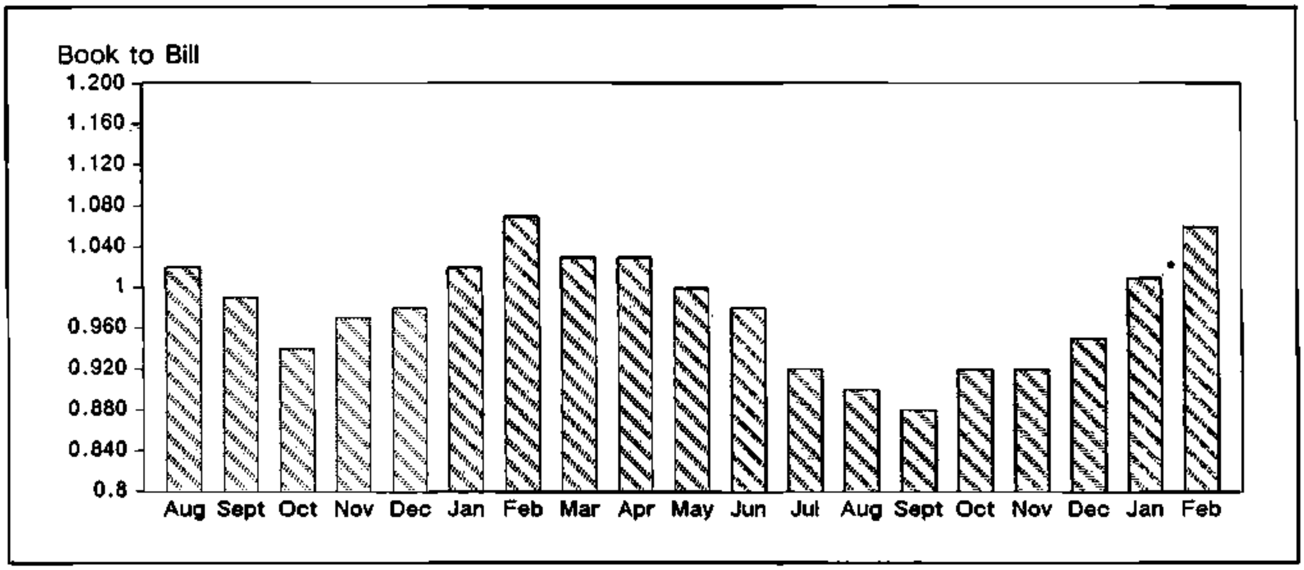
The book-to-bill ratio (see Figure 2) is only one of many indicators to watch when analyzing the semiconductor market. It can go up because billings are actually going down faster than bookings. It can go down because billings are actually going up faster than bookings. If billings and bookings move together, the ratio will indicate a flat market, even when the market is actually growing or shrinking. The book-to-bill showed a dip from March to April, while the average weekly bookings and weekly billings both grew.

DATAQUEST ANALYSIS

Dataquest believes that the semiconductor recovery is here and the market will remain untraditionally strong, with minor fluctuations into fall. The overall outlook for the next six months is improving sufficiently to project a 9.4 percent growth versus the 7.8 percent we forecast in April.

Marc Elliot
Patricia Galligan

FIGURE 2
US Market Book-to-Bill Ratio



Source: WSTS

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Research Newsletter

QUARTERLY SEMICONDUCTOR COMPANY FINANCIAL RESULTS

INTRODUCTION

Dataquest regularly reports on semiconductor company financial results through its weekly on-line news service, *The DQ Monday Report*. As a service to the *Products, Markets, and Technology* segment binderholders, a summary of this information is provided herein.

Table 1 summarizes the net sales and income disclosures of selected semiconductor companies based on data from quarterly report periods that ended during the February-through-April time frame. This information is compared with the corresponding 1989 time frame and is provided in millions of dollars unless otherwise indicated. Figures 1 and 2 show the percent change by quarter for aggregate company revenue and net income, respectively, from the first quarter of 1989 through the first quarter of 1990. Descriptive summaries of quarterly performance highlights for the companies listed follow.

TABLE 1
Quarterly Financial Summaries for Selected Semiconductor Companies (Millions of Dollars)*

Company (qtr. end, fiscal qtr.)	Latest Quarter Revenue	Percent Change	Latest Quarter Income	Percent Change
Adaptec (March 31, Q4)	30.6	57%	4.3	475%
AMD (April 1, Q1)	271.5	1%	13.1	23%
Altera (March 31, Q1)	17.3	39%	3.1	34%
Burr-Brown (March 31, Q1)	41.9	(5%)	1.6	(48%)
CMD (March 31, Q3)	6.9	(6%)	161K	NM
Chips & Technologies (March 31, Q3)	66.4	16%	5.0	(47%)
Cirrus Logic (March 31, Q4)	28.5	135%	5.2	184%
Cypress Semiconductor (March 31, Q1)	52.8	14%	8.3	16%
Dallas Semiconductor (April 1, Q1)	23.9	40%	3.3	53%
IDT (April 1, Q4)	52.1	10%	3.0	(29%)
Intel Corporation (March 31, Q1)	894.0	25%	144.0	48%
Lattice Semiconductor (March 31, Q4)	13.1	113%	2.7	272%
Linear Technology (April 1, Q3)	19.1	16%	2.9	35%

(Continued)

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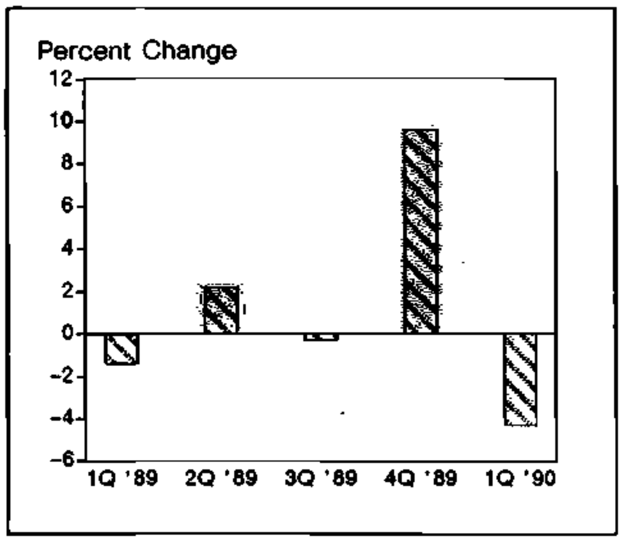
TABLE 1 (Continued)
Quarterly Financial Summaries for Selected Semiconductor Companies (Millions of Dollars)*

Company (qtr. end, fiscal qtr.)	Latest Quarter Revenue	Percent Change	Latest Quarter Income	Percent Change
Logic Devices (March 31, Q1)	3.3	(10%)	433K	(64%)
LSI Logic (April 1, Q1)	139.1	4%	2.1	(74%)
Maxim (March 31, Q3)	14.4	36%	2.0	33%
Micron Technology (March 1, Q2)	77.5	(32%)	14K	(100%)
Motorola (March 31, Q1)	2,533.0	16%	127.0	3%
National Semiconductor (Feb. 25, Q3)	404.2	7%	(10.2)	NM
SEEQ Technology (March 31, Q2)	11.5	(26%)	(4.5)	NM
Texas Instruments (March 31, Q1)	1,536.0	(4%)	13.0	(85%)
VLSI Technology (March 31, Q1)	78.8	31%	2.3	NM
Weitek (March 31, Q1)	15.2	42%	2.1	42%
Western Digital (March 31, Q3)	286.8	18%	8.8	100%
Xicor (March 25, Q1)	19.8	(10%)	(6.9)	NM

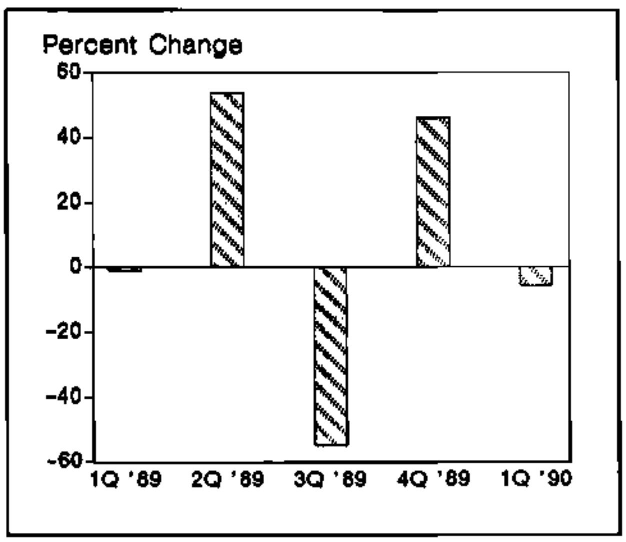
*Unless otherwise indicated
NM = Not meaningful
K = Thousands
Source: Company literature

FIGURE 1
Aggregate Company Revenue
Percent Change



Source: Dataquest (June 1990)

FIGURE 2
Aggregate Company Net Income
Percent Change



Source: Dataquest (June 1990)

THE COMPANIES

Adaptec

Adaptec announced net income of $4.3 million on sales of $30.6 million for its fourth fiscal quarter. The company reported net income of $13.2 million on sales of $109.3 million for the fiscal year ended March 31. These figures represent a 69 percent increase in revenue and a 689 percent increase in earnings over last year. Adaptec attributed its fifth consecutive quarter of record revenue to the company's continuing success in securing SCSI and AT design wins. The company also raised additional cash with another public offering in January.

Advanced Micro Devices (AMD)

AMD announced that its first-quarter revenue was essentially flat, compared with the prior quarter and with the first quarter of 1989. Revenue of $271.5 million resulted in marginal profitability of operations. The company attributes the $13.1 million in earnings to a one-time gain realized with completion of the sale, leaseback, and technology-transfer transaction with Sony. AMD reported surging bookings in the quarter, with bookings exceeding billings by the greatest margin in two years. Stronger bookings for EPROMs and PLDs came too late in the quarter to affect the quarterly revenue figure.

Altera

Altera announced net income of $3.1 million on sales of $17.3 million for the first quarter, ended March 31. These figures represent increases of 34 and 39 percent, respectively, over those reported in the same period a year ago. The company achieved record quarterly sales in the most recent quarter, the same period in which manufacturing operations were physically moved from Santa Clara, California, to a new and larger facility in San Jose, California.

Burr-Brown Corporation

Burr-Brown announced net income of $1.6 million on sales of $41.9 million for the first quarter of 1990, ended March 31. Although revenue was down only 4.8 percent from the same period in 1989, net income was down 48.0 percent from that earned in the first quarter of 1989. The company reported an increase in bookings of 30.0 percent over the fourth quarter of 1989. Slow growth in its Japanese market and pricing pressure were used by Burr-Brown to explain the company's slow growth.

California Micro Devices (CMD)

CMD reported net income of $161,000 on sales of $6.9 million for its third quarter, ended March 31. For the first nine months of fiscal 1990, CMD reported income of $1.1 million on sales of $25.3 million. The company enjoyed a 31 percent increase in revenue over the same period last year. CMD cites delayed bookings of several aerospace orders and sluggish bookings in the Microcircuits Division for the third quarter revenue decline.

Chips and Technologies

Chips reported net income of $5.0 million on sales of $66.4 million for its third fiscal quarter, ended March 31. Despite a 15.7 percent increase in revenue, Chips suffered a 46.8 percent decline in net income as compared with the like period a year ago. Price erosion and the shortage of 32-bit microprocessors were mentioned by the company as contributors to the sluggish quarterly results.

Cirrus Logic

Cirrus reported net income of $5.3 million on sales of $28.5 million for its fourth quarter, ended March 31. For fiscal year 1990, Cirrus announced revenue of $85.0 million and net income of $15.4 million. For the year, Cirrus recorded a 131 percent increase in revenue and a 279 percent increase in earnings. The company cites the strength of its major markets and the general acceptance of Cirrus Logic products as keys to the company's continued success.

Cypress Semiconductor

Cypress reported earnings of $8.3 million on sales of $52.8 million for the first quarter of 1990. During the quarter, Cypress broke records for both revenue and profits. The company reported operating profit margins at 21 percent of revenue while maintaining a strong R&D effort at 24 percent of revenue. Cypress also closed the quarter with a record backlog.

Dallas Semiconductor

For its first-quarter results, Dallas Semiconductor reported net income of $3.3 million on sales of $23.9 million. These figures represent increases of 53 and 40 percent, respectively, over the same quarter a year ago. The company attributed growth to the following 5 of its 14 product families: timekeeping, microcontrollers, battery backup, silicon-timed circuits, and telecommunications. During the quarter, Dallas Semiconductor purchased additional facilities and land to accommodate continued growth, and it was announced that the company's common stock was listed on the New York Stock Exchange.

Integrated Device Technology (IDT)

IDT reported that, although revenue for its fourth quarter increased 10 percent over the same quarter last year to $52.1 million, net income declined 29 percent to $3.0 million. The company cited ongoing pricing pressure as the reason for the earnings decline. Revenue for fiscal year 1990 was $209.5 million, an increase of 16 percent over the prior year. Net income for the year declined 5 percent to $17.0 million. During the fourth quarter, IDT achieved the first working silicon from its new fab, which will not start generating substantial revenue until the fourth quarter of this year.

Intel Corporation

Intel announced record quarterly earnings for the first quarter, ended March 31, 1990. Revenue for the quarter was $894 million, up 25 percent from $713 million a year ago. Net income was $144 million, a 48 percent increase from $97 million in the first quarter of 1989. First-quarter 1990 revenue was unchanged from fourth-quarter 1989 revenue of $895 million, while net income increased from $123 million in the previous quarter. The company attributes its success to strong demand for its 32-bit microcomponents, including a doubling of 386 shipments over last year's first quarter.

Lattice Semiconductor

Lattice announced year-end net income of $6.8 million on sales of $38.9 million. These figures represent increases of 206 percent and 81 percent, respectively, over last year. For the fourth quarter, ended March 31, the company reported net income of $2.7 million on sales of $13.1 million. In the past year, the company has opened a sales subsidiary in West Germany; a sales office in Tokyo, Japan; and a product development center in San Jose, California. Worldwide growth and market acceptance of its products have contributed to Lattice's recent success.

Linear Technology Corporation (LTC)

LTC announced record net sales of $19 million for its third quarter, ended April 1. The company also reported record net income of $2.9 million for the quarter. These figures represent a 16 percent increase in revenue and a 35 percent increase in net income, when compared with the same period a year ago. LTC attributed the strong financials to steady growth in all of its major markets, both foreign and domestic.

Logic Devices

Logic Devices reported net income of $433,000 on revenue of $3.3 million for the quarter ended March 31. These figures represent declines of 63.8 percent and 10.5 percent, respectively, from the same period a year ago. During the quarter, the company took steps to correct problems encountered in the last quarter of 1989 when Logic Devices reported a loss of $1.6 million on fourth quarter revenue of $3.1 million. Both direct and indirect expenditures were reduced.

LSI Logic

LSI Logic has reported a return to profitability in the first quarter, aided by record bookings, improved factory utilization, and cost controls. The company reported revenue of $139.0 million and net income of $2.1 million for the first quarter, ended April 1. Compared with the like quarter one year ago, revenue was up 4 percent and net income was down 74 percent. Despite this figure, the positive net income is a turnaround from a loss of $1.7 million in the fourth quarter of 1989.

Maxim

For its third fiscal quarter, ended March 31, Maxim reported record sales of $14.4 million and net income of $2.0 million, increases of 36 percent and 33 percent, respectively, over the same period a year ago. During the quarter, the company introduced 15 new products. Maxim also recorded $19 million in bookings in the third quarter.

Micron Technology

Micron Technology has reported revenue of $77.5 million for the second fiscal quarter of 1990, ended March 1. This figure represents a 32 percent decline in revenue compared with the same period last year. The company recorded net income of $14,000, thanks to an income tax benefit from the settlement of contingencies pertaining to prior years' income taxes. Micron registered a pretax loss of $4.36 million. The continued effects of downward price pressure on the company's principal products, the ongoing transition to the 1Mb DRAM, and the production ramp-up of Fab III all contributed to the soft financial results. Despite current market conditions, Micron intends to continue its efforts to reach full capacity utilization and to accelerate product and process development.

Motorola

Motorola reported record sales and earnings for its first quarter. Earnings of $127 million were 3 percent above earnings of the corresponding quarter last year, while sales grew 16 percent to $2.53 billion for the same period. A summary of the performance of Motorola's Semiconductor Product Sector indicated that sales increased 13 percent, orders rose 14 percent, and backlog was up, but operating profits were down compared with a year ago. However, chairman and CEO George Fisher noted that the company was encouraged by early signs of renewed strength in the semiconductor industry. All regions reported higher order levels, led by Asia/Pacific.

National Semiconductor

National Semiconductor announced a net loss of $10.2 million on $404.2 million for the third quarter, ended February 25. The sales figure represents an increase of 7 percent when compared with the same period a year ago. During the quarter, National completed the closure of its Danbury, Connecticut, facility, marking the final step in the cost-reduction and restructuring program announced in the fourth quarter of fiscal 1989. The company reported strong bookings in the latter part of the third quarter. National Semiconductor is the eleventh-ranked company in worldwide semiconductor market share, with 1989 revenue of more than $1.6 billion.

SEEQ Technology

SEEQ announced revenue of $11.5 million, with a net loss of $4.5 million for its second quarter, ended March 31. This compares with revenue of $15.5 million and net income of $0.7 million for the like period last year. Continued pricing pressure on the company's commodity EEPROM products and increased inventory reserves for slow-moving and obsolete products served to keep revenue and earnings down. SEEQ reports a strong increase in its bookings rate in the latter part of the quarter.

Texas Instruments (TI)

For the first quarter of 1990, TI's revenue declined about 4 percent from a year ago to $1,536 million. Net income plummeted to $13 million, an 85 percent decline over last year. Semiconductors operated at a loss in the quarter because of lower revenue as well as major investments for new products and capacity. Sharply lower DRAM prices and sluggish memory unit sales more than offset growth in VLSI semiconductor products. Although semiconductor order rates were below those of a year ago, they were improved over fourth quarter 1989. TI's plans for 1990 are based on a recovery in semiconductor demand later this year; despite current market softness, the company has maintained a high level of investment.

VLSI Technology

VLSI Technology has reported a net income of $2.3 million on revenue of $78.8 million for the first quarter ended March 31, 1990. This revenue figure represents a 31 percent increase over the corresponding quarter a year ago. The company reported increased gross margin percentages, attributed to manufacturing improvements in productivity and yields. VLSI experienced strong first quarter bookings across all product lines, exceeding levels from the third and fourth quarters of 1989. A VLSI spokesperson commented that the company's San Antonio, Texas, facility now accounts for 25 percent of total production revenue.

Weitek

Weitek reported revenue of $15.2 million and net income of $2.1 million in its first quarter, ended March 31. Compared with the first quarter of 1989, these results represent a 42 percent increase in both revenue and net income. During the first quarter, gross margins remained stable at 65 percent, while R&D expenses increased slightly to 20 percent of revenue. Additionally, operating revenue as a percentage of revenue also increased to nearly 21 percent.

Western Digital

Western Digital has reported a net income of $8.8 million on sales of $286.8 million for its third quarter, ended March 31. This quarterly revenue figure is a company record. Western Digital attributes this record performance to growth in most of its product lines, with demand particularly strong in the 3.5-inch intelligent drive business and higher-than-anticipated shipments in the imaging product line.

Xicor

Xicor announced a net loss of $6.98 million on revenue of $19.80 million for the first quarter, ended March 25, 1990. First-quarter revenue was down 10 percent from the same period a year ago. Factory underutilization and lower margins on shipments of products manufactured at high costs in prior periods were cited by the company as contributing factors to the negative earnings. The company anticipates higher R&D expenditures in 1990 than in 1989 as products are developed using the 6-inch wafer line.

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Research Newsletter

NACS MEETS IN SILICON VALLEY TO DISCUSS SEMICONDUCTOR INDUSTRY'S FATE

INTRODUCTION

The National Advisory Committee on Semiconductors (NACS) meeting, held in Santa Clara, California, on May 8, was the first plenary session held by the committee outside of Washington D.C. Established by Congress and appointed by President Bush, the NACS delivered its preliminary findings on the state of the U.S. semiconductor industry in its first annual report, made in November 1989. The NACS' recommendations were based on two basic premises—first, that the semiconductor industry is strategic to America and second, that it is in trouble. Hence, it follows that it is imperative for U.S. industry, in cooperation with government, to develop a strategy to retain strong semiconductor capability. The NACS organized three ad hoc working groups to pursue its basic recommendations to expand the U.S. industry's global semiconductor market share, establish a fully competitive and supportive business environment, and enable the industry to achieve a world-class competitive technology position.

This newsletter reviews the material presented at the meeting and provides Dataquest's commentary. The meeting presented the responses of 10 individuals, who represent various areas of expertise, to the findings published in the NACS report. Speakers included Representative Tom Campbell, Republican-CA; Regis McKenna, Regis McKenna Inc.; Andy Procassini, SIA; Ken Levy, KLA Instruments; Jim Norton, AEA; Dr. William Miller, SRI International; Dr. Tom Fryer, Chancellor, Foothill-DeAnza Community College District; Adam Cuhney, Kidder Peabody and Co.; Arthur Rock, Arthur Rock & Co.; and Pierre Lamond, Sequoia Capital.

SUMMARY: BASIC CONSENSUS

The speakers commented briefly on various aspects of the report, each according to his expertise. Almost unanimously, speakers favored changes regarding access to a lower cost of capital and policies to encourage long-term investment. The issue of the Consumer Electronics Capital Corporation (CECC), however, was controversial. The NACS report recommended expansion of the U.S. semiconductor industry's global market share by rebuilding a strong U.S. position in the growing high-volume, high-technology electronics systems market. The NACS proposed establishing a for-profit CECC to rebuild the U.S. consumer electronics industry infrastructure, with Federal Government encouragement and support for market reentry for the U.S. consumer electronics industry. At the meeting, support for the establishment of a CECC ran the gamut from an unequivocal yes to a resounding no, with various degrees of qualified support in between. Several speakers commented on the fundamental need for a better-educated work force to help the United States become more competitive.

Competition and Control

Venture capitalist Arthur Rock verbalized perhaps most directly what other speakers' presentations took for granted—that the United States would like to control its destiny and that it is competitive. Semiconductors have had an important impact on raising U.S. standards of living and are drivers for all technology. Manufacturing is closely linked to technology development. The industry has, however, demonstrated a lack of cooperation and has suffered from lack of long-term funding. In order to make any progress, it must focus its resources more effectively. However, unfair trading practices of the United States' major international competitors, combined with self-defeating U.S. policies, have put the U.S. semiconductor industry at a disadvantage. Mr. Rock asserted that Japan's dumping of low-priced products in the United

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States was supported by high prices in Japan's home market. Hence, the rules relating to capital, trade practices, and the elimination of dumping need to be changed.

Consensus on Capital

Without exception, the speakers agreed on the capital availability issue. Because of the highly capital-intensive nature of the semiconductor business, there was unanimous assertion that capital was an underlying issue. Speakers pointed to the financing methods prevalent in both the United States and Japan. Low-cost capital tends to be patient capital—this gives the United States' Japanese competitors an advantage over the U.S. semiconductor industry. Japanese companies' market entry is aided by their lower cost structure, which allows for low-cost entry into a market. R&D is a long-term prospect but return on investment (ROI) goes to market owners. So, although the United States may have invested in inventing and bringing new products to market, it does not get to enjoy the fruits of its labor. Examples of markets (e.g., TVs) once invented and controlled by U.S. companies, but which are all but bereft of U.S. participation, are numerous.

Mr. Procassini of SIA noted that the U.S. semiconductor industry is not losing market share *just* in other regional markets, but also in the United States, because of inadequate capital. In 1989, the U.S. semiconductor industry underinvested by $900 million compared with relative market share. Not only has the Japanese semiconductor industry outinvested the U.S. semiconductor industry, it has sustained its investments equally in good times and in bad.

However, just reducing taxes on capital gains is not sufficient—the industry needs a longer investment cycle (e.g., 10 years). For these reasons, steps must be taken to reward long-term investment by various means and to shorten depreciation time rules so that manufacturers can maintain their production equipment at state-of-the-art levels.

A Controversial Concept: CECC

Although one speaker after another made a case for access to lower cost of capital, there was no agreement on the proposed establishment of the CECC. Whereas the SIA representative endorsed the concept of the CECC and urged immediate action, the majority of opinion was that government intervention would most likely be "the kiss of death" to the industry, or at best be detrimental to industry concerns. Dr. Miller of SRI International made an interesting case for the CECC were it to support technology across a wide range of capital-intensive industries as opposed to being industry specific. He argued that some level of government involvement could be justified for public good, but the level of involvement could be kept to a minimum by adopting a Fannie-Mae-like structure. This structure has the advantage of keeping government intervention indirect and employing familiar financing mechanisms. There was fundamental agreement that consortia should be driven through private industry, perhaps with guarantees from corporate America and the government. The most specific suggestion regarding how the CECC could most effectively participate in the regeneration of U.S. high technology came from venture capitalist Pierre Lamond. He contended that traditional VCs are unable to meet the needs for large-scale investment, essentially stating that high-technology ventures requiring over $50 million are unfundable. Mr. Lamond used an example of flat-panel displays to illustrate the inherent weakness of the U.S. system for funding high-technology development. Although the United States still has access to good existing technology, because this market is large volume, just building one factory to produce even 200,000 displays would require a $100 million production facility. That does not include working capital! He suggested that the CECC be managed as a VC fund to build profitable companies with management compensation based on ROI. A CECC-type organization could provide later rounds of financing to improve the debt/equity position of such ventures.

Call for Action

The prospect of any immediate changes was rated rather poorly by both speakers and audience members. The only call for immediate action came from Representative Tom Campbell, who exhorted the industry not to await government action but to try to resolve its problems itself. Representative Campbell took a pragmatic approach to the issues. He concentrated his comments on those areas that he believed might best be pursued in the immediate to short-term future versus either longer-term issues or issues unlikely to receive favorable attention, at least from the current administration.

Dedication to free trade dominates the administration. Moreover, because the United States propounds free trade worldwide, it cannot afford to reverse itself at home. However, the administration recognizes the United States' special trade relationship with Japan. The recent Super 301 pronouncements did not include Japan because the administration had achieved some progress in its negotiations with Japan in the areas in which Japan had previously been cited (satellites, supercomputers, and wood products). However, Super 301 might be reviewed next year in connection with the expiration of the semiconductor trade arrangement. If no progress has been made on this front, semiconductors could become a candidate for inclusion on the list, although it was noted that there may be a conflict in timing in trying to pursue this approach. Representative Campbell summarized his response to the NACS report as follows:

- Progress is under way on export of high-technology goods to the Eastern European bloc. The United States should not allow prudent caution to preclude it from pursuing market opportunities in this region that already are being capitalized on by other countries.
- Consortia is being addressed through changes in antitrust law. In fact, the administration recently agreed to make changes to facilitate the formation of manufacturing consortia.
- Not much prospect exists for a CECC—it does not make sense for the administration to involve itself in picking and supporting industry winners, especially in light of the former's unimpressive track record. If industry were to devise its own strategy to achieve a CECC, some level of funding might possibly be forthcoming for basic research or work on large-scale projects (e.g., railroads) if the funding can be kept out of the political arena. Funneling funds through existing channels, such as national academies, might be more appropriate and expeditious.
- The Structural Impediments Initiative, i.e., increased access to distribution channels in Japan. This initiative represents a distant prospect and a long-term issue to be worked on.
- All aspects of the deficit are now prime for discussion, and the capital gains issue is paramount with President Bush.

New Rules

There was general consensus that the United States must recognize the need for new rules relating to the following:

- Cost of patient capital
- Intellectual property action
- Cooperative R&D
- Market access
- Industrial strength/national security
- Education

As venture capitalist Arthur Rock said, the United States has been guilty of self-defeating policies. Mr. Sporck of National Semiconductor declared that we need a "Sputnik" reaction to what he termed a crisis in the semiconductor industry even if it is not politically palatable. The longer the current situation prevails, the higher the barriers of reentry, and the harder it will be to overcome them! Time is of the essence. A strong industrial base is needed for strong long-term education; only a healthy industry can invest in education! An inadequate work force was cited as one of the industry's most acute problems. It is an issue that is key to U.S. competitiveness, but was touched upon only briefly in the context of this forum. A basic interdependence exists between education and industry, which implies a need for partnerships to formulate competitive, long-term solutions.

The dilemma now is the urgency of the situation with no apparent leadership in sight. Whereas Japan has a national purpose to dominate, the United States lacks that drive and focus. Apparently, the United States lacks the will, and its politicians, who are interested in votes in the short term, are not interested in developing strategic long-term policies.

DATAQUEST CONCLUSIONS

Dataquest agrees with the general audience assessment of the meeting—the material presented did not cover any new ground. Although the topic engendered strong rhetoric from many of the participants, little was offered in the way of constructive solutions.

Because of the global nature of the U.S. semiconductor industry today, there are no safe retreats for U.S. industry. It would be one matter for the U.S. semiconductor industry to die a natural death; it is an entirely different matter for a healthy industry to be driven to an early grave through negligence and lack of foresight on its own part and the part of its government, aided and abetted by its competitors. No country, including the United States, can afford to write off its participation in a viable, strategic industry. If the tenets of free trade are to continue as a guiding light to the nation, then it must strive for structural changes that advance the cause of free trade worldwide. Moreover, as well as harnessing its own strengths, it also would behoove the United States to adapt to or learn from the best of its competitors' attributes.

We agree that there are new rules. Some will require that U.S. companies adapt themselves to new realities, as well as try to remedy the inequities in their business environment. Although many of the areas targeted for improvement related to larger issues such as international trade, education, and capital formation that will require action at the federal level to have any significance, some issues could be tackled by the industry itself. As well as urging the administration to provide a level playing field for the industry to compete globally, the industry must exert itself to work more cooperatively. For instance, Sematech can provide a ready-made vehicle for increased cooperation between semiconductor equipment vendors and semiconductor suppliers. Sematech was mostly applauded as a step in the right direction; although it represents only a small percentage of the total R&D budget, it has the advantage of focusing its resources. The vested interest that both industry segments have in their mutual success appears to imply that mutual investment of both time and money could help ensure long-term survival. Moreover, the mutual self-interest among semiconductor equipment suppliers and semiconductor manufacturers extends further along the food chain to the end-user community, whose representation at the meeting was limited to a few comments from the AEA spokesman.

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Research Newsletter

QUARTERLY SEMICONDUCTOR COMPANY FINANCIAL RESULTS

INTRODUCTION

Dataquest regularly reports on semiconductor company financial results through its weekly online news service, *The DQ Monday Report*. As a service to SIS' Products, Markets, and Technology segment binderholders, a summary of this information is provided herein.

Table 1 summarizes the net sales and income disclosures from selected semiconductor companies based on data from quarterly report periods that ended during the November through January time frame. This information is compared with the November through January 1988 time frame and is provided in millions of dollars unless otherwise indicated. Table 2 provides a similar summary for fiscal year revenue and income for applicable companies. Descriptive summaries of quarterly performance highlights for the companies listed follow these tables.

Figures 1 and 2 show the 1989 percent change by quarter for the aggregate company revenue and income, respectively.

COMPANIES

Adaptec

Adaptec's financial results for the third fiscal quarter reflect the company's fourth consecutive quarter of record revenue and third consecutive quarter of record earnings. This performance amounts to 22 quarters of profitability. Adaptec is experiencing increasing demand for its SCSI and AT single-chip controllers. In a separate announcement, the company said that a recently completed public offering of 1.6 million common shares had raised approximately $26.6 million.

Advanced Micro Devices

AMD announced a return to profitability, as had been anticipated by analysts at Dataquest, who recently had advised their clients that AMD is in better shape than might be evident to the outside world. Like a middle-aged man who has just survived cardiac arrest, the company has changed its lifestyle and now is leaner and wiser. The more than $1 billion investment made in R&D over the past five years, much of it focused on CMOS technology, is beginning to pay off. Fourth quarter CMOS revenue accounted for 26 percent of total sales. Shipments of programmable logic devices (PLDs), EPROMs, and 80286 microprocessors all reached record unit volumes, although they were subject to intense price pressure. In keeping with Dataquest's outlook for 1990, AMD chairman and CEO, W. J. (Jerry) Sanders III, expects 1990 to be a year of slow growth for the industry, which may give AMD an opportunity to perform better than the market average.

Altera

Altera experienced significant revenue growth from both domestic and overseas sales. According to Dataquest's preliminary market share data survey, Altera remains the leading worldwide supplier of CMOS PLDs.

California Micro Devices

California Micro Devices said that its return to profitability can be attributed largely to higher demand for its telecommunications and thin-film products. This quarter's income of $503,000 was

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Table 1
Quarterly Financial Summaries for Selected Semiconductor Companies
(Millions of Dollars, Unless Otherwise Indicated)

Company	Latest Quarter Revenue	% Change*	Latest Quarter Income	% Change*
Adaptec Inc. (Dec. 29, Q3)	29.0	86.0	3.9	1,656.0
Advanced Micro Devices (Dec. 31, Q4)	285.3	15.0	11.8	N/M
Altera Corp. (Dec. 31, Q4)	16.2	52.0	3.0	42.0
California Micro Devices (Dec. 31, Q2)	10.0	59.0	0.5	N/M
Chips & Technologies (Dec. 31, Q2)	74.4	37.0	8.9	12.0
Cirrus Logic Inc. (Dec. 31, Q3)	23.7	135.0	4.3	223.0
Cypress Semiconductor (Jan. 1, Q4)	50.8	23.0	8.1	28.0
Dallas Semiconductor (Dec. 31, Q4)	21.5	29.0	3.0	29.0
Integrated Device Tech. (Dec. 31, Q3)	51.6	19.0	3.0	4.0
Intel Corporation (Dec. 30, Q4)	895.0	23.0	122.7	43.0
International CMOS (Dec. 29, Q1)	3.2	26.0	(901K)	N/M
Lattice Semiconductor (Dec. 30, Q3)	10.2	90.0	1.9	250.0
Linear Technology (Dec. 31, Q2)	17.9	14.0	2.5	17.0
LSI Logic (Dec. 31, Q4)	138.4	16.0	(1.7)	N/M
Maxim (Dec. 31, Q2)	13.2	28.0	1.8	40.0
Micron Technology (Nov. 30, Q1)	66.5	(40.0)	40K	(99.0)
Motorola (Dec. 31, Q4)	2,650.0	21.0	132.0	6.0
National Semiconductor (Nov. 26, Q2)	416.8	3.0	2.4	N/M
SEEQ Technology (Dec. 31, Q1)	12.3	(15.0)	1.1	(200.0)
Silicon General (Dec. 31, Q2)	8.9	(7.3)	268K	(41.0)
Siliconix (Dec. 31, Q4)	39.3	(1.0)	(9.0)	N/M
Standard Microsystems (Nov. 30, Q3)	19.0	6.2.0	1.6	N/M
Texas Instruments (Dec. 31, Q4)	1,724.0	(0.5.0)	36.0	(62.0)
VLSI Technology (Dec. 31, Q4)	80.7	24.0	2.8	(3.0)
Weitek Corporation (Dec. 31, Q4)	14.2	41.0	1.9	37.0
Western Digital (Dec. 30, Q2)	264.9	3.0	8.6	(32.0)
Xicor (Dec. 31, Q4)	25.0	10.0	(5.6)	N/M

*Compared with corresponding time one year ago
N/M = Not meaningful, comparison is being made with a prior loss
K = Thousands

Source: Dataquest
April 1990

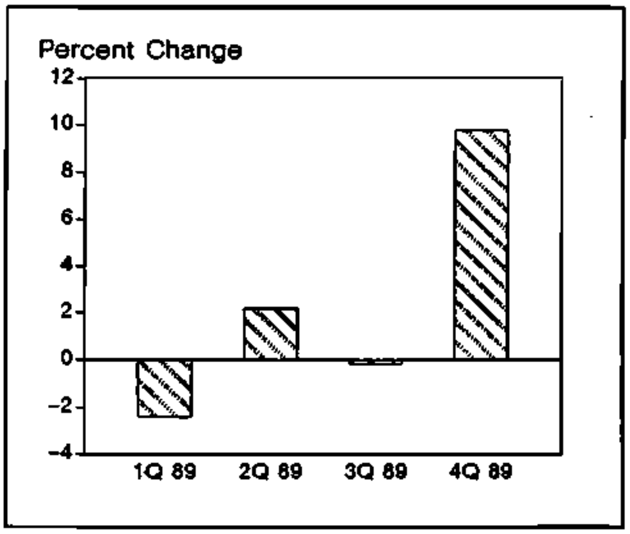
TABLE 2
Fiscal Year Financial Summaries for Selected Semiconductor Companies
(Millions of Dollars, Unless Otherwise Indicated)

	Fiscal Year Revenue ($)	% Change*	Fiscal Year Income ($)	% Change*
Advanced Micro Devices	1,104.6	(2)	46.1	138
Altera Corp.	58.9	55	10.8	52
Cypress Semiconductor	199.3	43	50.8	23
Dallas Semiconductor	82.2	42	11.1	11
Intel Corporation	3,126.8	9	391.0	(14)
LSI Logic	547.0	44	(25.0)	N/M
Motorola	9,620.0	17	498.0	12
Siliconix	122.5	(5)	(26.0)	N/M
Texas Instruments	6,522.0	1	292.0	(20)
VLSI Technology	288.5	30	0.5	(92)
Weitek	49.2	40	6.9	72
Xicor	90.2	N/M	423K	(97)

*Compared with corresponding time one year ago
N/M = Not meaningful; comparison is being made with a prior loss
K = Thousands

Source: Dataquest
April 1990

Figure 1
Company Revenue



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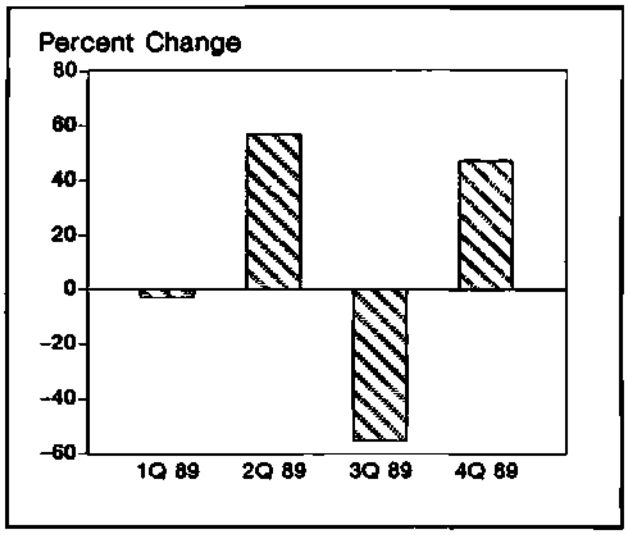
Source: Dataquest
April 1990

Figure 2
Company Net Income



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Source: Dataquest
April 1990

18 percent higher than income for the first quarter and a marked improvement over the $606,000 loss reported in the second quarter of the prior fiscal year 1989.

Chips & Technologies

Chips' sales growth reflects higher unit shipments of the company's CHIPSet products, with particular strength in products for laptops and 386- and 386SX-based personal computers. However, the company's gross margin of 46 percent of net sales was below its historical average, due primarily to price concessions given on certain low-end products. Stockholders' equity now stands at $123.1 million, with retained earnings representing more than two-thirds of this amount.

Cirrus Logic

Cirrus Logic's revenue growth reflects recent capacity increases implemented to meet the strong demand for the company's mass storage and video graphics array (VGA) products. Cirrus' mass storage business has increased as a percentage of revenue on a year-to-date basis. The display graphics portion of the company's business grew this past quarter on the incremental strength of the liquid-crystal display (LCD) VGA market segment. The percentage of quarterly growth in Cirrus' VGA business is not expected to continue, although orders remained strong throughout the quarter.

Cypress Semiconductor

Cypress achieved record annual revenue of $199.3 million, up 43 percent from 1988. However, the company did not set its 24th record for quarterly revenue growth. The revenue figures softened during the fourth quarter because of a major reduction in shipments in the personal computer sector. During the fourth quarter, however, Cypress and its subsidiaries introduced 17 new products, a quarterly record, which helped offset the decline in revenue from personal computer-related products.

Dallas Semiconductor

Dallas Semiconductor reported a 29 percent improvement in fourth quarter revenue and income compared with the same period in 1988. Compared with the preceding quarter, revenue declined 7 percent while income dropped 8 percent. This decline was partially the result of a strong third quarter, when company shipments caught up on certain product backlog. Dallas Semiconductor experienced continued strength in the domestic market for its time-keeping family, which is oriented toward high-end PC applications. Fiscal-year income went up 12 percent on a 42 percent increase in sales. The company looks forward to modest growth in the first quarter of 1990.

Integrated Device Technology

The company's cautiously optimistic outlook for the third quarter, from a second quarter vantage point, did not materialize. As indicated by Integrated Device Technology earlier this month, results for its third fiscal quarter ended December 31 were below those of the prior quarter. Compared with second quarter results of $54.1 million in revenue and $5.8 million in income, the company experienced declines of 5 percent and 48 percent, respectively. Lower-than-expected orders booked, combined with severe price pressure on some products, resulted in a disappointing third quarter. Compared with the corresponding quarter a year ago, the company's revenue grew 19 percent while income increased a slight 4 percent.

Intel

Intel's fourth quarter and full-year revenue reached record levels. The company earned $122.7 million on fourth quarter sales of $895.0 million. For 1989, Intel's revenue totaled $3.1 billion with income of $391 million. Intel's solid performance in 1989 accorded the company eighth place in Dataquest's preliminary worldwide semiconductor market share ranking survey. The company referred to its product portfolio as the strongest ever. Commenting on product performance, Dr. Andrew Grove, president and CEO, characterized sales of the 386DX as "good," the 386SX "took off," and demand for the i486 is "strong." In terms of regional sales growth, the Asia/Pacific region was singled out as being especially strong.

International CMOS Technology

ICT achieved record shipments and revenue for the quarter ending December 29, 1989. Unlike

1988, this year's net income figure does not include revenue from technology and licensing agreements, which amounted to $825,000 for the same period last year. The demand for the company's products continues to be strong, as evidenced by increasing revenue and shipments during 1989.

Lattice

Very strong third quarter performance reflects ongoing customer acceptance of the company's PLDs. This quarter's results mark the ninth consecutive quarter of record net income for Lattice. Based on preliminary market share data, Dataquest estimates that in terms of calendar 1989 PLD revenue, Lattice ranked fourth in the worldwide CMOS PLD market.

Linear Technology

Although Linear Technology experienced improved overseas business, it was offset somewhat by lower domestic sales, particularly through its distributor channels. The company said that it would continue to respond to the sluggish industry environment by introducing proprietary circuits, thus improving the company's product positioning in new-generation customer products.

LSI Logic

LSI Logic reported an operating profit of $431,000 for the fourth quarter compared with an operating loss of $6.8 million before a restructuring charge in the prior quarter. However, there was a net loss of $1.7 million for the quarter compared with net income of $5.3 million for the like quarter a year ago. Although the company reported record revenue of $547 million for 1989, it experienced a loss of $25 million versus a profit of $25 million in 1988. The 1989 loss was attributed to a one-time pretax charge of $43 million when the company aggressively wrote off costs associated with the restructuring of less efficient manufacturing operations in the third quarter. The company believes that it is now more competitively positioned to face 1990. LSI's fourth quarter book to bill exceeded 1:1. Fourth quarter revenue of $138.4 million was 4 percent above third quarter revenue.

Maxim Integrated Products

With a 40 percent earnings growth over the same period one year ago, Maxim's second quarter of fiscal 1990 became the Company's 15th consecutive increasingly profitable quarter. For the six months of fiscal 1990 to date, earnings were $3.5 million, up 41 percent from the prior fiscal year to date. During this most recent quarter, Maxim introduced 15 new products. Also, the company acquired a Class 10 wafer fabrication facility from Saratoga Semiconductor for $5.3 million, which was capable of producing 1.2-micron BiCMOS RAMs for Saratoga.

Micron Technology

Micron Technology reported a revenue decrease of 40 percent and a net income decrease of approximately 100 percent for its first fiscal quarter compared with the corresponding quarter one year ago. This decline in financial performance was attributed to decreasing memory prices as well as Micron's transition from 256K to 1Mb DRAMs.

Motorola

Motorola reported revenue of $9.6 billion and earnings of $498 million for its fiscal year ended December 31, 1989. These figures represent a 17 percent growth in revenue and a 12 percent improvement in earnings when compared with fiscal year 1988. Fourth quarter sales were $2.7 billion, an increase of 21 percent over the same period last year. Earnings for the quarter grew 6 percent to $132 million. Comparing year-end 1989 results for the company's Semiconductor Products Sector with those of the previous year, president and chief operating officer Gary L. Tooker noted that sales and orders both increased by 11 percent and backlog was 12 percent higher. Increased investments in R&D and new facilities, the voluntary severance program, and falling average selling prices (ASPs) on some commodity devices worked to drive operating profits down. Orders in all major regions were higher, with the Japan and Asia/Pacific regions providing the largest boost in order growth. Memories, semicustom logic devices, and microprocessors were the product areas with the greatest order growth in 1989. Semiconductor order growth was highest in the personal computer, consumer, and communications market segments. Semiconductor sales represent 32 percent of the company's total sales.

National Semiconductor

Results for National's second fiscal quarter reflect progress on the financial front. The company reported both an increase in sales (albeit a small one) and a profit of $2.4 million compared with a loss of slightly more than $25.0 million in the same quarter a year ago. However, although the company claims that it expects such progress to continue, a company spokesperson characterized the third quarter as "historically a difficult one and will present a strong challenge in continuing this trend."

SEEQ Technology

Although revenue and earnings were down from the same period a year ago, first quarter figures are a substantial improvement over the prior quarter. The revenue increase and reduction in losses from the previous quarter were due to increased Ethernet and flash memory sales. At the same time, EEPROM sales remained soft. To improve margins on its commodity EEPROM products, SEEQ entered into foundry agreements with Philips Components and Signetics.

Silicon General

Revenue for the six-month period ended on December 31, 1989, were $17.9 million, a 2 percent decline from the same period last year. Earnings for this period were $694,000, a 2 percent drop from the same period one year ago. All of these results are for the semiconductor business only. Silicon General is in the process of making its telecommunications business a separate company.

Standard Micro Systems

Standard Micro Systems' revenue for the third quarter represented a 6 percent gain over the same quarter one year ago. Net income showed a marked improvement amounting to record net income of $1.5 million compared with a net loss of $4 million for the corresponding quarter last year. The decline in product sales was mainly due to a shortfall in product sales from the Component Products Division, whose customers had built up inventories of ARCNET component products. The company believes that this condition is temporary and that demand will improve during the fourth quarter.

Texas Instruments

For the fiscal year ended December 31, 1989, the company earned $292 million on net revenue of $6,522 million, which represents a 2 percent growth in revenue and a 20 percent drop in earnings. TI's growth strategy is to shift more of its business toward proprietary and differentiated products, such as ASICs, advanced linear devices, microcontrollers, and special-purpose processors. During 1989, TI increased investments in submicron CMOS capacity. The company told Dataquest that it plans to boost semiconductor capital spending from the already substantial 1989 level of $641 million to $780 million in 1990, a 22 percent increase. By 1991, the company expects to double its present number of submicron CMOS wafer fabrication facilities around the world. At the same time, TI is phasing out older facilities.

VLSI Technology

VLSI Technology's fourth quarter revenue grew 24 percent over the same quarter a year ago, and 5 percent over the previous quarter. The ASIC and logic divisions achieved record revenue. Although quarterly operating profits were at a record $5.3 million in the fourth quarter, foreign exchange losses and a higher tax provision resulted in a lower net income figure that reflected declines of 5 and 15 percent compared with the same quarter last year and the prior quarter. The company noted that annual revenue from Europe and Asia/Pacific increased significantly over last year.

Weitek Corporation

For the year ended December 31, 1989, Weitek reported revenue of $49.2 million and net income of $6.9 million. Compared with 1988, these results represent a 40 percent increase in revenue and a 72 percent increase in earnings. In the fourth quarter, Weitek posted its 11th consecutive quarter of revenue and income growth, and the company's book-to-bill ratio remained over 1.0. Gross margins remained stable at 65 percent as operating income held at 20 percent of revenue. The Weitek staff grew by 21 percent in 1989.

Western Digital

Second quarter financial results mark a return to profitability for Western Digital, following a loss of $2.7 million in the first quarter ending September 30, 1989. The rebound was led by strong performances from the Storage Products and Microcomputer Products operating units. Company-wide bookings for second quarter reached record levels.

Xicor

Xicor reported revenue for fiscal year 1989 of $90.2 million, which is virtually equal to 1988 figures. Net income for 1989 was $423,000, a 97 percent decrease from 1988. The fourth quarter loss and revenue shortfall are primarily due to factory underutilization, lower margins on shipments of products manufactured in prior periods, continued price erosion, and temporary shortages of certain products. The company expects gains in overall manufacturing capacity in the future. Booking rates in the second half of the fourth quarter grew by 20 percent over those during the summer and the first half of the fourth quarter.

Patricia Galligan
Phil Mosakowski

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Research *Newsletter*

THE HITACHI/MOTOROLA DECISION: AN OBJECT LESSON IN "IMPROVIDENT" LITIGATION

PANIC IN SILICON VALLEY

The decision by Federal Judge Lucius Bunton in the patent dispute between Hitachi Ltd. and Motorola, Inc., touched off a maelstrom of apocalyptic musings in press circles and sent Motorola customers scurrying to count their inventory of 68030 microprocessors. If ICs are the "crude oil" of the electronics industry, Judge Bunton's injunction against Motorola's U.S. shipments of its flagship microprocessor is the industry equivalent of an oil embargo to certain systems companies.

Ironically, the implications of the March 29 decision, reached in a U.S. District Court in Austin, Texas (the site of Motorola's Microprocessor Products Group), may be more profound, although less immediately dramatic, than initial media reaction might imply. Of greatest immediate importance to Motorola and its clients is that as of March 30 the company was granted a stay of the injunction against the M68030, which permits Motorola to conduct business as usual pending an appeal—or an out-of-court settlement.

THE DECISION

Judge Bunton basically decided in Motorola's favor, saying that Hitachi's H8 microcontroller was not licensed under the parties' 1986 Patent License Agreement; consequently, Hitachi committed patent infringement on three of Motorola's patents. Hitachi therefore was ordered to cease selling the H8 for the life of the affected patents and to compensate Motorola in the amount of $1.9 million. The judge also ruled that Motorola infringed on an Hitachi patent and therefore was barred from marketing or selling its 68030 microprocessor for the duration of that patent; Motorola thus was required to pay Hitachi $500,000 in damages.

A CHRONOLOGY

As the following chronology reveals, the Hitachi/Motorola case opened a legal Pandora's box that has had severe and unanticipated consequences for Motorola. It may be instructive at this point to briefly review the following events, which led to the March 29 decision:

- In January 1989, Motorola filed a lawsuit against Hitachi charging patent infringement and unfair competition that Motorola claimed began after it had granted Hitachi a patent license for certain devices in 1986. Motorola's position was that Hitachi's new H8 microcontroller series infringed on at least four Motorola patents.
- Approximately one week after Motorola's charges, Hitachi responded by filing a patent infringement suit against Motorola. Hitachi alleged infringement of one of its patents by Motorola's 68HC11 8-bit microcontroller and countered that not only did its H8 *not* infringe on any Motorola patent but that the device was covered by a patent license. Hitachi described itself as "greatly surprised" by Motorola's action in filing the lawsuit.
- In April, Motorola switched its legal venue and withdrew its lawsuit from the Federal District Court in Chicago, Illinois, to refile the charges in Austin, Texas.
- In June, Hitachi filed an amendment to its pending lawsuit against Motorola to include allegations of patent infringement by Motorola's 68030 microprocessor. In what has since proved to be a poetic use of foreshadowing, a spokesperson from Hitachi described Motorola's original lawsuit as "improvident" in that it caused Hitachi to "reexamine its patent portfolio."

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- In August, Hitachi submitted its claims to the U.S. Patent Office for resolution, hoping for a speedier outcome on the infringement issues. In the meantime, the courtroom trial was scheduled for October 23, 1989.

AN EMBARRASSING SETBACK FOR MOTOROLA

At the outset of the litigation, the legal battle was over two 8-bit microcontroller products. As events unfolded, both Motorola's 68030 and 88000 microprocessors were dragged into the legal fray because of their incorporation of a content addressable memory (CAM) used as an on-chip cache, which Hitachi claimed to be in violation of its patent rights.

To the undoubted shock and embarrassment of Motorola's legal department, Judge Bunton's decision has proved painfully "asymmetrical" in its impact on the Hitachi and Motorola devices in question. Although the decision may seem quite severe, Dataquest believes that the ruling was deliberately intended to force the two parties to settle their differences out of court. Quoting from the judgment, Judge Bunton notes that "What is more perplexing to this Court is these two parties have dealt personally with each other for years...Yet suddenly they left behind their prior relationship and expected this Court to ferret out the wrongdoings of which each is accused."

GOOD REASONS FOR A QUICK SETTLEMENT

Clearly, the irate judge sent a powerful signal to Hitachi and Motorola that they had chosen the wrong method to resolve their problems. The fact that the judge readily granted Motorola's request for a stay of injunction may indicate that he is not blind to the consequences of his initial decision on Motorola's customers. At this point, both parties have 30 days either to appeal...or to take Judge Bunton's suggestion of a negotiated peace.

Both Hitachi and Motorola have good reasons for seeking a resolution to their litigation. In Motorola's case, the threat of injunction hangs over a product that Dataquest believes garnered revenue in the $120 million to $150 million range in 1989. Of greater long-term significance, stopping the flow of 68030s represents a serious hardship that would be inflicted on Motorola's customers. Companies such as Apple Computer, Hewlett-Packard, and NCR Corporation are dependent on the 68030 as the sole-source heart of significant portions of their systems sales. Clearly, Motorola's motivation to resolve this dilemma is paramount.

Hitachi also is motivated to resolve this problem. Although the U.S. sales of its H8 product may not be as monetarily significant as the 68030, sales of the device in Japan would be jeopardized if the final destination of domestic equipment was the United States. As has been demonstrated by Intel and Texas Instruments, invoking the powers of the International Trade Commission (ITC) in defense of one's intellectual property can empower customs to seize imports of equipment that contain an offending product. Consequently, many of Hitachi's customers also hope for a hasty resolution of the issue.

BROADER IMPLICATIONS FOR JAPAN

In the initial hoopla over the 68030 injunction order, what seems to be overlooked is that Motorola scored a significant win in terms of the court's decision that Hitachi was in breach of a basic Patent License Agreement covering a broad range of microprocessor devices (including microcontrollers and microperipherals). Given the fundamental nature of the patents involved, upholding Motorola's patent position could have profound implications for all Japanese microdevices shipped to the U.S. market.

LINGERING QUESTIONS

Given the stakes involved for both Hitachi and Motorola, Dataquest anticipates a fairly speedy settlement and an end to the jitters currently felt by 68030 customers. The settlement may cost Motorola the millions of dollars that it might have hoped to gain from Hitachi when Motorola first pressed its lawsuit more than one year ago. The nature of such a settlement raises some interesting questions, such as the following:

- Would a cross-license deal, as part of a settlement, imply access to selected technologies or the outright second-sourcing of the 68030?
- If the 68030 were to be second-sourced to Hitachi, how would this affect Motorola's agreement with Toshiba, with which it has a DRAM/ microprocessor joint venture?
- How will a settlement of the current Hitachi/ Motorola litigation affect the renegotiation of their 1986 microprocessor license agreements, which will take place in 1991?

This last conjecture may shed some light on Motorola's underlying intent in filing its lawsuit in the first place. Aside from the potential royalty income, Motorola may have hoped to strengthen its bargaining position in the 1991 renegotiation of its patent licenses with Hitachi through a successful legal battle over the H8.

A MORAL VICTORY FOR HITACHI

Although it must now contend with an unfavorable ruling concerning its violation of patent license agreements, Hitachi has won a moral victory of sorts through its litigation with Motorola. In our brief review of the complaints filed by Motorola against Hitachi, we noted a level of invective that may well have stung and surprised Hitachi, coming as it did from a "supposed" business partner. By digging into its own bag of patent tricks and pulling out a rabbit that could force an injunction against Motorola's 68030, Hitachi must certainly have shocked Motorola into realizing that it is dealing with an equal.

DATAQUEST CONCLUSIONS

Beyond a settlement based on cash and technology licensing, it is doubtful that Hitachi will want to inflict any greater damage on Motorola. Judge Bunton's actions seem to have given Hitachi a strong negotiating position, but it is not likely that Hitachi will want to exploit this position to the extent that it injures the business interests of U.S. systems companies. Nervous 68030 users should keep in mind that many of Motorola's customers are Hitachi's customers as well.

Currently, the lesson that emerges from Judge Bunton's decision is that U.S. semiconductor companies must approach patent license issues with their Japanese competitors differently in the '90s than they may have in the '70s or '80s. If the legal departments of U.S. chipmakers are working from an outdated model of "copycat" Japan, they will likely walk into an ambush in court when faced with Japanese companies that have become formidable competitors in the field of intellectual property. Dataquest believes that in the new decade of U.S./Japan relations, the use of litigation as a "preemptive first strike" against a competitor's market thrust is more likely to lead to the equivalent of "mutually assured destruction." From this point of view, Hitachi and Motorola now must move to a speedy settlement of their legal differences and give their customers some peace.

Michael Boss
Patricia Galligan

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Research Newsletter

CONSORTIA AND CONSUMERS ARE KEY TO JAPANESE OPTOELECTRONIC DOMINANCE

INTRODUCTION

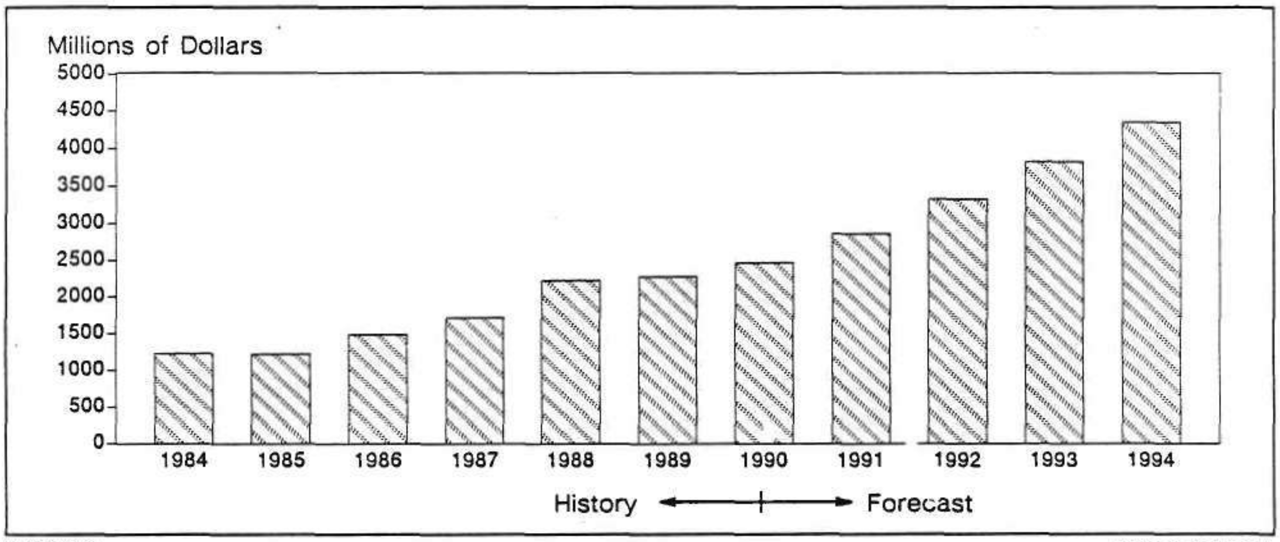
The Japanese strongly dominate the optoelectronics industry in both production and consumption of devices. The dwindling U.S. position is not due to any lack of innovation, but rather to a lack of product development and markets. In fact, the absence of U.S. suppliers of large-panel, active matrix liquid crystal displays (LCDs) is a festering problem for producers of military avionics. Beyond the military needs, the future of high-resolution computer graphics and North American high-definition television (HDTV) efforts are debatable without an indigenous source of the optoelectronic products needed for these systems.

This newsletter examines the optoelectronic semiconductor market. Attachment A looks at some of the recent announcements in optoelectronics.

A GROWING MARKET—OPTOELECTRONIC SEMICONDUCTORS

Although Dataquest follows only the semiconductor optoelectronics sector of the market (which excludes LCDs, CRTs, plasma displays), the semiconductor segment is one of the faster-growing segments and is quite representative of the market's future direction. Figure 1 shows Dataquest's estimate of semiconductor optoelectronics revenue history and forecast. Although this product group has not grown as strongly in the past as most semiconductor types—14 percent compound annual

FIGURE 1
Optoelectronic Semiconductor Revenue History and Forecast



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Source: Dataquest
April 1990

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growth rate (CAGR) versus 16 percent CAGR for ICs from 1984 through 1989—it does have some strong product types that are important to the emerging markets of imaging and display. Dataquest expects the 14 percent CAGR to continue into the next five-year period from 1989 to 1994.

U.S. RESEARCH STILL STRONG

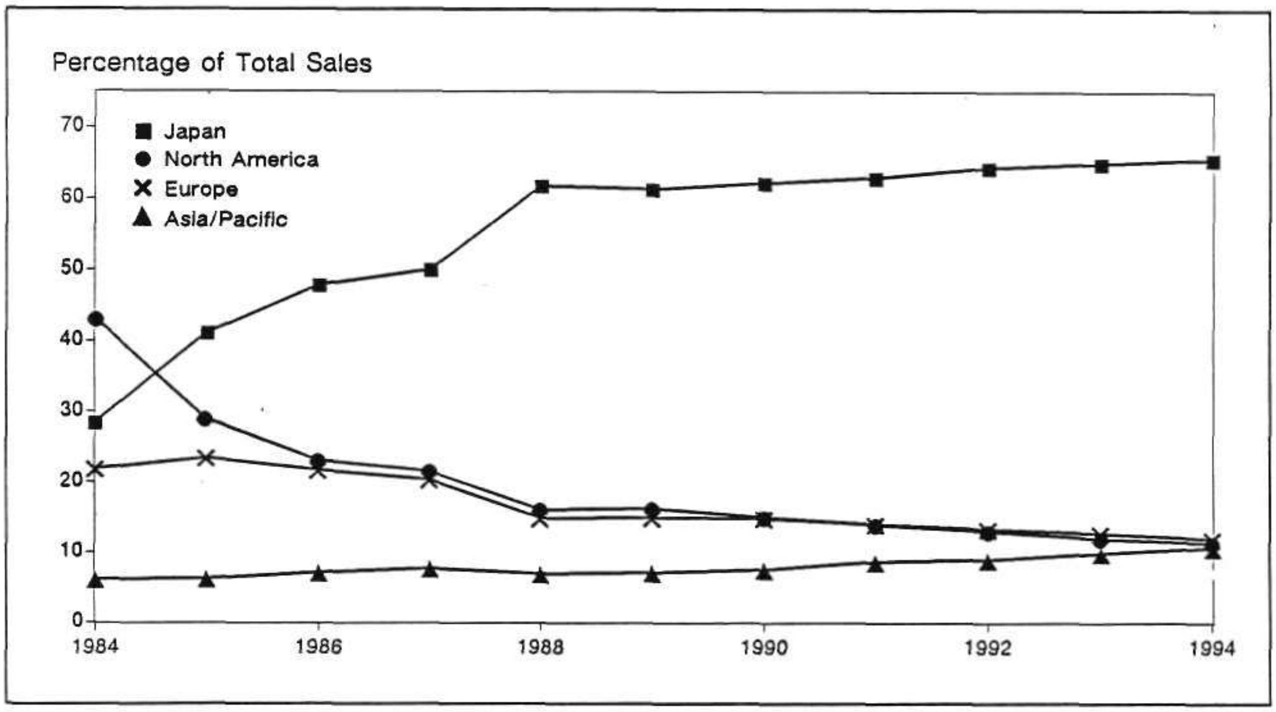
Research and development (R&D) on optoelectronic products remains strong. The David Sarnoff Research Center, Eastman Kodak Company, SRI International, Tektronix, Xerox Palo Alto Research Center, Zenith, and others remain at the leading edge of optoelectronics R&D. In a panel discussion last May, the National Science Foundation (NSF) of the United States concluded that there seems to be no mechanism by which basic-device R&D is carried through to a marketable system in the United States. The problem is that the United States consumption, which would have driven North American production, has been weak except in very specialized niche markets. The Japanese, by contrast, have had their R&D efforts spurred by the strong product potentials of consumer products.

Figure 2 shows the growth in the percentage of total semiconductor optoelectronics by region. Note the extremely strong growth in consumption by the Japanese segment. This growth is attributable to diode lasers (CD, audio, and CD-ROM), CCDs (camcorders, fax machines), and photosensors. The U.S. position in optoelectronics has been deteriorating. Limited products and limited domestic markets have provided limited growth.

The fact that consumption drives domestic production in Japan is illustrated by the two charts in Figure 3. Consumption and domestic production are within a few percentage points of each other. Because optoelectronics represents one of the major enabling technologies for electronics in the coming decade, Japanese production and consumption can be expected to remain large and dynamic.

The magnitude of the Japanese market dominance is enormous both in its size and in its implications for the future of electronics. Figure 4 contrasts the Japanese position in optoelectronics with other semiconductor types to illustrate this perspective.

FIGURE 2
Optoelectronic Semiconductor History and Forecast by Region



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Source: Dataquest
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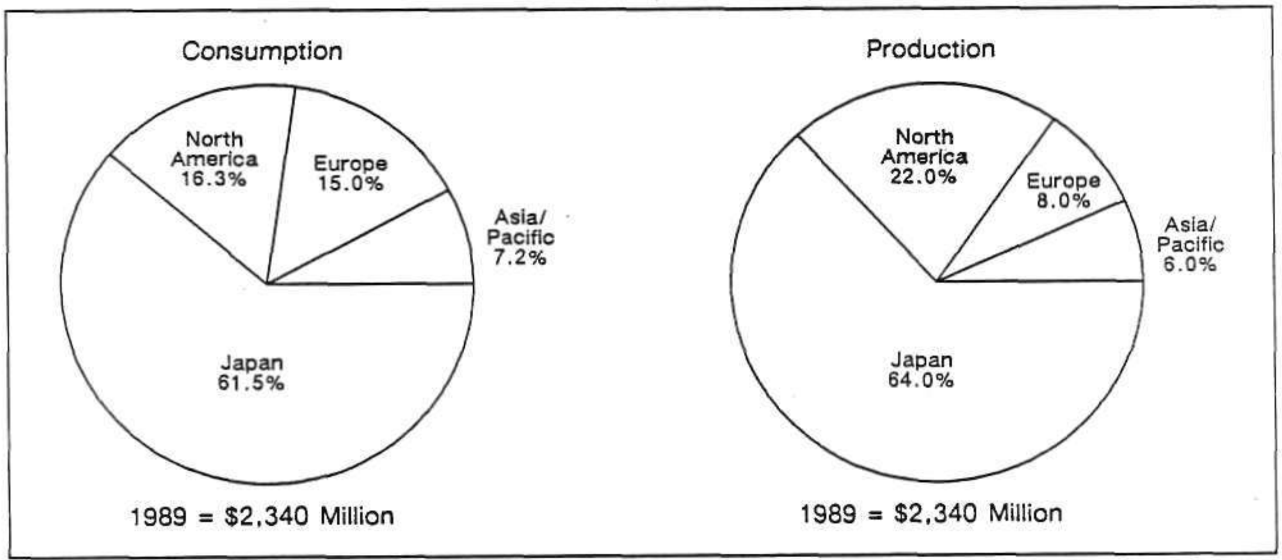
FIGURE 3
Optoelectronic Semiconductors by Region



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Source: Dataquest
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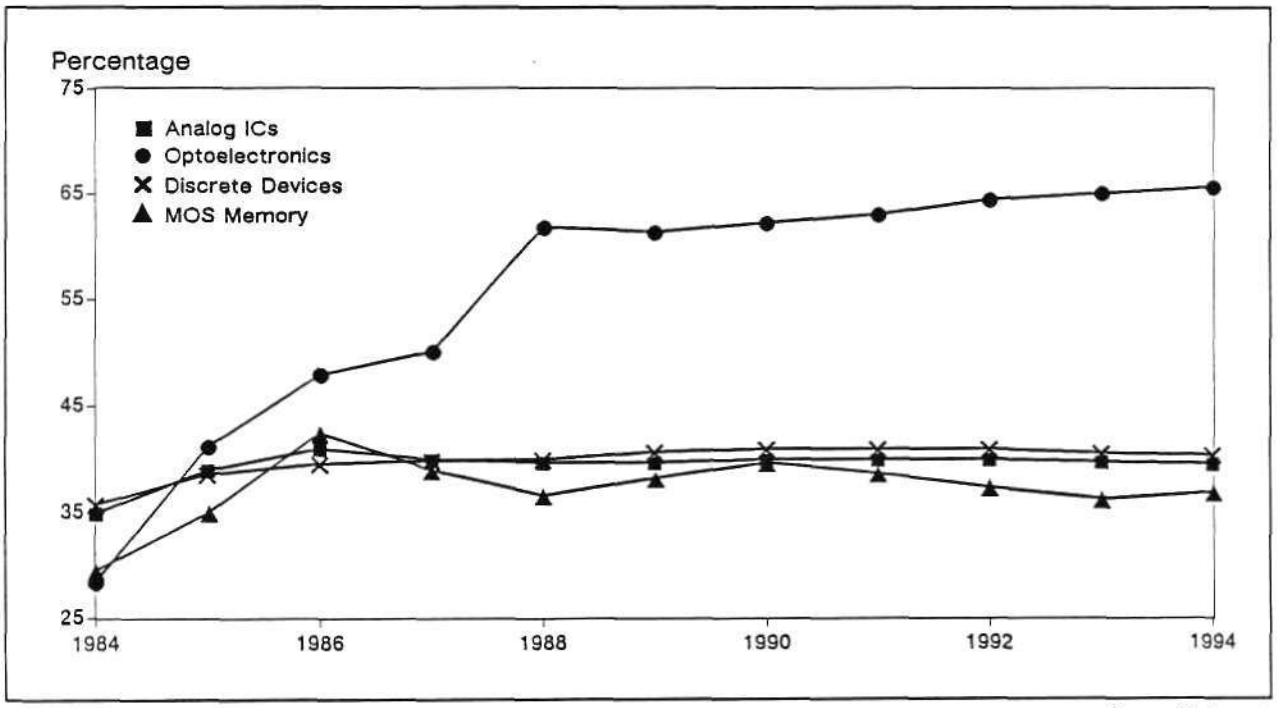
FIGURE 4
Total Japanese Consumption by Product Type



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Source: Dataquest
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Are Consortia the Answer?

In order for the United States to regain a significant position in the opto market, it is evident that some kind of government funding or industry-based consortium will be necessary. Both the Japanese government-based optoelectronic consortium and the European Esprit consortium are gearing up to participate in the semiconductor optoelectronics boom foreseen in the 1990s.

More than a production consortium is needed in the United States, however. A significant domestic market must also exist. Without a consumer-type industry to invest in the product, an optoelectronic consortium will continue down the path of providing limited products to limited markets. An industry focus on lower-volume niches may be unable to compete with Japanese products honed and tempered by the demands of the consumer market.

Computer Manufacturers Unite

In the United States, some leading computer manufacturers are currently meeting with the intention of forming a consortium to develop and manufacture high-definition LCDs. These companies include Apple, Compaq, and Sun Microsystems, and relatively high-end PC and workstation manufacturers. The question remains: Will the combined volume of these manufacturers represent the type of unit volume that drives the creation of cost-efficient, high-resolution displays useful to broad markets? Although the distinction between personal computers and home entertainment products may blur in the future, it is quite distinct now and is likely to remain so for at least the better part of the decade.

Beyond LCDs, other consortia have been and are being proposed as a means to bridge the gap between U.S. R&D and marketable semiconductor optoelectronics.

DATAQUEST CONCLUSIONS

Dataquest believes that successful U.S. efforts in high-resolution graphics and HDTV may be sparse if one of the crucial technologies—the flat-panel, high-resolution display—is not developed, manufactured, and consumed domestically.

Other enabling optical products include semiconductor lasers (which are finding increasing use in scanners, instrumentation, optical data storage in both entertainment and industry, and fiber-optic data transmission) and image sensors (which are key to visual cognition and image processing).

Among the more exotic future applications for laser diodes are optical computers and more efficient lighting schemes that are beyond present fluorescent lighting.

We believe that optoelectronic products should not be viewed as merely visual input or output devices. The trend in both the image sensing and display ends of optical electronics is to increasingly add the signal processing to the image sensor or display device. On-board image processing may eliminate many signal processing applications for standard IC products. Consumer products and government-led consortia may be the only way for the United States to regain a viable position in this important technology.

Gary Grandbois

Attachment A

RECENT OPTOELECTRONIC NEWS

CCD

Sony has developed a 1-inch-square, 2-million-pixel CCD using 0.3-micron design rules (as have NEC and Toshiba). This latest development is comparable to 64Mb DRAM processing requirements, and it underscores another technology driver that Japan is leading in.

LASER DIODES

Toshiba has introduced a high-output (10-milliwatt) 670-nanometer laser diode. This product expands the market for laser diodes by allowing a semiconductor replacement for the standard red helium-neon lasers found in bar code scanners, pointers, and long-distance instrumentation. Initial pricing is $200 per unit.

LCD PANELS

Ovonic Imaging Systems in Troy, New York, is building the first large-size active LCD panel production facility in the United States. This $26 million facility is largely funded by the state of New York (to the tune of $20 million). Initial panel size will be 15 x 15 inches and will be aimed at the defense industry (avionics and laptop computers). This LCD panel, smaller than that proposed by other ventures (IBM/Toshiba joint venture, the proposed U.S. consortium, Toshiba's $300 million large-panel LCD manufacturing investment, and the $100 million *Giant Electronics* consortium in Japan) is not a development-intensive, state-of-the-art product. It is intended to set up domestic manufacturing base quickly and provide a product to a waiting market. The panel, besides being of limited dimensions, will require external driver ICs.

Ovonic's intent to provide military displays underscores a recent problem whereby C-5B military transports had to be assembled with active matrix LCDs from Hoseiden of Japan. Without a domestic supplier, Japanese LCDs were being designed into a score of U.S. air and naval vehicles.

FTM DISPLAYS

Zenith Electronics Corporation plans to spend $50 million to develop high-resolution flat tension mask (FTM) CRT displays beyond the present limit of 14 inches. Larger FTM displays will be introduced in increasing sizes on an annual basis until the limit of a 35-inch display is reached. Large-screen HDTV use will be eliminated by this 35-inch FTM display limit.

FLAT EMISSION DISPLAYS

Flat emission displays (FEDs) are emerging from the laboratory. FEDs are essentially flat CRT displays that can be as thin as one-tenth of an inch and offer the advantages of CRTs while eliminating the normal beam deflection requirements. Although this technology has existed for decades, it has never been brought to market because of problems in achieving manufacturability. SRI International, which developed FED technology, believes that these problems have been resolved and has granted commercialization rights to Coloray Display Corp., a start-up located in Fremont, California.

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Research *Bulletin*

KOBE STEEL AND TEXAS INSTRUMENTS: FROM STEEL TO SEMIS

SUMMARY

This week Kobe Steel and Texas Instruments (TI) announced the establishment of a joint venture in Japan to manufacture VLSI ICs and ASICs. Construction of the $350 million wafer fab in Hyogo Prefecture, Japan, is expected to commence early in 1991 and be completed within the year. Kobe Steel will provide the majority of the equity capital and will own a majority interest in the joint venture. TI will provide the technical assistance in the form of design and manufacturing technology required to build and operate the plant and will provide some additional funding. TI will have the option to increase its ownership in the joint venture, although no specific terms have been divulged. Both companies will contribute personnel to the venture, which is called KTI Semiconductor Ltd. The semiconductor output from KTI will be sold exclusively to TI, which will have worldwide sales and distribution rights.

SILICON: THE NEW "CORE MATERIAL"

During the past three years, Kobe Steel, while strengthening its core businesses in steel and machinery, has been increasing its emphasis on other businesses such as electronics, advanced materials, biotechnology, and services. In 1986, Kobe Steel began diversifying into computers and telecommunications in response to several years of declining steel prices and sales. The company's fiscal year 1988 sales were $8.9 billion, and it employed 21,436 people. Based on these data, Kobe Steel was Japan's twentieth largest industrial firm in 1988. By the year 2000, Kobe Steel plans to have its non-steel line account for 40 percent of total sales. The company's mid- to long-range management plan features further diversification into electronics as a key element. The firm's diversification plans incorporate overseas expansion and target opportunities in the high-technology area through acquisitions or alliances. Kobe's current semiconductor-related activities include marketing inspection equipment and providing testing services through its subsidiary, Genesis Technology.

In recent years, there has been an observable trend among Japanese steel and heavy industry companies toward diversification into the electronics industry, partly to offset the strengthening yen and weakening markets. Steel companies such as Kawasaki Steel, Kobe Steel, and Nippon Kokan, which supply core materials for steel, have turned their attentions toward the core materials of the electronics market: ICs. In the mid-1980s, LSI Logic formed Nihon Semiconductor, a joint venture with Kawasaki Steel. Now Kawasaki Steel is gearing up to run its own wafer fab facilities, which should be operational next year and will produce ASICs and general-purpose memory ICs.

TI'S GLOBAL STRATEGY

TI, which ranked as the sixth largest semiconductor company worldwide and the leading nondomestic supplier to the Japanese market in 1989, has ambitious capital spending plans for 1990. TI, the first U.S. company to operate and own a semiconductor company in Japan, has always pursued aggressive regional investment. Table 1 shows that only one of the company's planned submicron CMOS memory and advanced logic fabs is located in the United States.

TI has embraced the globalization of manufacturing and is pursuing its goals through innovative financing that is global in scope. Dataquest estimates that TI will spend approximately $1 billion on semiconductor property, plant, and equipment this year—more than any other company in the world and a whopping 36 percent of total semiconductor revenue (represented in

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Table 1
Texas Instruments' Submicron Memory and Advanced Logic Fabs

Location	Product Type	Status
Avezzano, Italy	4Mb DRAM	Under construction
Freising, West Germany	Advanced logic	Upgrading
Miho, Japan	4Mb DRAM	Upgrading
Hiji, Japan	4Mb DRAM	Upgrading
Dallas, Texas	4Mb DRAM, advanced logic	Upgrading
Taiwan	4Mb DRAM	Under construction

Source: Dataquest
March 1990

1989 dollars). Of this amount, $780 million would be internally funded. The remainder of the funding would be generated through TI's customers, local governments, and joint-venture partners.

TI AS JAPANESE SUPPLIER

TI ranks as the seventh largest ASIC supplier worldwide. The company garners slightly more than one-third of its ASIC revenue from the Japanese market. TI Japan wants to continue to increase its market penetration in Japan by addressing the consumer electronics segment of that market, where it is investing both in terms of local design centers, (it currently has four), and through strategic partnerships with Japanese companies. Aside from the large dollar volume represented by the consumer market, the economies of scale associated with it and the impetus it provides to hone quality and cost performance ensure that participation in this market segment coincides with TI's strategic program. For example, one area of next-generation consumer ICs that TI has targeted is through an agreement with Nippon Hoso Kyokai (NHK), Japan's public television broadcasting company, for its "hi-vision" advanced TV receiver technology, which TI will use to develop chip sets for the different HDTV markets. Currently the consumer portion of the Japanese semiconductor market, which is about one-third of the market, is softening and is not expected to resume growth until 1992.

DATAQUEST ANALYSIS

From TI's perspective, this venture is expected to aid its market penetration of the Japanese market while availing it of a more risk-averse approach to the financing of additional manufacturing capability through Japan's lower cost of capital. Kobe Steel is forging ahead with its diversification goals through this partnership. However, a broader issue relates to how Japanese companies are adopting a comprehensive strategy that ranges from the location of overseas fabs, regionally based R&D, technology exchanges and alliances, and the procurement of foreign-made ICs in terms of its strategy to address the increasingly globalized nature of the semiconductor industry. Under the shadow of strained trade relations between Japan and the United States, Dataquest sees that Japan is responding to U.S. criticism of the inaccessibility of Japan's marketplace by directing its efforts toward opening its markets through alliances, thereby achieving increased market access on a partnership basis.

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Research *Bulletin*

NEC MOVES TO BOOST PURCHASE OF FOREIGN ICs THROUGH ALLIANCE WITH AT&T

INTRODUCTION

Against the backdrop of an SIA filing with U.S. Trade Representative Carla Hills that Japan be designated a Super 301 offender because of noncompliance with the U.S.-Japan Semiconductor Trade Arrangement, AT&T and NEC last week announced a major agreement whereby NEC and other Japanese firms will be able to boost their purchases of foreign semiconductors.

NEC LEADS AGAIN

As the battle lines are being drawn over what action to take concerning the apparent lack of progress on increased U.S. market share in Japan, Japanese press accounts are reporting that the Ministry of International Trade and Industry (MITI) continues to exhort Japanese companies to increase their purchases of foreign ICs. Preliminary market share data compiled by Dataquest (based on a survey of 83 companies) reported a somewhat bleak assessment that North American semiconductor suppliers' Japanese market share increased from 9.5 percent in 1988 to 9.7 percent in 1989. The input that we have received from analysts in our Tokyo office emphasizes that this agreement is because of renewed Japanese efforts to increase purchases of U.S.-made semiconductors. An increase in ASIC-type alliances between U.S. and Japanese semiconductor manufacturers is considered an optimum way to achieve the United States' target of 20 percent market share in Japan. Just a week prior to the announcement of this agreement, NEC said that it could increase its foreign semiconductor market share to 23 percent by the end of July 1991, having already reached a 20 percent level. As the leading worldwide semiconductor supplier for the past five years, NEC was viewed as one of the few major Japanese companies without a major U.S. partner. By comparison, Toshiba has aligned itself with Motorola, and Texas Instruments (TI) and Hitachi are closely associated.

NEC ALLIES WITH AT&T

NEC has chosen to align itself with AT&T, a move that is expected not only to raise NEC's purchases of U.S.-made ICs but also to provide an additional source of NEC products to other Japanese customers. The five-year agreement licenses AT&T to design, manufacture, and market NEC's gate array products. AT&T also will provide manufacturing support for NEC's 4-bit microcontrollers, a segment in which NEC is among the leading suppliers worldwide. Part of the agreement provides for an accelerated design-in of AT&T's semiconductors into a variety of NEC products, such as communications systems and computers. As significant semiconductor users and suppliers to the telecommunications industry, one could anticipate further cooperation between these two giants in this area.

The terms of the agreement provide AT&T with NEC's gate array products, starting with the CMOS 6/6a family of gate arrays introduced in April 1989. The CMOS 6 Series represented NEC's first use of channelless arrays. Manufactured using a 1-micron geometry, the products feature between 5,000 and 177,000 gates with usability ranging from 50 to 75 percent. Future generations of gate arrays and CAD technology developed by the companies during the term of the agreement are also included.

MARKET SHARE RANKINGS

Dataquest's preliminary market share rankings of the top ASIC suppliers in 1989 show that both AT&T and NEC number among the top 10. Table 1 also shows that NEC's number two ranking is overwhelmingly attributable to revenue derived from gate arrays, while AT&T's number six position is due to its considerable cell-based IC revenue. The $46 million that AT&T garners in

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Table 1
Top 10 Suppliers' Estimated 1989 Worldwide ASIC Shipments—Total (Millions of Dollars)

1989 Ranking*	Company	Gate Arrays	CBICs	PLDs	Total
1	Fujitsu	621	48	-	669
2	NEC	548	27	-	575
3	LSI Logic	420	37	-	457
4	Toshiba	299	101	-	400
5	AMD	24	-	314	338
6	AT&T	46	257	-	303
7	TI	28	155	91	274
8	Hitachi	263	6	-	269
9	VLSI Tech.	47	122	-	169
10	National	106	12	42	160

*Preliminary

Source: Dataquest March 1990

gate array sales comes from ECL gate arrays and analog arrays.

Clearly, in terms of its product portfolio, AT&T's deficiency in MOS gate arrays represented a significant gap, which this alliance addresses. It appears that, from AT&T's perspective, alliances are serving as a cornerstone to a more extensive product portfolio. In December, AT&T, Microelectronics, and Xilinx, Inc., signed a five-year agreement that addressed AT&T's shortfall in the PLD area. Significantly, the majority of AT&T's CBIC revenue is generated by intracompany sales. The company has the applications expertise to implement such devices in its systems offerings. What will be important to the company, in addition to achieving higher sales in the world's largest semiconductor market, will be to increase its penetration in the merchant arena. NEC also will benefit from access to AT&T's powerful computer-aided design (CAD) tools. Depending on execution, the potential advantages to AT&T from this agreement are utilization of spare capacity, greater economies of scale from larger volume sales, and further exposure to the competitive rigors of the merchant market, which drives leading-edge products. Manufacture of the devices initially will take place in Allentown, Pennsylvania, and may in the future also be accomplished at AT&T's facility in Spain.

Partnerships: A Cornerstone of Japan's Strategy

Although it almost seems like a cliche nowadays to talk about strategic alliances, it nevertheless bears reiteration that "partnerships will become standard business practice." (See Dataquest Components Group newsletter 1989-11, entitled "Semiconductor Megatrends in the 1990s.") Whereas in the 1980s many U.S. companies tended to trade strategic long-term technology for short-term manufacturing capability in the name of alliances, Dataquest is observing a new caliber of alliances that are being utilized more as competitive and strategic tools. Regarding Japan's strategy to open its market further, a trend seems to be emerging. In an effort to respond to the increasingly globalized nature of the semiconductor industry, Japanese companies are formulating a comprehensive strategy that includes the location of overseas fabs, regionally based R&D, technology exchanges and alliances, and procurement of foreign-made ICs. In addressing U.S. criticism regarding the inaccessibility of its marketplace, Japan is directing much of its efforts toward responding to this issue through the vehicle of alliances, so that greater market access can be achieved on a partnership basis. Not only does this strategy seem to follow Japan's culture of business through close relationships, it also may be a more effective way for a foreign supplier to negotiate both the language barriers and the inherent complexities of that country's infrastructure.

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