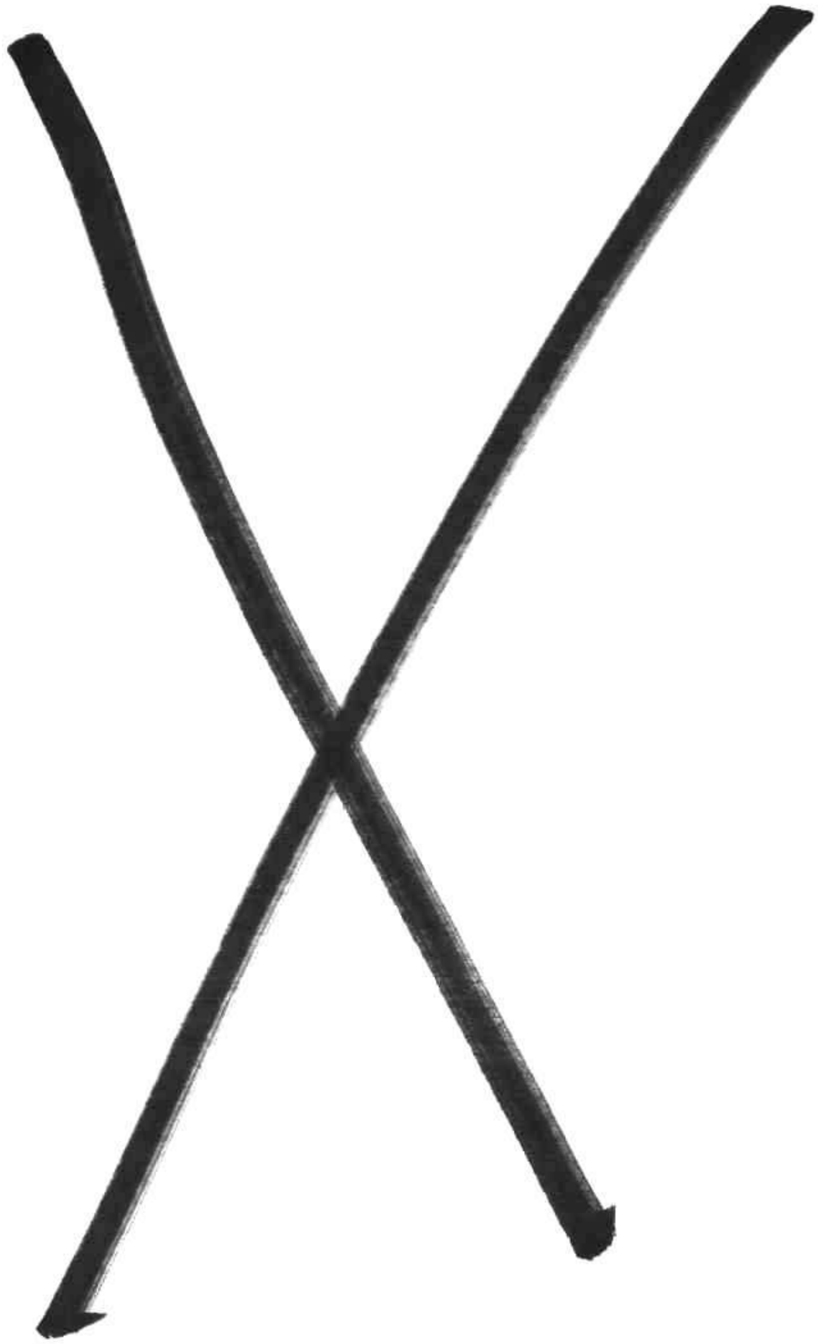


Dataquest
a company of The Dun & Bradstreet Corporation

Research *Bulletin*

ANOTHER GIANT IN A WORLD OF START-UPS: TOSHIBA ENTERS THE PC CHIP SET MARKET

BACKGROUND

On January 11, 1991, Toshiba introduced an 80486-based Micro Channel Architecture (MCA) chip set for applications in high-end desktop computer systems. The new chip set is the product of a strategic alliance between Toshiba and Micral, an independent affiliate of Groupe Bull. The 4-chip family is designed by Micral and will be manufactured and marketed by Toshiba. Toshiba is among the first manufacturers to announce a 486 MCA chip set, although Dataquest expects the 486 MCA market to achieve the most significant growth of any segment in the PC chip set market over the next two years. Toshiba's market entry is a very significant development, indeed. What we are observing is a first-tier semiconductor manufacturer teaming with a leading MCA design house to compete with its own customers in the merchant arena of a most significant emerging market.

COMPETITIVE ISSUES

One of the more interesting issues surrounds Toshiba's foundry customers. Toshiba provides manufacturing services for a large number of PC chip set suppliers. Of particular note is Chips & Technologies, the market leader. Although Chips has foundry relationships with several other manufacturers including Fujitsu, LSI Logic, National Semiconductor, NEC, Oki, Seiko, Ricoh, and Yamaha, the company does not want to be in a situation where one of its major competitors controls its cost of silicon. It is realistic to believe that Toshiba's presence in the chip set market may catalyze the dissolution of its relationship with Chips & Technologies.

Chips & Technologies is not alone. Many fabless chip set suppliers that rely on foundry services from Toshiba and other semiconductor manufacturers are faced with an interesting predicament: As the level of complexity and integration in systems logic chip sets increases, the number of silicon suppliers with adequate processes to produce the chips decreases. In previous generations of AT-bus products, the level of design complexity was such that silicon was virtually a commodity product and much of a chip set company's added value resided in the chip design. With dozens of qualified silicon suppliers, the technological barriers to entry were relatively low for any design house with a reasonable amount of systems expertise. However, as design complexity increases, the number of designers and silicon vendors qualified to supply the product shrinks. Much of the added value in a high-end chip set will reside in the fabrication process technology. This situation poses a significant challenge to the league of fabless chip set design houses.

Toshiba is the second broad-line semiconductor manufacturer to enter the chip set market in the past four months. The first was National Semiconductor in October 1990 with AT-bus chip sets for 286- and 386SX-based systems. Other large semiconductor manufacturers in this market include Texas Instruments, Intel, and Motorola (through its relationship with ACC Microelectronics). Dataquest believes that broad-line suppliers have a greater chance for success in this cutthroat market, financially and technologically, as manufacturing capability becomes the determining factor. Many niche chip set suppliers eventually will be squeezed out of the market or acquired by larger semiconductor companies. Those that do survive will focus on leading-edge and enabling products such as data/voice compression and multimedia/DVI. These features and functions will reside within the PC in future generations.

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

Dataquest believes that the 486 MCA-based chip set market will experience significant growth in the next two years as the industry continues to progress along the MPU performance path. Intel has stated that shipments of the 80386DX peaked in 1990 because it was being "squeezed at both ends" of the performance spectrum by the 486 and the 80386SX. Now that AMD has introduced its Am386 clone of the 80386, Intel has still further reason to make the 386DX obsolete. Intel's goal is to establish the image of performance and desirability for the 486 products. The achievement of this goal likely will mean substantial price reductions in 1991 for the 486, particularly the 486-25. As a result, Dataquest expects to see a marked increase in the number of 486 shipments and resultant shipments of 486-based chip sets in 1991. Furthermore, although the number of 486-based chip set vendors currently is limited, we expect to see regular introductions of new 486-based products throughout 1991.

DATAQUEST CONCLUSIONS

As expected, the PC chip set business is maturing quite rapidly. No longer the high-margin niche market with low entry barriers, the highly competitive chip set arena has quickly become an overpopulated market with intense competition. As more companies have entered the market, product differentiation has become more difficult to achieve and vendors are facing increased competition on the basis of price. The critical competitive advantage is becoming low-cost manufacturing. At the same time, the determining factor for added value is quickly becoming manufacturing process technology. For these reasons, Dataquest believes that the balance of power in this market is shifting to the large, well-diversified manufacturers with leading-edge processes. In the next two years, we expect a shakeout to occur in this market, with the survivors being the well-established broad-line suppliers and other companies that have the design expertise and the agility to pursue other leading-edge niche opportunities.

Ken Pearlman
Phil Mosakowski

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

MICROCOMPONENT MARKET SLOWS: FORECAST OVERVIEW

MICROCOMPONENT MARKET CONTAINED BY SLOW GROWTH

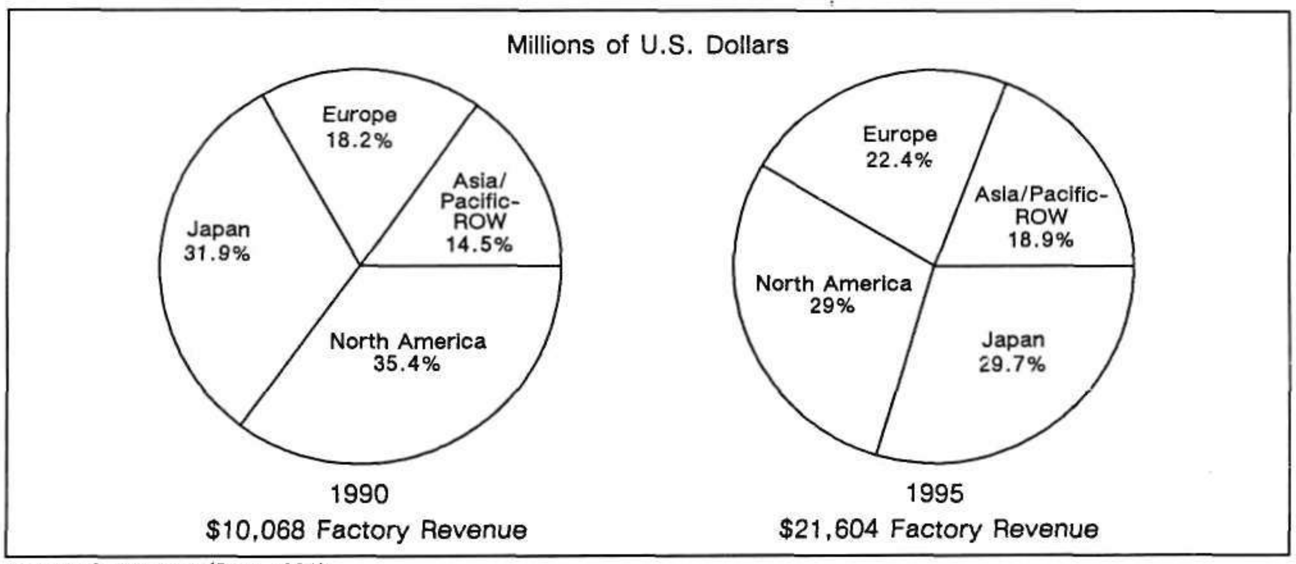
Like a forest fire, the microcomponent market began kindling in the mid-'70s. It blazed throughout the '80s, but, as with any fire, containment is inevitable. Dataquest expects microcomponent growth to be moderately paced in the '90s. In 1990, the market reached $10.1 billion in revenue, representing a 22.8 percent increase over 1989. Looking back over the last decade, the compound annual growth rate (CAGR) for microcomponents has exceeded that of the total semiconductor industry. The microcomponent CAGR was 26.1 percent for 1980 through 1985 and 29.7 percent for 1985 through 1990, while the total semiconductor CAGR was 11.5 percent for 1980 through 1985 and 19.1 percent for 1985 through 1990.

Dataquest forecasts the microcomponent CAGR for the next five years to slow dramatically to 16.5 percent. The drop in growth can be primarily attributed to the maturing electronic equipment industry. The demand for microcomponents is still rising because of the pervasiveness of embedded control applications. Yet, growth is slowing because the electronic equipment growth is flattening, specifically in the PC market, which consumes approximately 25 percent of all microcomponent sales.

REGIONAL SHIFTS: THE GAPS ARE CLOSING

With expanding electronic equipment production in the European and Asia/Pacific-Rest of World (ROW) regions, the differences in microcomponent consumption between these regions and North America and Japan are equalizing. As shown in Figure 1, Dataquest expects North

FIGURE 1
Microcomponent Regional Consumption Forecast



Source: Dataquest (June 1991)

SIS Newsletters 1991—Microcomponents

0010763

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

America and Japan to remain the dominant regions. High growth is expected in Asia/Pacific for two reasons—a booming PC export business and a growing market resulting from increased domestic income. As equipment manufacturers shift operations to these two regions, Europe and Asia/Pacific's electronic equipment production will increase at a 9.0 and 12.7 percent CAGR, respectively, through 1995. Europe may also experience additional growth as a result of a unified Europe. As shown in Figure 2, North America is expected to grow at a slower pace than Japan because of Japan's more robust equipment market.

THE 32-BIT MPU DOMINATES, WITH 64-BIT MPU EMERGING

Representing a 28.3 percent increase in growth over 1989, the microprocessor (MPU) market totaled $2.4 billion in revenue during 1990. Figure 3 clearly shows that 32-bit MPUs accounted for more than one-half of the 1990 MPU sales (approximately 60 percent). Dataquest believes that the 32-bit MPU will continue to dominate the market, with growth being driven by the expanding application markets of high-end PCs, laser printers, workstations, graphics, military control, and various other embedded applications.

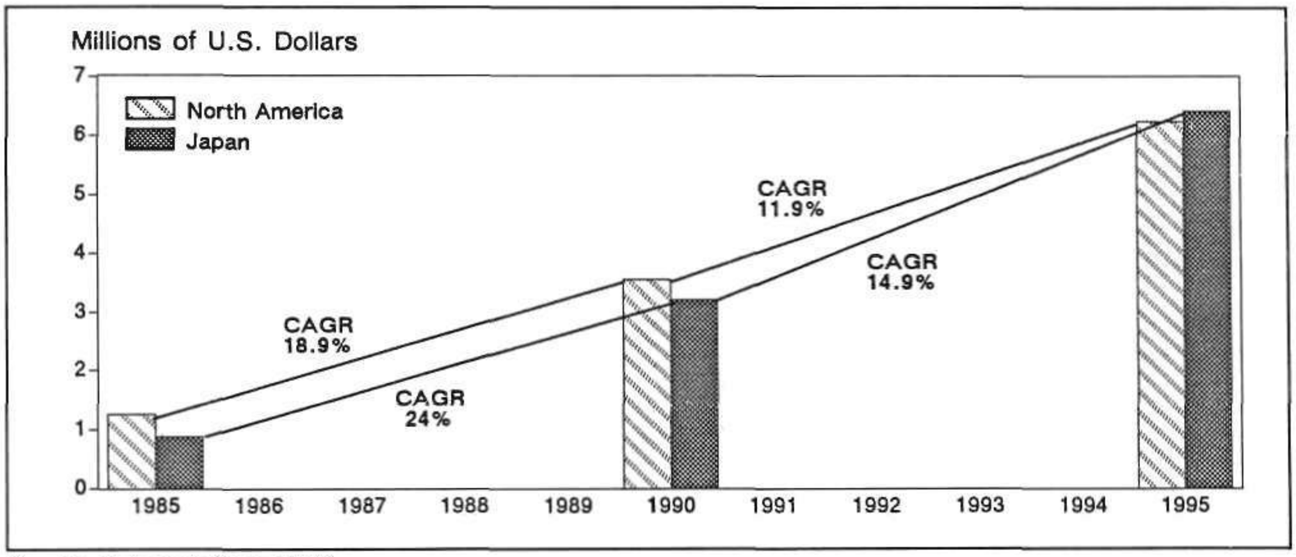
The 64-bit MPU is expected to make its entrance in 1992; however, its impact is questionable. The primary area for 64-bit MPU exploitation will be in the scientific and technical industries that require heavy-duty graphics and computing-intensive applications. These industries account for one-fifth of the $106.1 billion computer systems market. Although Dataquest does not foresee the 64-bit MPU making a significant impact in the upcoming five years, a number of 64-bit products are already in development, including products from Intel, Matsushita (Panasonic), MIPS, and Motorola.

The 64-bit MPU may follow the 32-bit MPU's acceptance cycle into the business world, particularly if Intel's 80586 is a 64-bit processor as expected. However, a major obstacle with the 64-bit MPU will be software availability. With the growing demand for 32-bit software, the majority of software manufacturers are concentrating on 32-bit software, as well as maintaining and upgrading their current product lines.

OPPORTUNITIES FOR HIGH-END MCUs

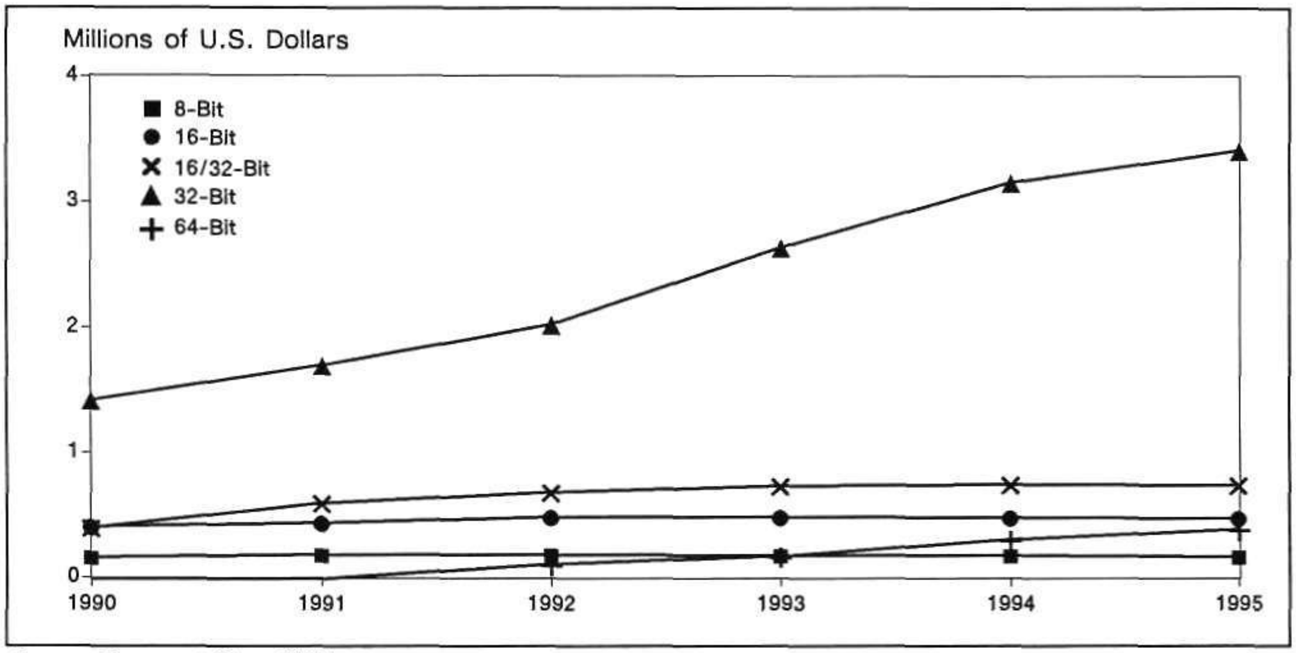
Although its growth will be slowing, the 8-bit microcontroller (MCU) will account for more than one-half of the revenue generated in the MCU market during the next five years. As shown in Figure 4, the 8-bit MCU will continue to take demand away from the 4-bit MCU, making 4-bit growth relatively flat. This shift has occurred as applications become more feature intensive and price disparity between 8- and 4-bit MCUs narrows. Although shifts in consumer preference

FIGURE 2
Microcomponent Consumption Forecast: North America and Japan



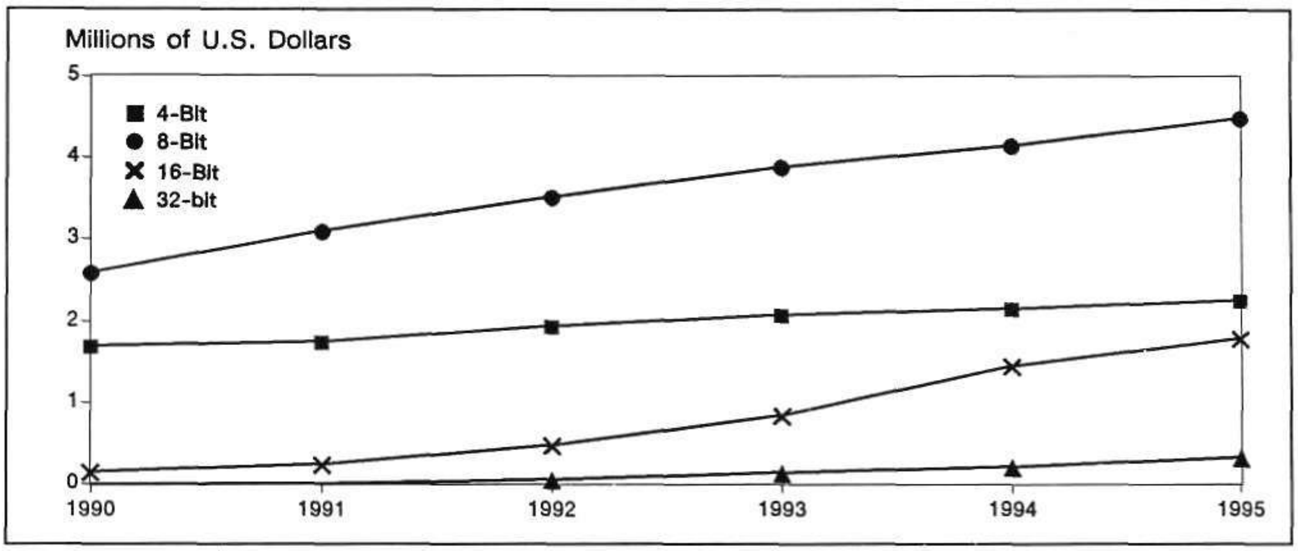
Source: Dataquest (June 1991)

FIGURE 3
Microprocessor Revenue Forecast by Word Length



Source: Dataquest (June 1991)

FIGURE 4
Microcontroller Revenue Forecast by Word Length



Source: Dataquest (June 1991)

occur, the basic demand for consumer goods remains; therefore, 4- and 8-bit MCU consumption will continue to grow. However, their expected 1990-through-1995 CAGRs will be moderately low at 5.8 and 11.8 percent, respectively.

The increased demand for 32-bit systems will create opportunity for high growth in the 16- and 32-bit MCU market. Dataquest expects CAGRs of 62.4 percent for 16-bit MCUs and 178.5 percent for 32-bit MCUs. Currently, the 16-bit MCU is being heavily utilized in the automotive industry. Growth opportunities exist for 16-bit MCUs in disk drives, advanced PC peripheral controls, and high-end consumer audio/video equipment. The 32-bit MCU made its entrance in 1990. With its initial big design win in the automotive industry, Dataquest expects 32-bit MCUs to displace 16-bit MCUs in engine control applications.

DATAQUEST CONCLUSIONS

The major conclusions drawn from Dataquest's microcomponent forecast are as follows:

- Microcomponent market growth is slowing as the market matures.
- Europe and Asia/Pacific-ROW are emerging as regions of opportunities for electronic equipment production and microcomponent consumption.
- The 32-bit MPU will be the driving force in the microprocessor market.
- In this forecast period, the 64-bit MPU is not expected to be a significant factor, primarily because of the lack of application software for the 64-bit processor.
- Growth of 8-bit MCUs is expected to be moderately strong at a 11.8 percent CAGR.
- The automotive industry will drive 16- and 32-bit MCU demand.
- The focus on 32-bit systems will result in major opportunities for high-end embedded control products.

Lisa Costa

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

SEMATECH'S CONGRESSIONAL REVIEW: IS THE BEST IT CAN BE GOOD ENOUGH?

"SEMATECH could meet all of its R&D objectives on schedule and still not restore U.S. manufacturing leadership." *SEMATECH 1990: A Report to Congress*

SUMMARY

The National Defense Authorization Act for fiscal years 1988 and 1989 established the Advisory Council on federal participation in SEMATECH and charged it with, in the council's words, "reviewing SEMATECH's operations each year and assessing continued federal participation." The Advisory Council, chaired by John A. Betti, Under Secretary of Defense for Acquisitions, has once again recommended to Congress that the federal government continue its funding of America's most visible high-technology consortium.

The Advisory Council report, however, also raises issues about SEMATECH's long-term effectiveness. In particular, the report expresses concerns about the following:

- SEMATECH has not been a sufficient antidote to continuing erosion in the U.S. semiconductor manufacturing equipment and materials base.
- SEMATECH's focus on external R&D activities has "exposed a division of interest among the consortium's participants."
- SEMATECH's Phase 2 and 3 objectives rely too much on current-generation lithography.

Although these concerns may seem to reflect a gloomy assessment of the consortium's future, the report as a whole shows a healthy sense of pragmatism. Dataquest has been concerned that SEMATECH might be held accountable for goals that are simply unrealistic, given the consortium's structure and resources. Overall, the Advisory Council report views SEMATECH's main benefits to Americans as "indirect" in the sense that they are "likely to come from the continued operation of commercially vigorous U.S.-based manufacturing firms ready and able to exploit emerging technologies." The value of such indirect contribution to U.S. competitive strength, in the Advisory Council's opinion, is sufficient justification for continued federal support.

This newsletter reviews the conclusions of *SEMATECH 1990: A Report to Congress* and focuses on the Advisory Council's assessment of SEMATECH's progress in 1989 and the concerns it raises about the program's future.

REORGANIZATION IN 1989

The Advisory Council report attributes much of SEMATECH's progress in 1989 to its reorganization, which signaled a shift in balance between the two models that have guided the consortium since its founding. The report said that the first of these models concerned "the development and demonstration of world-class manufacturing processes on-site, and the transfer of resulting technology directly to members in large, integrated, connectable chunks." Yet another operative model for the consortium was that of a facilitator and testing ground for leading-edge semiconductor equipment and materials.

Although SEMATECH theoretically adheres to both of these models, the consortium's limited resources have made it impossible to develop an ambitious in-house production strategy as well as invest in the preservation of domestic sources of first-class tools and materials. According to the Advisory Council report, "The consortium cannot

SIS Newsletters 1991 PMT

0009154

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

afford to address strategic interests of the industry at large *and* install fully integrated high-volume production lines at the same time."

Under the late Bob Noyce, SEMATECH increased its emphasis on the second of its two underlying models. The June 1989 reorganization called for an increased volume of off-site R&D projects to meet specific equipment, materials, and manufacturing process requirements for 0.50- and 0.35-micron production. The consortium amended its mission statement to read (SEMATECH's mission is) "to provide the U.S. semiconductor industry the domestic capability for world leadership in manufacturing." To SEMATECH, domestic capability translates into U.S. equipment and materials suppliers. In preserving this capability, SEMATECH has crystallized its mission into the following two highly strategic objectives:

- Protect U.S. semiconductor manufacturers from dependence on foreign sources of supply
- Ensure that new and improved equipment and materials are developed "in place with chipmakers; purchasing cycles for the next two generations of semiconductor device technology"

Resource Reallocation

Given its objectives, SEMATECH underwent a major reallocation of its resources in 1989. In rationalizing its form with its function, the consortium canceled plans for a second fab, scaled back hiring projections, and doubled its original budget for off-site R&D. Of SEMATECH's $260 million 1990 budget, 53 percent ($137 million) was set aside for R&D contracts. In contrast, external R&D accounted for only 20 percent of the consortium's 1988 budget. Whereas plant and equipment accounted for $75 million of SEMATECH's 1989 expenditures, the current operating plan calls for plant and equipment spending to fall to $19 million in 1991—9 percent of the consortium's projected budget.

Beyond the issue of resources, the report expresses other doubts concerning SEMATECH's success in the in-house demonstration of a high-volume production capability. The report states that "to establish and operate a fully integrated fab line...SEMATECH would have been obliged to produce some version of a saleable device and to rely on its members to supply the necessary device and process designs. Whether members would have provided such support is uncertain."

Impact on Programs

The Advisory Council credits SEMATECH's reorganization with progress in the following areas:

- Technology development
- Technology transfer
- Improving supplier relations
- Strengthening the U.S. technology base

Technology Development

At the heart of SEMATECH's project-based operating system is its Master Deliverables List (MDL). This list is the result of SEMATECH's competitive analysis and comparison of U.S. and foreign manufacturing capabilities. Out of this analysis has come the current targeting of the following major thrust areas: lithography, metrology, multilevel metallization, furnace and implantation technology, and manufacturing methods and processes. At the time of the Advisory Council report, SEMATECH's MDL included 56 projects in various stages, more than one-half of which were being generated through joint-development projects (JDPs).

The Advisory Council report reveals that the increased momentum of JDP activity observed during the latter half of 1989 was due not only to changes in the consortium's structure and budget, but, more importantly, to changes in the development contract process. Quoting from an SEMI/SEMATECH annual report, the Advisory Council notes that "intellectual property proved an insurmountable barrier to starting up the development contract process." The Advisory Council report cites progress in making the participation agreements more flexible and observes that "SEMATECH now negotiates the rights to jointly developed technology (e.g., preferential purchasing and licensing rights) on a case-by-case basis, with final arrangements largely dependent on how project costs are shared and the market strength of the contractor."

With the removal of intellectual property barriers, contracting activity accelerated at SEMATECH during the second half of 1989. As a result, the Advisory Council report states that "senior officials at SEMATECH and DARPA report that the consortium's R&D program is on track and on time." Table 1 lists SEMATECH contract activity, as observed by Dataquest, organized on the basis of major technology thrust areas.

TABLE 1
SEMATECH External Development Contracts

SEMATECH Thrust Areas	Contract Partner	Program Type	Contract Date
Lithography			
Submicron Reticle and Mask Exposure System	ATEQ	JDP	May-1989
Optical Wafer Stepper	GCA	JDP	May-1989
Advanced Photoresist Processing	Silicon Valley Group	JDP	Dec.-1989
X-Ray	Hampshire	JDP	Mar.-1990
I-Line Steppers	GCA	EIP	NA
Laser Mask Writer	ATEQ	Other	May-1990
Advanced Reticle and Mask Exposure System	ATEQ	JDP	Jul.-1990
Ion Implant			
High-Energy Implantation Technology	Ion Implant Services	TAA	Feb.-1990
PECVD			
Dielectric CVD	Applied Materials	EIP	Apr.-1990
Global Planarization Process	Westech Systems	JDP	May-1990
Dry-Etch Technology			
Metal-Etch Systems	Lam Research	EIP	Nov.-1989
Plasma-Etch Technology	Oak Ridge Nat'l. Lab.	TAA	Dec.-1989
Electron Cyclotron Resonance (ECR)	Lam Research	JDP	Jan.-1990
Low-Temperature Etch	Drytek	EIP	Mar.-1990
Sputter Cluster Tool	Eaton	JDP	Jul.-1989
Metrology			
Wafer Defect Detection	KLA	JDP	Dec.-1989
Critical Dimension Measurement Systems	Angstrom Measurement	EIP	Jan.-1990
Metrology Standards	NIST	JDP	Aug.-1989
Process Architecture/Integration			
Test Chips	HP	JDP	May-1989
Advanced Isolation	NCR	JDP	Aug.-1989
Manufacturing Methods			
Ultrapure Gas Management Systems	SemiGas Systems	JDP	May-1989
Establishment of SETEC	Sandia Nat'l. Lab.	TAA	Sep.-1989
Manufacturing Specialist Training Program	Texas State Tech. Inst.	TAA	Dec.-1989
Furnaces			
Vertical Furnace	SVG	EIP	Jun.-1990

JDP = Joint-Development Program, EIP = Equipment Improvement Program, TAA = Technical Assistance Agreement
NA = Not available
Source: Dataquest (January 1991)

Technology Transfer

Prior to its reorganization, SEMATECH had stressed a horizontal transfer of technology to its member companies. This strategy was largely predicated on on-site technology development. The Advisory Council report observes that SEMATECH now relies more heavily on two-way vertical technology transfers "mediated by SEMATECH but occurring with increased frequency in direct exchanges between members and suppliers."

Although some of the tool development and prototype testing that originally was planned for the consortium's canceled tool applications process facility (TAPF) will be performed in its main fab, most of this work will be assigned to member companies. An example of such an arrangement involves GCA. At an estimated cost of $24 million to $32 million, SEMATECH is buying between 15 and 20 GCA i-line steppers to distribute to five or more member companies. With technical support from GCA, the member companies will use the steppers in their production lines, compare them with foreign alternatives, improve upon them, and share the resulting information with GCA.

With its emphasis on vertical relationships, much of SEMATECH's horizontal transfer of technology will take place through its member company assignees and through SEMATECH technology transfer teams that regularly visit member companies.

Improving Supplier Relations

The Advisory Council concludes that, in a broad sense, SEMATECH has improved communication among equipment suppliers and users through its program of workshops, symposia, and joint sessions of the SEMATECH and SEMI/SEMATECH boards. SEMATECH also has created a supplier relations action council consisting of senior purchasing and materials managers from its member companies. The purpose of this group, known in SEMATECH circles as "the partnering posse," is to "promote strategic relations with U.S. suppliers at their home companies." The report credits these efforts with the structuring of a joint effort by U.S. semiconductor manufacturers and suppliers to acquire Perkin-Elmer's e-beam and optical lithography divisions rather than risk its acquisition by a non-U.S. company.

Strengthening the Technology Base

In addition to its R&D contract efforts, the Advisory Council report notes that SEMATECH's $10 million investment in 11 universities (the SEMATECH Centers of Excellence, or SCOEs) has "generated some early unanticipated returns." The report cites four cases involving improved scientific understanding, six cases involving new experimental capability, and seven cases involving new product concepts. As of December 1989, SEMATECH had graduated more than 75 employees from its manufacturing specialist program. In August 1989, SEMATECH established a Semiconductor Equipment Technology Center (SETEC) with Sandia National Laboratory. The center, which will receive $10 million in SEMATECH funds during the next three years, is charged with the development of reliability technology for semiconductor manufacturing equipment. In another National Lab program, SEMATECH and the Oak Ridge National Laboratory joined forces in December 1989 to develop electron cyclotron resonance etch reactors for 0.5-micron wafer processing.

THE EROSION CONTINUES

Ironically, although the Advisory Council report on SEMATECH provides Congress with a highly favorable evaluation of the consortium's activities, it also points out that during this period of positive accomplishments, "erosion in the market position of U.S.-owned semiconductor manufacturing equipment and materials companies seemed to accelerate." According to Sam Harrell, president of SEMI/SEMATECH, 65 U.S. equipment and materials companies were acquired during the year of SEMATECH's incorporation. Out of these acquisitions, 37 were made by U.S. companies, 12 were made by European companies, and 16 were made by Japanese companies.

In addition to the issue of consolidation, the report runs through a now-familiar litany of industry woes such as declining U.S. market share in equipment and materials, greater size and business diversity of foreign competitors, lower hurdle rates on prospective investments for foreign competitors, and lower rates of capital spending by U.S. semiconductor companies compared with their Japanese rivals.

In the face of such broad and pernicious environmental factors, the report concludes that "even at their most successful, SEMATECH and similar measures are palliatives—selective and temporary efforts to compensate for general conditions in the U.S. economy that have contributed to competitive weakness in a range of domestic industries." Moving from palliative to competitive antidote would, however, make SEMATECH a much more expensive prescription for the industry's ills. The Advisory Council states the recommendation of the National Advisory Committee on Semiconductors (NACS) that SEMATECH be used "to channel increased R&D support to the U.S. SME (semiconductor manufacturing equipment) and materials industry." However, the NACS report estimates that "a full-scale effort to meet the needs of U.S. equipment and materials firms would require an additional $800 million over the next three years."

Areas of Concern

Beyond the question of financial resources, the Advisory Council report raises interesting queries about SEMATECH's future based on some implications of its 1989 restructure. First, the report notes that "SEMATECH intends to sustain or create one world-class U.S. producer in each major category of chipmaking equipment, second-sourcing only in special cases where the back-up company uses an entirely different tool architecture or represents a particular high-risk/high-return investment opportunity." This objective seems to confirm fears voiced by equipment makers during SEMATECH's creation that the consortium would be a catalyst to further attrition in the U.S. semiconductor equipment base rather than a force for healthy diversity.

The report also says that SEMATECH's project-based approach and external R&D activities has "exposed a division of interest among the consortium's participants." The nature of this division as characterized by the report has to do with the desire of smaller members for major infusions of leading-edge process technology. SEMATECH's focus on the preservation of domestic sources of first-class tools and materials is more in keeping with the priorities of its larger members, which already have advanced processing capability. Under SEMATECH's 1987 Partnership Agreement, December 1989 marked the first time that consortium members could give the required two-year notice activating their option to leave the alliance. As the report observes, "some of the consortium's smaller firms may have reassessed their ability to support the considerable cost of membership" (which is 1 percent of the previous year's semiconductor sales with a $1 million minimum and a $15 million cap).

The Advisory Council report also expresses concern over the implications of SEMATECH's emphasis on short-loop rather than full-flow wafer processing. The report concludes that this approach "will be insufficient for conclusive demonstrations of equipment and will impose some limitation on the development of important process technologies." In addition, the generic process architectures on which SEMATECH will base its Phase 2 and 3 objectives "could omit important steps or tools that member firms would need to make their own 0.50- or 0.35-micron products." The Advisory Council, however, recognizes that the establishment of an in-house, high-volume capability for SEMATECH is more than just a matter of financial resources. "To establish and operate a fully integrated fab line...SEMATECH would have been obliged to produce some version of a saleable device and to rely on its members to supply the necessary device and process designs. Whether members would have provided such support in uncertain."

The report's concern over SEMATECH's long-term effectiveness extends also to its R&D contracts, which its notes "focus mainly on wafer processing rather than important antecedent steps (e.g., product design, materials development) or final chip assembly and packaging." The Advisory Council also worries that SEMATECH's Phase 2 and 3 objectives rely too much on current-generation lithography rather than "technologies that may be the basis of competitive high-volume production at the end of the 1990s."

Reconciling Public and Private Interests

In coming to grips with the adequacy of SEMATECH's Phase 2 and 3 goals, the Advisory Council correctly concludes that increasing SEMATECH's funding would not necessarily provide a solution. The problem is more in the very nature of SEMATECH's public/private identity. The report points out that SEMATECH's "tendency to shorten planning horizons appears to be a recurrent pattern in consortia exposed to market pressures." Although a key objective of publicly supported cooperative R&D would seem to be the extension of private investment horizons, the aim of industry leadership is to keep such programs responsive to market requirements—in other words, keep R&D in phase with chipmakers' purchasing cycles.

DATAQUEST CONCLUSIONS

The Advisory Council views the NACS recommendation of increasing the SEMATECH budget by $100 million in the near term as a way to "reduce the risks inherent in the consortium's R&D enterprise" through the development of a full-flow demonstration environment and increased on-site testing of unsolicited equipment and materials. Increasing federal funding by a larger amount would allow the consortium to address high-cost, long-term projects such as X-ray and excimer laser lithography technology, advanced device concepts, and new materials. What concerns the Advisory Council about such a funding increase is the strain it could place on the SEMATECH alliance. An increase in federal funding in support of long-term projects (and the consequent increase in membership fees to preserve the public/private balance) would "appeal mainly to SEMATECH's largest members (and) would conflict with the consortium's evolving corporate culture, which is inclusive, cooperative, and responsive to near-term market conditions."

Based on this evaluation, the Advisory Council argues for the status quo in terms of federal support to the consortium while concluding that the SEMATECH program may not be sufficient on its own to revitalize the global competitiveness of the U.S. semiconductor industry. However, SEMATECH clearly is a means to that end and has played a major role in facilitating the application of technology from existing sources within industry, academia, and government for the improvement of existing manufacturing tools and the creation of new ones. The Advisory Council concludes that to hold SEMATECH accountable for the ultimate salvation of the U.S. semiconductor industry is to ignore the responsibilities of its member companies to incorporate the technologies it fosters and "the role of national policy in general."

Note: This newsletter was produced as a cooperative effort between the Semiconductor Industry Service (SIS) and the Semiconductor Equipment, Manufacturing, and Materials Service (SEMMS).

Michael J. Boss
Jeff Seerley

Dataquest
a company of
The Dun & Bradstreet Corporation

Research *Bulletin*

CYPRESS HAS A "FAB" NEW YEAR

On January 2, Cypress Semiconductor announced its purchase of a CMOS wafer fab belonging to Control Data Corporation (CDC). Cypress is purchasing the Bloomington, Minnesota, facility for just under $15 million. Acquiring this added capacity comes at an interesting time for Cypress Semiconductor, which is using only about 50 percent capacity at its Round Rock, Texas, fab. To understand the significance of Cypress' purchase of additional capacity when it has not fully utilized what it now has, and with a less than bullish market on the horizon, one must appreciate two aspects of the deal: timing and price.

BACKGROUND

The fact that CDC has had the VTC fab on the market is certainly not news. Under the heading "Company For Sale," the November 11 issue of *Electronic Engineering Times* advertised the offering of CDC's VTC CMOS business located near Minneapolis, Minnesota—a 170,000-square-foot facility with 16,000 square feet of Class 1 clean room, capable of handling 1.4-, 1.1-, and 0.8-micron processes. According to Dataquest's Semiconductor Equipment, Manufacturing, and Materials Service (SEMMS), the VTC CMOS line is theoretically capable of between 2,000 and 3,000 6-inch wafer starts per week.

The VTC-CDC relationship goes back many years. CDC invested $56 million in VTC at the time of the company's founding in 1984, giving CDC nonvoting preferred shares in VTC that were convertible to 49 percent of VTC's voting stock. Since then, VTC has manufactured and marketed a broad line of high-performance linear and digital ICs, using both bipolar and CMOS process technologies. VTC's product portfolio also includes a wide range of semicustom and custom ASICs, as well as standard products for the aerospace, telecommunications, and computer markets. In June 1987, not long after receiving a nearly $8 million contract from Control Data Government Systems Division, the employees of VTC sold their collectively owned 51 percent of the company to CDC, which continued to be a major customer.

CDC recently sold VTC's bipolar operations back to the management of VTC, setting a tentative deadline of mid-December to divest itself of VTC's remaining unprofitable operations. CDC's eagerness to cut a deal attracted the interest of at least two other companies besides Cypress. Given the fact that 1990 has been a lackluster year for the semiconductor industry overall, one might expect a buyer's market for wafer fabs.

TIMING

But why would Cypress be interested? In April 1990, when Altera Corporation invested $7.4 million in Cypress' Round Rock, Texas, fab in exchange for foundry, Cypress touted the deal as an opportunity to sop up unutilized fab capacity. By the end of 1990, it still appeared that the Cypress fab was running at only 50 percent utilization. The timing of the Minnesota fab's coming on line with developments in the rest of Cypress' business is important to note. In spite of current capacity utilization, T.J. Rodgers, founder and CEO of Cypress Semiconductor, has enough irons in the fire to make additional fab capacity desirable. To begin with, Cypress has its fast SRAM business to attend to—a market in which it has been particularly successful. With the 1990 MOS memory business as a whole experiencing negative growth of 17 percent, Cypress' MOS memory revenue grew 7 percent on the strength of its SRAM sales, making Cypress the 19th largest MOS memory supplier

SIS Newsletters 1991 PMT
0009193

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

in the world. Looking ahead, Dataquest has forecast a 20 percent unit growth in the fast SRAM market in 1991.

In addition to its SRAM business, Cypress has other obligations to satisfy. To begin with, Altera's April agreement with Cypress gives Altera an ownership position in the Round Rock fab, which Altera has licensed to produce four of its 0.8-micron MAX EPLDs. The deal also gives Altera access to Cypress' 0.65-micron process technology. Mr. Rodgers has other mouths to feed as well, in the form of companies that Cypress has helped create and/or sustain. These companies are Aspen Semiconductor, whose ECL RAMs and PLDs use Cypress' BiCMOS process; Multichip Technology, whose memory modules require access to Cypress' 0.8-micron wafer fab; and Ross Technology, whose SPARC microprocessors require foundry capacity from Cypress. It is likely that the VTC fab will be used primarily for additional SRAM production, freeing the submicron resources at Round Rock in 1991 for ramping up the other production commitments that Cypress has taken on.

PRICE

In addition to the timing of Cypress' fab acquisition, there is the matter of its cost to Cypress. For less than $15 million, Mr. Rodgers has picked up a CMOS facility that VTC constructed at a cost estimated to be roughly $60 million. In addition to this bargain, Dataquest sources have suggested that the terms of the deal involve no up-front cash, with CDC making the equipment payments for a two-year period and picking up the operating costs until the second quarter of 1991. Essentially, the acquisition of the VTC fab will not affect Cypress' bottom line until the third quarter of this year—plenty of time to generate some revenue. As with the Round Rock fab, the former VTC facility will be treated as a Cypress subsidiary and will be known as Cypress Minnesota Inc.

Finally, the Cypress purchase of the VTC CMOS fab gives the ring of truth to the rhetoric of T.J. Rodgers. In contrast to the generally accepted wisdom that state-of-the-art fab facilities must cost hundreds of millions of dollars to build, Mr. Rodgers has proudly pointed out that Cypress has invested only $73 million in its San Jose, California, and Round Rock facilities. Eschewing the notion that government must play a role in helping the U.S. semiconductor industry offset the growing capital costs inherent in the business, Mr. Rodgers made the following observation at Dataquest's October 1990 Semiconductor Industry Conference: "I don't know how the $400 million to $700 million fab came around, but if any of you need to build one I will guarantee to build it for you for $200 million, as long as I can keep half of the difference between the budget your people propose to you and what I actually spend doing it." Given the difference that T.J. Rodgers would have between even a $200 million facility and the price he will pay for the VTC fab, he could easily afford to buy a few more. The question that remains to be answered is just what advantage a good price on a used fab will buy for Cypress in the long run.

Michael J. Boss
Phil Mosakowski

Dataquest
a company of The Dun & Bradstreet Corporation

Research *Bulletin*

ANOTHER GIANT IN A WORLD OF START-UPS: TOSHIBA ENTERS THE PC CHIP SET MARKET

BACKGROUND

On January 11, 1991, Toshiba introduced an 80486-based Micro Channel Architecture (MCA) chip set for applications in high-end desktop computer systems. The new chip set is the product of a strategic alliance between Toshiba and Micral, an independent affiliate of Groupe Bull. The 4-chip family is designed by Micral and will be manufactured and marketed by Toshiba. Toshiba is among the first manufacturers to announce a 486 MCA chip set, although Dataquest expects the 486 MCA market to achieve the most significant growth of any segment in the PC chip set market over the next two years. Toshiba's market entry is a very significant development, indeed. What we are observing is a first-tier semiconductor manufacturer teaming with a leading MCA design house to compete with its own customers in the merchant arena of a most significant emerging market.

COMPETITIVE ISSUES

One of the more interesting issues surrounds Toshiba's foundry customers. Toshiba provides manufacturing services for a large number of PC chip set suppliers. Of particular note is Chips & Technologies, the market leader. Although Chips has foundry relationships with several other manufacturers including Fujitsu, LSI Logic, National Semiconductor, NEC, Oki, Seiko, Ricoh, and Yamaha, the company does not want to be in a situation where one of its major competitors controls its cost of silicon. It is realistic to believe that Toshiba's presence in the chip set market may catalyze the dissolution of its relationship with Chips & Technologies.

Chips & Technologies is not alone. Many fabless chip set suppliers that rely on foundry services from Toshiba and other semiconductor manufacturers are faced with an interesting predicament: As the level of complexity and integration in systems logic chip sets increases, the number of silicon suppliers with adequate processes to produce the chips decreases. In previous generations of AT-bus products, the level of design complexity was such that silicon was virtually a commodity product and much of a chip set company's added value resided in the chip design. With dozens of qualified silicon suppliers, the technological barriers to entry were relatively low for any design house with a reasonable amount of systems expertise. However, as design complexity increases, the number of designers and silicon vendors qualified to supply the product shrinks. Much of the added value in a high-end chip set will reside in the fabrication process technology. This situation poses a significant challenge to the league of fabless chip set design houses.

Toshiba is the second broad-line semiconductor manufacturer to enter the chip set market in the past four months. The first was National Semiconductor in October 1990 with AT-bus chip sets for 286- and 386SX-based systems. Other large semiconductor manufacturers in this market include Texas Instruments, Intel, and Motorola (through its relationship with ACC Microelectronics). Dataquest believes that broad-line suppliers have a greater chance for success in this cutthroat market, financially and technologically, as manufacturing capability becomes the determining factor. Many niche chip set suppliers eventually will be squeezed out of the market or acquired by larger semiconductor companies. Those that do survive will focus on leading-edge and enabling products such as data/voice compression and multimedia/DVI. These features and functions will reside within the PC in future generations.

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

Dataquest believes that the 486 MCA-based chip set market will experience significant growth in the next two years as the industry continues to progress along the MPU performance path. Intel has stated that shipments of the 80386DX peaked in 1990 because it was being "squeezed at both ends" of the performance spectrum by the 486 and the 80386SX. Now that AMD has introduced its Am386 clone of the 80386, Intel has still further reason to make the 386DX obsolete. Intel's goal is to establish the image of performance and desirability for the 486 products. The achievement of this goal likely will mean substantial price reductions in 1991 for the 486, particularly the 486-25. As a result, Dataquest expects to see a marked increase in the number of 486 shipments and resultant shipments of 486-based chip sets in 1991. Furthermore, although the number of 486-based chip set vendors currently is limited, we expect to see regular introductions of new 486-based products throughout 1991.

DATAQUEST CONCLUSIONS

As expected, the PC chip set business is maturing quite rapidly. No longer the high-margin niche market with low entry barriers, the highly competitive chip set arena has quickly become an overpopulated market with intense competition. As more companies have entered the market, product differentiation has become more difficult to achieve and vendors are facing increased competition on the basis of price. The critical competitive advantage is becoming low-cost manufacturing. At the same time, the determining factor for added value is quickly becoming manufacturing process technology. For these reasons, Dataquest believes that the balance of power in this market is shifting to the large, well-diversified manufacturers with leading-edge processes. In the next two years, we expect a shakeout to occur in this market, with the survivors being the well-established broad-line suppliers and other companies that have the design expertise and the agility to pursue other leading-edge niche opportunities.

Phil Mosakowski
Ken Pearlman

Dataquest
a company of The Dun & Bradstreet Corporation

Research *Bulletin*

U.S. SEMICONDUCTOR BOOK-TO-BILL REPORT AND ANALYSIS—DECEMBER 1990

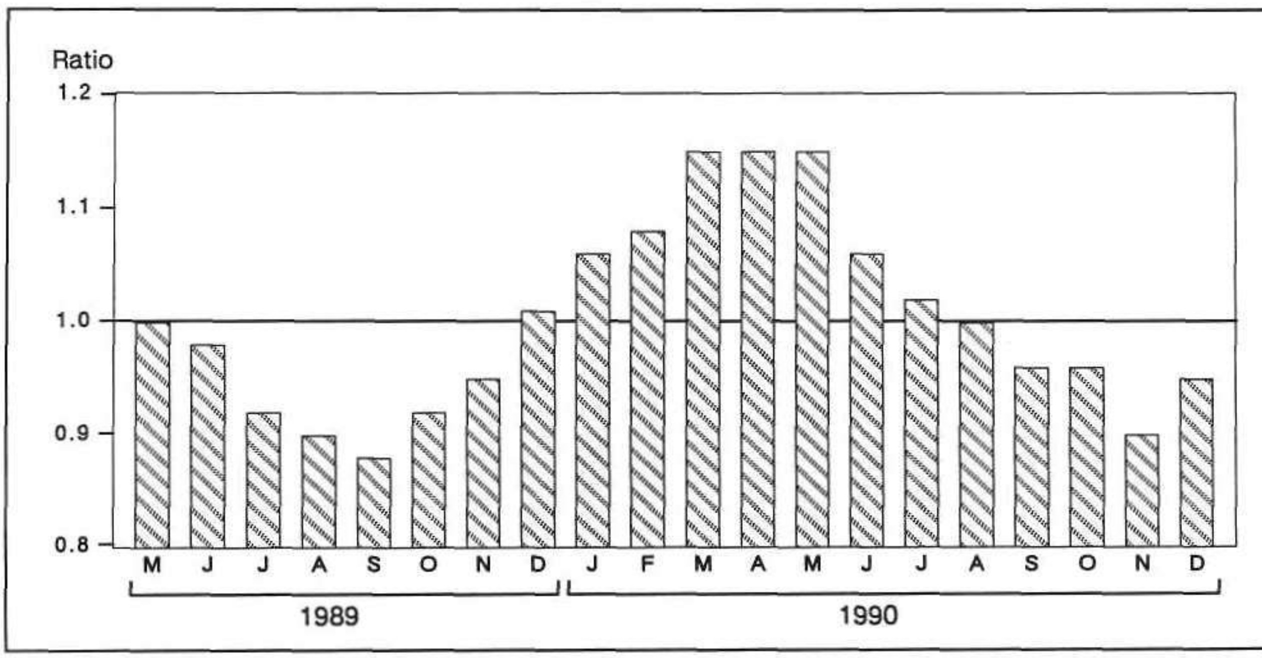
BOOK-TO-BILL RATIO

The level of orders booked to the U.S. semiconductor market in December grew 1.6 percent, while the level of sales billed declined 3.2 percent compared with November. As a result, the book-to-bill rose from 0.90 in November to 0.95 in December, 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 December increased 1.6 percent to $1,139.0 million from November's $1,121.5 million (see Figure 2). December orders are 3.4 percent lower than September's $1,179.4 million (the last end-quarter month). In addition, December 1990 bookings are 7.2 percent lower than December 1989's $1,228.0 million level. Actual billings to the U.S. semiconductor market in December were $1,192.3 million, a 1.2 percent decrease from November. In addition, December billings are 10.7 percent lower than September's $1,335.9 million and 2.7 percent lower than December 1989's $1,225.3 million.

FIGURE 1

U.S. Market Book-to-Bill Ratio (May 1989 to December 1990)



Source: WSTS, Dataquest (January 1991)

SIS Newsletters 1991 PMT

0009268

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

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 remains constant at 28 and 19 days, respectively. Buyers also maintain a positive systems sales growth outlook. They predict an average 7.1 percent growth during the next six months. This is the second consecutive month in which respondents predicted positive growth in the next six months, following a December prediction of 4.1 percent growth. Semiconductor procurement managers expect the semiconductor order rate to increase by 47.0 percent in January on a month-to-month basis. This positive outlook appears warranted, as procurement managers begin to replenish semiconductor stock after year-end inventory write-downs.

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 November over October. However, actual billings of computers and office equipment for November fell 1.5 percent from October and rose 6.3 percent over the level recorded in August (the last midquarter month). Actual bookings rose 6.3 percent from October and were up 17.3 percent over August. In addition, the three-month average growth rate for bookings of computers and office equipment rose to 4.4 percent from 1.4 percent in October.

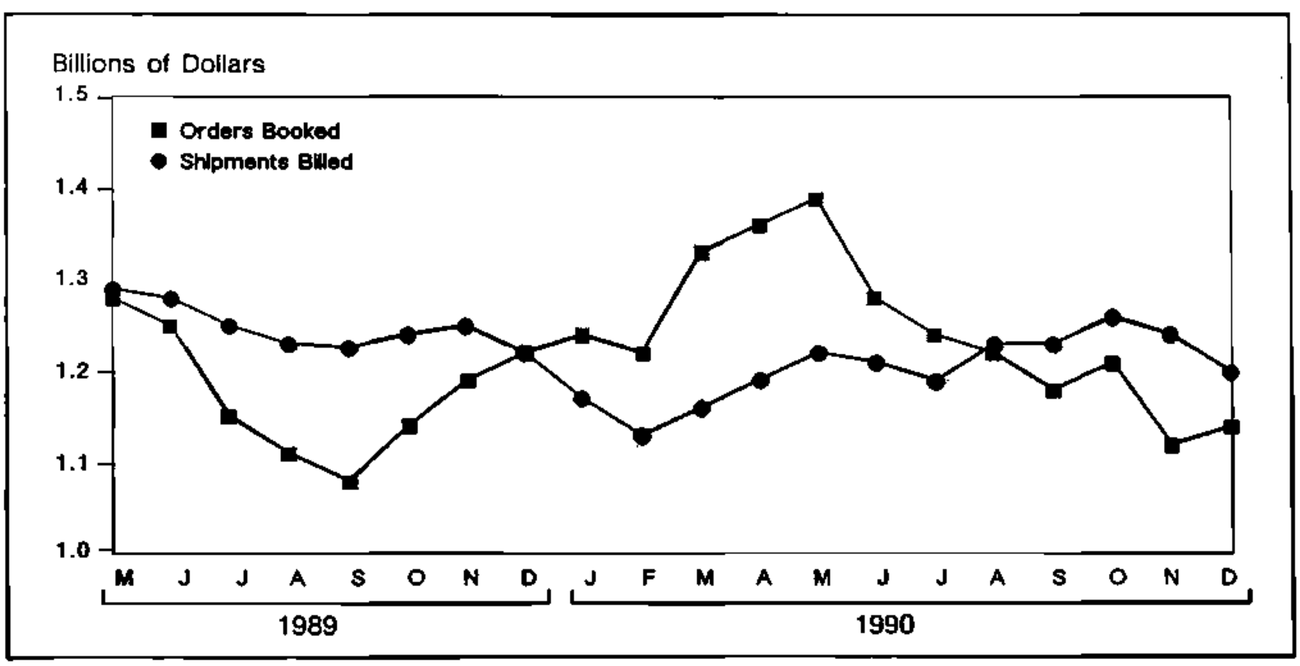
DATAQUEST CONCLUSIONS

Although economic leading indicators continue to paint a gloomy picture for the U.S. economy, indicators of the general health of the semiconductor industry remain fairly positive. November bookings of computers and office equipment showed growth of 6.3 percent over October. On a three-month moving average, both shipments and bookings of computers and office equipment exhibited positive growth in November. Semiconductor inventory levels remain quite low, which should allow increased systems sales to translate more easily into semiconductor sales growth. Semiconductor procurement experts maintain a very positive outlook for system sales and semiconductor orders. The need to replenish semiconductor stock after year-end inventory write-downs, combined with the expected uptick in system sales, lends credence to the buyers' bullish outlook. Although the current semiconductor picture is not exactly rosy, there continue to be indications that the worst may be over.

Phil Mosakowski

FIGURE 2

Three-Month Average Orders and Shipments (May 1989 to December 1990)



Source: WSTS, Dataquest (January 1991)

Dataquest
a company of The Dun & Bradstreet Corporation

Research *Newsletter*

MEMORY DOMINANCE FUELS TOSHIBA'S SUCCESS

INTRODUCTION

This newsletter is the second in a series of newsletters focusing on the semiconductor operations of leading semiconductor suppliers. Additional corporate financial information is provided in Dataquest's forthcoming Toshiba company backgrounder.

THE COMPANY

This newsletter discusses Toshiba Corporation, a leading worldwide electronics manufacturer headquartered in Tokyo, Japan. In 1989, Toshiba was the second-largest worldwide supplier of semiconductor devices, with annual sales of $4.93 billion. With stronger relative growth rates in the past two years, Toshiba is set to take over the number one position in worldwide semiconductor market share from NEC. The company's recent activities may help to catapult Toshiba into the market share lead.

In the past year, Toshiba announced several strategic actions. In April 1990, the company announced that its was in the process of selecting a site on the west coast of the United States to establish a new wafer fab. Toshiba is evaluating locations in California, Oregon, and Washington and had planned to announce the site selection in June 1990. To date, no announcement has been made regarding the choice of a location. The new fab, with an estimated construction cost of $127 million, is expected to process ASICs including gate arrays, 4Mb DRAMs, and 1Mb SRAMs. In July, Toshiba announced further expansion of its Microelectronics Center, which will provide additional master arrays and package options for quick-turn ASICs. The expansion was expected to quadruple Toshiba's quick-turn ASIC capacity to 400,000 pieces per month by December 1990, eventually reaching 500,000 pieces per month. The facility has been upgraded from 5-inch wafers to 1.0 micron, 6-inch wafers. The company reports that the added capacity allows a two-week turnaround on gate array prototypes.

In October, the company announced the opening of a self-contained design center in Portland, Oregon. The new design center, which supports Toshiba's advanced gate array and cell-based IC (CBIC) technology, services Toshiba's customer base in the Pacific Northwest including Oregon, Washington, Idaho, and Western Canada. In addition to the new Portland design center, Toshiba supports six other design centers in North America, located in Sunnyvale and Tustin, California; Burlington, Massachusetts; Atlanta, Georgia; Richardson, Texas; and Ottawa, Ontario.

In December, Toshiba announced that the construction of a new semiconductor fab at Yokkaichi City, Mie Prefecture, Japan, had begun. The plant is expected to produce next-generation memory ICs including 4Mb and 16Mb DRAMs. Toshiba expects to invest approximately $750 million over two to three years to construct a clean room facility on the 75-acre site. The total floor area will cover approximately 160,000 square feet. The plant is scheduled to begin production of 4Mb DRAMs in March 1992. The clean room will require only slight modification for the production of 16Mb devices. Toshiba plans to build more clean rooms on the site in the future, in line with growth in market demand for next generation DRAMs. The construction of the new Yokkaichi plant follows the recent completion of a new clean room at the Oita plant in Kyushu, the company's primary memory facility, to increase production of 4Mb DRAMs. The company currently produces two million 4Mb devices per month.

Tables 1 and 2 and Figures 1 through 4 detail Toshiba's product segmentation, revenue growth, and recent capital spending history.

SIS Newsletters 1991 PMT

0009270

PRODUCTS

ASICs

In 1989, Toshiba was the fourth-largest worldwide supplier of ASICs. Most of Toshiba's ASIC production is made up of gate arrays. The company is also the fourth largest worldwide supplier of gate arrays. Toshiba recently introduced a triple-metal process for gate arrays, joining the other suppliers with triple-metal capability including Fujitsu, Hitachi, National Semiconductor, and NEC.

One of the keys to Toshiba's success in the gate array market has been its relationship with LSI Logic. Through its cooperative agreement with LSI, Toshiba received LSI's design software. As a result, Toshiba served as a virtual second source to LSI Logic, which allowed the company to establish a North American gate array business of substantial volume. Although its relationship with LSI Logic, which began in 1981, has ended, the in-house tool sets of the two companies remain similar.

In addition, Toshiba has succeeded in covering its bases in the third-party EDA arena. The company has ported its ASIC library to all of the leading EDA vendors, including Cadence, Dazix, Mentor, Racal-Redac, Synopsys, Valid Logic, and Viewlogic.

TABLE 1
Toshiba Semiconductor Revenue by Product Segment
(Millions of Dollars)

	1988	1989	Percent Change	Worldwide Market Percent Change
Semiconductor	4,395	4,930	12	12
IC	3,316	3,774	14	14
Bipolar digital	108	102	(6)	(13)
Total MOS	2,639	3,100	17	22
Memory	1,516	1,918	27	40
Micro	346	407	18	15
Logic	777	775	0	4
Analog	569	572	1	6
Discrete	864	848	(2)	1
Optoelectronics	215	308	15	21
Exchange Rate (¥ per US$1)	130	138		

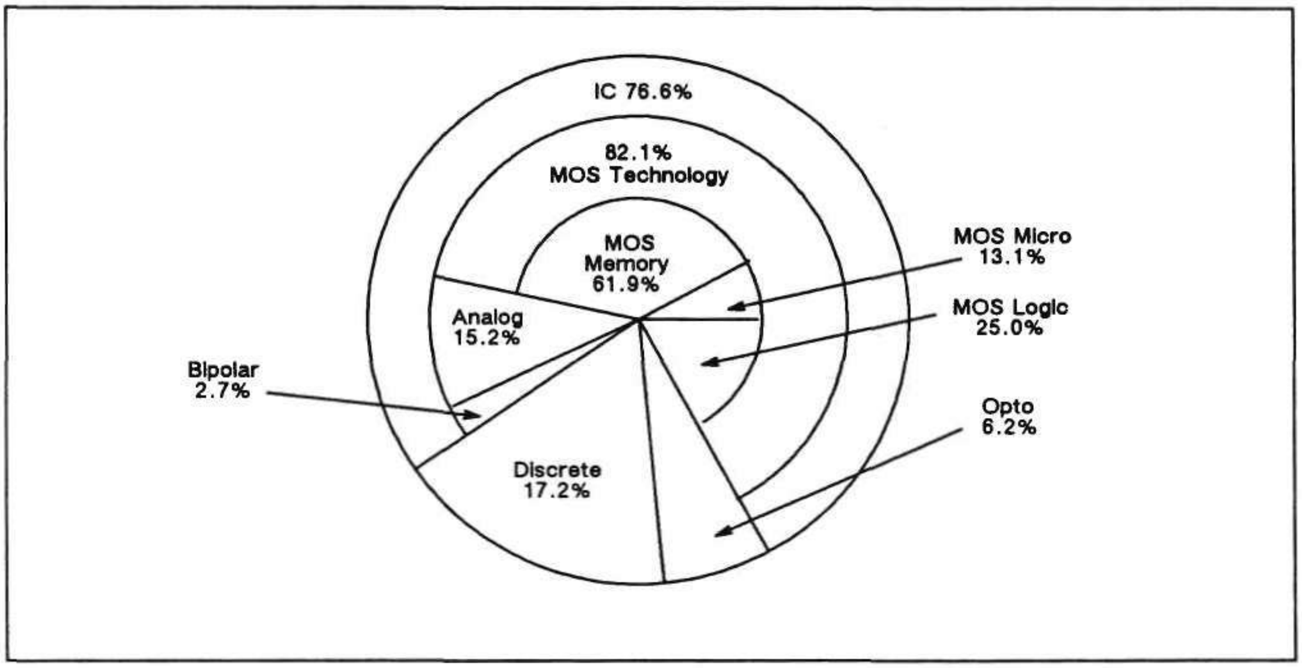
Source: Dataquest (February 1991)

TABLE 2
Estimated Semiconductor Capital Spending Compared with Total Revenue
Calendar Year
(Millions of Dollars)

	1985	1986	1987	1988	1989
Revenue	1,468	2,281	3,029	4,395	4,930
Semiconductor Capital Spending	517	387	417	615	639
Growth Rate of Capital Spending (%)	(10)	(25)	8	47	4
Percent of Revenue (%)	35	17	14	14	13
Exchange Rate (¥ per US$1)	238	168	144	130	138

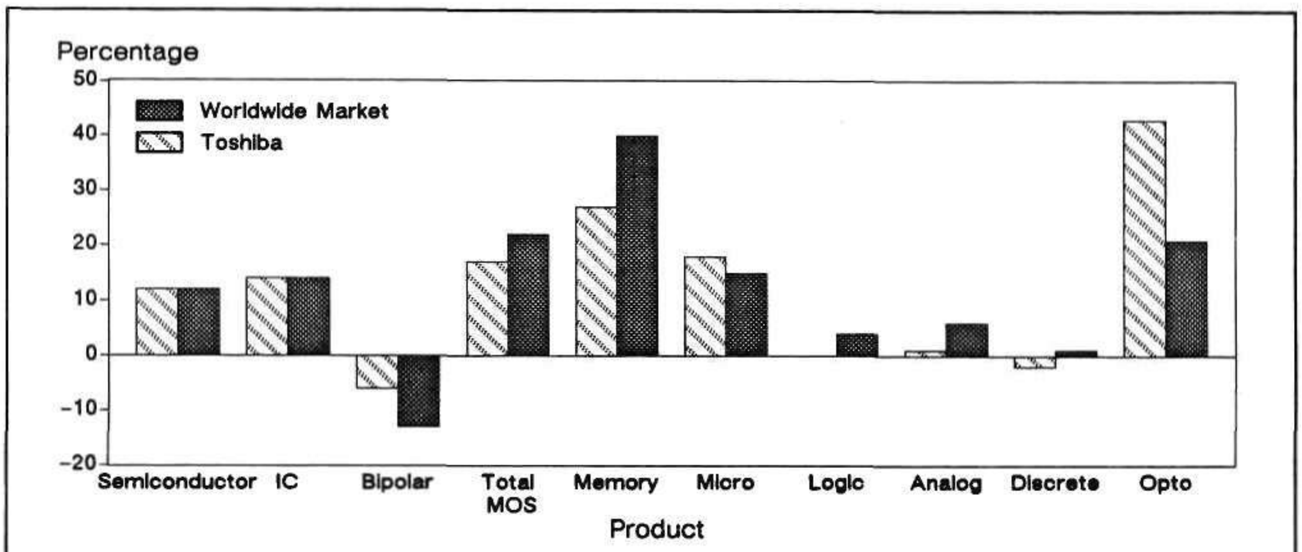
Source: Dataquest (February 1991)

FIGURE 1
1989 Toshiba Semiconductor Revenue Percentage by Product



Source: Dataquest (February 1991)

FIGURE 2
Toshiba Growth Rate Compared with Worldwide Market

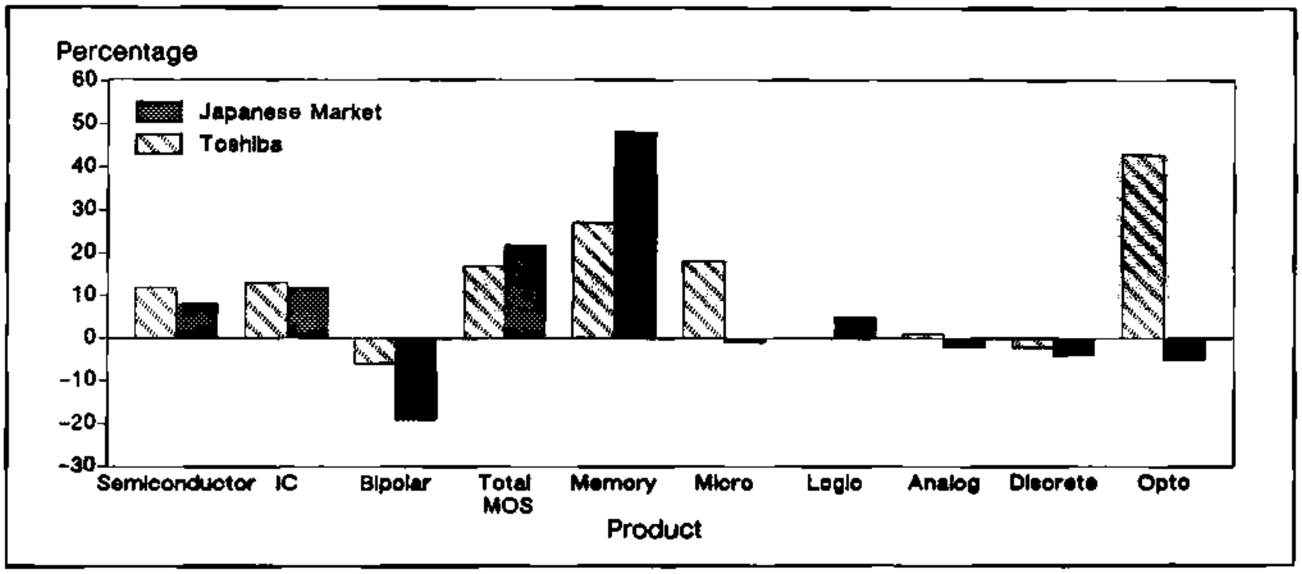


Source: Dataquest (February 1991)

The company's large internal market for semiconductors, high degree of vertical integration, and resulting high-volume semiconductor production allows Toshiba to be price-competitive with any vendor in the gate array market. Toshiba's internal gate array consumption generally consists of lower-density devices. Unlike NEC, which uses its internal consumption needs to drive merchant product development, Toshiba tends to develop products for the merchant market, which then filter into Toshiba's internal market. Toshiba's earlier strategy was to pursue low-density/high-volume gate array applications. However, the company is now pushing toward high-density/high-margin gate array designs.

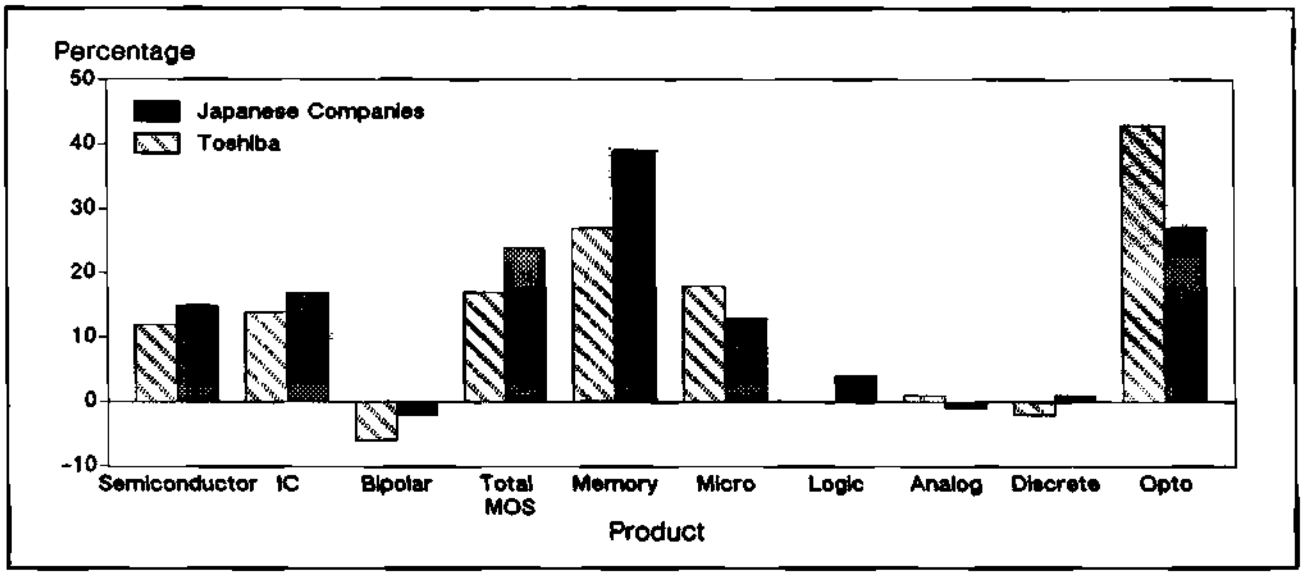
In some instances, Toshiba has decided not to produce its own standard products and has instead

FIGURE 3
Toshiba Growth Rate Compared with Japanese Market



Source: Dataquest (February 1991)

FIGURE 4
Toshiba Growth Rate Compared with Japanese Companies



Source: Dataquest (February 1991)

signed foundry agreements with several chip set vendors including Chips & Technologies. The company is enjoying significant volumes in production of chip set products for other companies on a foundry basis.

Memory

According to Dataquest's preliminary estimated worldwide market share ranking, Toshiba retained its number one position in the MOS memory market in 1990, followed by NEC. In 1989, Toshiba was the worldwide leader in MOS memory production with a 27 percent share of the market. NEC was second with a 17 percent share.

In addition, Toshiba was the number one DRAM supplier with an 18.5 percent share of the market. NEC was next with a 12.8 percent share. Toshiba has been the number one supplier of DRAMs since 1987. The company was also among the top 10 worldwide SRAM suppliers in 1989.

Perhaps the key ingredient to Toshiba's success in the worldwide memory market is its strong international marketing strategies. Because NEC controls a large portion of the Japanese memory market, a strong international presence is necessary for Toshiba's success in the remaining memory market. As NEC dominates the Japanese DRAM market, Toshiba dominates the rest of the worldwide DRAM market. Part of this international strength comes from the company's large number of subsidiaries. Toshiba is well vertically integrated on an international scale. In addition, the company has a very aggressive new product development strategy. Toshiba was among the first companies to sample the 16Mb DRAM.

Analog

In 1989, Toshiba was the world's leading supplier of analog ICs. Preliminary 1990 Dataquest estimates, however, indicate that the company has slipped to second in market share behind Philips, which vaulted up from the number four position. The driver of Toshiba's analog business is consumer electronics applications. Although Toshiba is not particularly strong in standard industrial analog ICs, it is the number one worldwide supplier of consumer-specific ICs. A portion of Toshiba's output supplies internal demand, but most of the production supports other manufacturers of consumer electronics products. Much of Toshiba's analog IC production goes into consumer audio and video products. In addition, the company has a growing presence in the data-processing segment of the electronic equipment industry, particularly in disk drives. As personal telecommunication products take off, Toshiba may enjoy higher sales of data converters and telecom-specific ICs. The company was the number five manufacturer of power ICs in 1989 as well. The particular applications for these devices include consumer audio and video, automotive electronics, and electronic data processing. Toshiba is an application-oriented company, which explains its low market share in standard commodity analog products.

Toshiba was also the number two supplier of optoelectronic products and number one in discrete devices in 1989. Most of the company's optoelectronic sales were CCDs for camcorders and laser diodes for CD players. Consumer audio and video products also have a high discrete content.

Microcomponents

According to preliminary market share estimates, Toshiba was the number six worldwide supplier of microcomponent products in 1990 behind Intel, NEC, Motorola, Hitachi, and Mitsubishi garnering 4.5 percent market share. Toshiba's market share ranking is unchanged from 1989. In addition, the company was the world's number two supplier of 4-bit microcontrollers, trailing only NEC and holding 13.1 percent of the market.

Toshiba's basic strategy in the microcomponent arena has been to second-source existing microprocessor products from two major vendors, Motorola and Zilog. Toshiba's 8-bit microcomponent products are derivatives of the Zilog Z80 family of microprocessors, and the company's 16- and 32-bit offerings contain the Motorola 68000-series core. The company's 4-bit products are generally Toshiba designs, although some are derivatives of National Semiconductor or Rockwell products. Toshiba acquired a license to the Z80 to convert the NMOS Zilog part to a CMOS device. In addition to second-sourcing the Z80, Toshiba quickly spun off a number of application-specific standard products incorporating the microprocessor. This strategy proved very successful.

In exchange for DRAM technology, Toshiba also gained rights to Motorola's 32-bit MPU technology. In addition to second-sourcing Motorola's 68000 family of MPU's (through the 68020 generation), Toshiba used the 68000 core to develop peripheral controllers such as the TMP68301 laser printer controller. Toshiba's penetration of the MPU and MCU markets has been very good. The company employs an aggressive product development and marketing strategy, and it has paid off.

Toshiba recently announced its entry into the PC logic chip set market. In January 1991, the company unveiled a 486-based MCA chip set for applications in high-end desktop computer systems. The 4-chip family (which comprises a 5-chip set) was designed by Micral, an independent affiliate of Groupe Bull, and will be manufactured and marketed by Toshiba. Toshiba is the second major semiconductor supplier to enter this very competitive market in the past four months, the first being National Semiconductor with 286- and 386-based AT offerings. Toshiba's strength in process technology should make it a formidable competitor in this fast-growing segment of the PC logic chip set market.

DATAQUEST ANALYSIS

Like many large Japanese semiconductor suppliers, Toshiba Corporation possesses a high degree of vertical integration. This characteristic is probably the primary factor in the success of its semiconductor operation. Given that 46 percent of the corporation's $29.6 billion revenue in 1989 was derived from the sale of information systems and electronic devices, the company's internal demand for semiconductors is obviously high. The corporation's large revenue base allows it to support significant investment in its semiconductor development program. In absolute terms, Toshiba, along with Hitachi, is one of the two largest Japanese investors in semiconductor capital spending. In 1988 and 1989, the company spent in excess of $600 million on capital improvements (see Table 2). The company spent 14 percent and 13 percent, respectively, of its total semiconductor revenue on capital investment in 1988 and 1989.

Toshiba also is a well-diversified semiconductor supplier (see Figure 1). The company's semiconductor growth rate in 1989 equaled the 12 percent rate posted by the industry as a whole. In terms of revenue growth rates for specific product segments, Toshiba outperformed the rest of the industry in the microcomponent and optoelectronic segments (see Figure 2). The only market segment in which Toshiba exhibited significantly slower growth in 1989 was MOS memory, which recorded an industry-wide growth rate of 40 percent. Although Toshiba had the largest increase in MOS memory revenue in the industry in absolute terms, several other manufacturers, including Matsushita, Motorola, SGS-Thomson, Samsung, and Siemens posted growth rates in excess of 40 percent. Because of the volatility of the current semiconductor memory market, and because such a large portion of Toshiba's revenue derives from memory sales, Dataquest believes that it is important for Toshiba to continue to push memory product development cycles while using its manufacturing strength to capitalize on opportunities in other product markets such as ASICs and microcomponents.

Dataquest's preliminary 1990 worldwide market share estimates indicate that Toshiba remained within $100 million of overtaking NEC for the number one position in total semiconductor market share. In fact, the estimates indicate that the gap between the revenue figures of the two companies has shrunk. Toshiba's dominance in the memory market is clearly a major competitive factor. If the company can continue its success in penetrating foreign markets and build upon a strong foundation in the ASIC and microcomponent markets, it is entirely conceivable that the 1991 worldwide market leader will be Toshiba.

Phil Mosakowski

Dataquest
a company of
The Dun & Bradstreet Corporation

Research Newsletter

BIG STEEL ROLLS THE DICE: NKK'S INVESTMENT IN PARADIGM FITS A PATTERN

SUMMARY

NKK Corporation, a major Japanese steel manufacturer, has taken a 10-percent equity position in Paradigm Technology Inc., a supplier of fast SRAM devices, based in San Jose, California. Under the terms of the seven-year agreement reported by Paradigm on January 10, NKK will gain licenses to the U.S. start-up's 256K and 1Mb SRAM products, with exclusive rights to sell these and future codeveloped products in the Pacific Rim. Paradigm will retain the rights to sell its products worldwide. Until 1993, Paradigm will manufacture SRAM products for NKK at its San Jose fab. Beyond this time frame, NKK plans to shift manufacturing to its own 8-inch wafer fab, which is currently in the planning stage.

NKK is not alone among Japanese steel manufacturers in its interest in the semiconductor business. This newsletter looks at the specifics of the NKK/Paradigm deal in the context of similar investments that have been made by other Japanese steel companies. Collectively, these investments represent the growing presence of highly capitalized corporations in an industry that is notable for its capital intensiveness. The consequences of such investments, particularly as they affect the future manufacturing capacity, are important to the long-term competitiveness of not only the U.S. partners involved, but to the industry as a whole.

THE NKK/PARADIGM DEAL: WHO GETS WHAT?

At present, Paradigm is a small player in the SRAM business. This situation could change, however, in light of its relationship with an entity whose fiscal 1990 revenue exceeded $8 billion. Paradigm notes that it will be able to double the size of its San Jose wafer fab during 1991—a feat that otherwise would not have been easy to achieve in a market environment characterized by tight capital.

The relationship with Paradigm will give NKK more than just an investment position in a key segment of the MOS memory business. NKK has expressed its intention to become a chip producer in its own right, presumably with a focus on memory and ASICs. In May 1990, analysts in Dataquest's Semiconductor Equipment, Manufacturing, and Materials Service (SEMMS) reported that NKK Steel planned to spend $1.4 billion on semiconductor wafer fab facilities during the next 10 years and would have a fab operational by 1992 in Japan's Kanagawa prefecture at a cost of $171 million. Dataquest analysts noted at the time that the Japanese steel manufacturers were actively looking for a partnership or acquisition.

Through its equity position in Paradigm, NKK is gaining something to put in its fab along with the equipment it purchases—a process technology. Dataquest believes that Paradigm's triple-poly, double-metal CMOS process, which produces a compact SRAM cell, is both technologically sound and applicable to a volume manufacturing situation.

BIG STEEL COMES TO TOWN

One of the trends noticed by Dataquest in 1990 was the departure of some big name companies from the SRAM business, notably AMD, National Semiconductor, Philips, and VLSI Technology. Another trend, however, was the continued investment in the semiconductor industry by Japanese steel manufacturing concerns. The first quarter of 1990 saw alliances by Kawasaki Steel and Kobe Steel with U.S. companies, along with an investment by industrial machinery manufacturer Kubota

SIS Newsletters 1991 PMT

0009281

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

(see Table 1). These alliances took place in areas of the chip business ranging from ASICs to LSI testing equipment.

THE SUMOS OF STEEL

In a May 1990 research newsletter, the SEMMS group tracked 11 Japanese start-ups—all large, well-established companies that had decided to diversify into semiconductor manufacturing. Of these 11 companies, 5 are in the steel manufacturing industry. The potential such companies have for shaping the future of the semiconductor industry can best be appreciated by comparing the sheer size of their assets with the current value of today's semiconductor market. As of March 1990, Kawasaki Steel, Kobe Steel, NKK Steel, and Nippon Steel had combined current assets of approximately $38 billion—a figure equal to roughly 60 percent of Dataquest's forecast for worldwide semiconductor consumption in 1991.

But how is this great weight currently being leveraged in the semiconductor industry? In addition to the recent move by NKK, analysts in SEMMS and the Japanese Semiconductor Industry Service (JSIS) note the following developments by other Japanese suppliers of core materials.

Kawasaki Steel

Following its joint venture with LSI Logic, known as Nihon Semiconductor, Kawasaki established its LSI Research Center in 1988. The company plans to spend $700 million on new manufacturing facilities over the next 10 years for the production of SRAMs and ASICs in the near future and for DRAMs later on. Steel manufacturers are aiming for annual semiconductor production of $1.5 billion by the year 2000.

Kobe Steel

Through its joint venture with Texas Instruments, known as KTI Semiconductor Ltd., Kobe will construct a $350 million fab in Hyogo prefecture for the production of VLSI logic and ASICs. Completion is planned for 1992.

Nippon Steel

Nippon Steel has started developing and marketing ASICs under its own brand name by partnering with VLSI Technology. It will complete a $70 million VLSI pilot line for production of ASICs in Kanagawa prefecture by the end of 1991.

Sumitomo Metal Mining

Although currently lacking a semiconductor alliance partner, the company plans to construct an IC plant in Oita prefecture with a modest plan for production of $18 million in semiconductor devices in five years.

TABLE 1
Japanese Steel Company Semiconductor Alliance

Company	Date	Partner	Product
Kawasaki Steel	5/88	SDA Systems	ASIC CAD tools
	6/88	LSI Logic	LSI manufacturing
	6/89	Harris Semiconductor	LSI chips
	2/90	Kodak, Olivetti	Optoelectronics disks
Kobe Steel	3/90	Texas Instruments	ASICs
Kubota	3/90	Rasna Corporation	CAE software
	3/90	Megatest	LSI testers
Nippon Steel	6/88	Minnesota Mining	Tape-automated bonding
	11/89	VLSI Technology	ASICs

Source: Dataquest (January 1991)

DATAQUEST CONCLUSIONS

In the face of declining steel prices and sales, brought on in part through the entry of South Korea into the steel business, Japanese steel manufacturers began to diversify their traditional business lines years ago. Kobe Steel, for example, plans to have its nonsteel line account for 40 percent of total sales by the year 2000. Given its ambitions in the semiconductor industry over the next decade, NKK, with investments in Silicon Valley that also include Silicon Graphics, is obviously moving down a path already blazed by several of its industry peers.

With the financial resources available to companies such as NKK, it may seem surprising that Japanese steel manufacturers simply do not acquire U.S. companies with technologies and markets attractive to them. Acquisition has certainly been the means by which mature industry segments in the United States have diversified in the past. To begin with, however, joint ventures and other forms of partnering appear to be much more in keeping with Japanese business culture than are mergers and acquisitions.

Perhaps a more powerful reason for Japanese steel manufacturers to pursue their diversification strategies through strategic alliances rather than acquisitions is that partnerships are likely to have fewer political repercussions. The recent announcement by the antitrust division of the Department of Justice that it will sue to prevent the sale of SemiGas Systems to Nippon Sanso and the efforts of a number of U.S. concerns to prevent Perkin-Elmer's semiconductor equipment division from potentially falling into the hands of Nikon, point to a climate that is not favorable to the Japanese purchase of U.S. high-technology companies. A recent newsletter on the sale of SemiGas noted that "Dataquest expects high-technology trade policy to be pursued more actively through the Justice Department's antitrust arm and new legislation currently being proposed in Congress." As a result of U.S. concerns about its current competitive position vis-à-vis Japan, we should expect to see alliances rather than acquisitions as the diversification avenue of choice.

As we approach the 21st century, Japanese steel manufacturers are realizing that silicon is every bit as much a core material as the metals that have been the foundation of 20th century industry. As noted by Dataquest's JSIS analysts, steel companies in Japan generally are cash-rich industries that have been making a difficult transition from a protected industry to one that sees limited onshore growth due to the cost-of-labor advantage of less industrialized countries in the Far East. As a result, the semiconductor industry can expect that a larger number of the new kids on the block will, in fact, be giants. In the short term, their partnering activities will prove an undoubted boon to those U.S. start-ups that find their technology-based ambitions thwarted by cash-flow concerns. In the long run, the greater participation of companies such as Kawasaki Steel, NKK Steel, and Nippon Steel may move the competitive advantage in the semiconductor industry closer to those players that compete with dollars rather than simply with creativity.

Michael J. Boss

Dataquest
a company of
The Dun & Bradstreet Corporation

Research Newsletter

MEMORY DOMINANCE FUELS TOSHIBA'S SUCCESS

INTRODUCTION

This newsletter is the second in a series of newsletters focusing on the semiconductor operations of leading semiconductor suppliers. Additional corporate financial information is provided in Dataquest's forthcoming Toshiba company backgrounder.

THE COMPANY

This newsletter discusses Toshiba Corporation, a leading worldwide electronics manufacturer headquartered in Tokyo, Japan. In 1989, Toshiba was the second-largest worldwide supplier of semiconductor devices, with annual sales of $4.93 billion. With stronger relative growth rates in the past two years, Toshiba is set to take over the number one position in worldwide semiconductor market share from NEC. The company's recent activities may help to catapult Toshiba into the market share lead.

In the past year, Toshiba announced several strategic actions. In April 1990, the company announced that its was in the process of selecting a site on the west coast of the United States to establish a new wafer fab. Toshiba is evaluating locations in California, Oregon, and Washington and had planned to announce the site selection in June 1990. To date, no announcement has been made regarding the choice of a location. The new fab, with an estimated construction cost of $127 million, is expected to process ASICs including gate arrays, 4Mb DRAMs, and 1Mb SRAMs. In July, Toshiba announced further expansion of its Microelectronics Center, which will provide additional master arrays and package options for quick-turn ASICs. The expansion was expected to quadruple Toshiba's quick-turn ASIC capacity to 400,000 pieces per month by December 1990, eventually reaching 500,000 pieces per month. The facility has been upgraded from 5-inch wafers to 1.0 micron, 6-inch wafers. The company reports that the added capacity allows a two-week turnaround on gate array prototypes.

In October, the company announced the opening of a self-contained design center in Portland, Oregon. The new design center, which supports Toshiba's advanced gate array and cell-based IC (CBIC) technology, services Toshiba's customer base in the Pacific Northwest including Oregon, Washington, Idaho, and Western Canada. In addition to the new Portland design center, Toshiba supports six other design centers in North America, located in Sunnyvale and Tustin, California; Burlington, Massachusetts; Atlanta, Georgia; Richardson, Texas; and Ottawa, Ontario.

In December, Toshiba announced that the construction of a new semiconductor fab at Yokkaichi City, Mie Prefecture, Japan, had begun. The plant is expected to produce next-generation memory ICs including 4Mb and 16Mb DRAMs. Toshiba expects to invest approximately $750 million over two to three years to construct a clean room facility on the 75-acre site. The total floor area will cover approximately 160,000 square feet. The plant is scheduled to begin production of 4Mb DRAMs in March 1992. The clean room will require only slight modification for the production of 16Mb devices. Toshiba plans to build more clean rooms on the site in the future, in line with growth in market demand for next generation DRAMs. The construction of the new Yokkaichi plant follows the recent completion of a new clean room at the Oita plant in Kyushu, the company's primary memory facility, to increase production of 4Mb DRAMs. The company currently produces two million 4Mb devices per month.

Tables 1 and 2 and Figures 1 through 4 detail Toshiba's product segmentation, revenue growth, and recent capital spending history.

SIS Newsletters 1991 PMT

0009270

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

PRODUCTS

ASICs

In 1989, Toshiba was the fourth-largest worldwide supplier of ASICs. Most of Toshiba's ASIC production is made up of gate arrays. The company is also the fourth largest worldwide supplier of gate arrays. Toshiba recently introduced a triple-metal process for gate arrays, joining the other suppliers with triple-metal capability including Fujitsu, Hitachi, National Semiconductor, and NEC.

One of the keys to Toshiba's success in the gate array market has been its relationship with LSI Logic. Through its cooperative agreement with LSI, Toshiba received LSI's design software. As a result, Toshiba served as a virtual second source to LSI Logic, which allowed the company to establish a North American gate array business of substantial volume. Although its relationship with LSI Logic, which began in 1981, has ended, the in-house tool sets of the two companies remain similar.

In addition, Toshiba has succeeded in covering its bases in the third-party EDA arena. The company has ported its ASIC library to all of the leading EDA vendors, including Cadence, Dazix, Mentor, Racal-Redac, Synopsys, Valid Logic, and Viewlogic.

Table 1
Toshiba Semiconductor Revenue by Product Segment
(Millions of Dollars)

	1988	1989	Percent Change	Worldwide Market Percent Change
Semiconductor	4,395	4,930	12	12
IC	3,316	3,774	14	14
Bipolar digital	108	102	(6)	(13)
Total MOS	2,639	3,100	17	22
Memory	1,516	1,918	27	40
Micro	346	407	18	15
Logic	777	775	0	4
Analog	569	572	1	6
Discrete	864	848	(2)	1
Optoelectronics	215	308	15	21
Exchange Rate (¥ per US$1)	130	138		

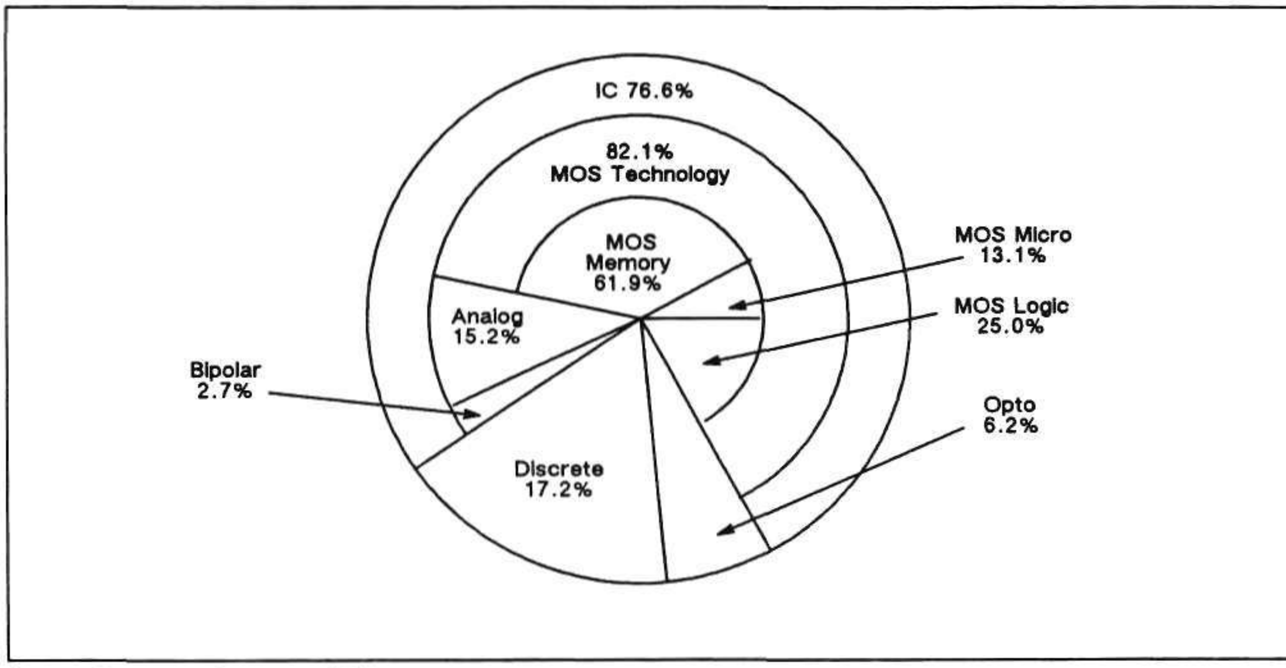
Source: Dataquest (February 1991)

Table 2
Estimated Semiconductor Capital Spending Compared with Total Revenue
Calendar Year
(Millions of Dollars)

	1985	1986	1987	1988	1989
Revenue	1,468	2,281	3,029	4,395	4,930
Semiconductor Capital Spending	517	387	417	615	639
Growth Rate of Capital Spending (%)	(10)	(25)	8	47	4
Percent of Revenue (%)	35	17	14	14	13
Exchange Rate (¥ per US$1)	238	168	144	130	138

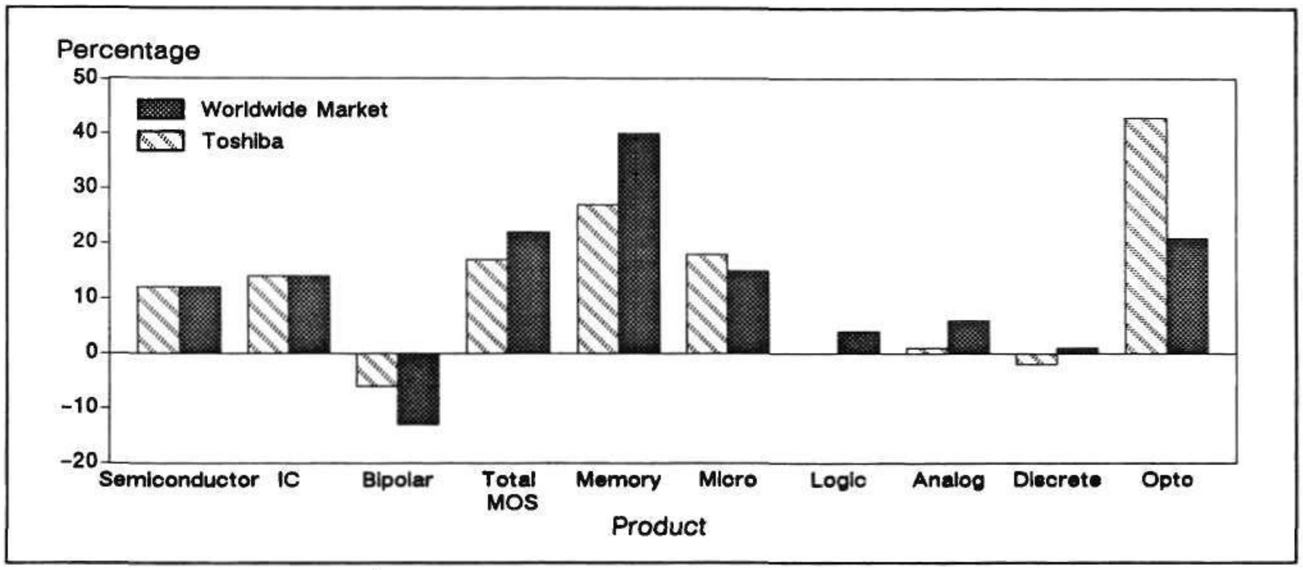
Source: Dataquest (February 1991)

FIGURE 1
1989 Toshiba Semiconductor Revenue Percentage by Product



Source: Dataquest (February 1991)

FIGURE 2
Toshiba Growth Rate Compared with Worldwide Market

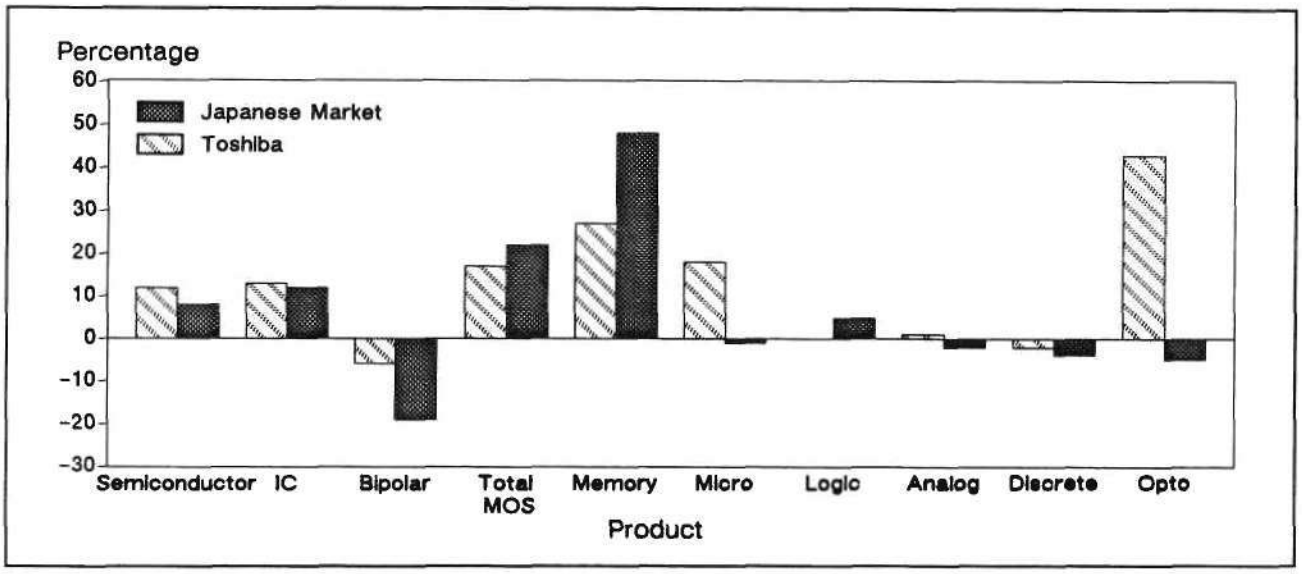


Source: Dataquest (February 1991)

The company's large internal market for semiconductors, high degree of vertical integration, and resulting high-volume semiconductor production allows Toshiba to be price-competitive with any vendor in the gate array market. Toshiba's internal gate array consumption generally consists of lower-density devices. Unlike NEC, which uses its internal consumption needs to drive merchant product development, Toshiba tends to develop products for the merchant market, which then filter into Toshiba's internal market. Toshiba's earlier strategy was to pursue low-density/high-volume gate array applications. However, the company is now pushing toward high-density/high-margin gate array designs.

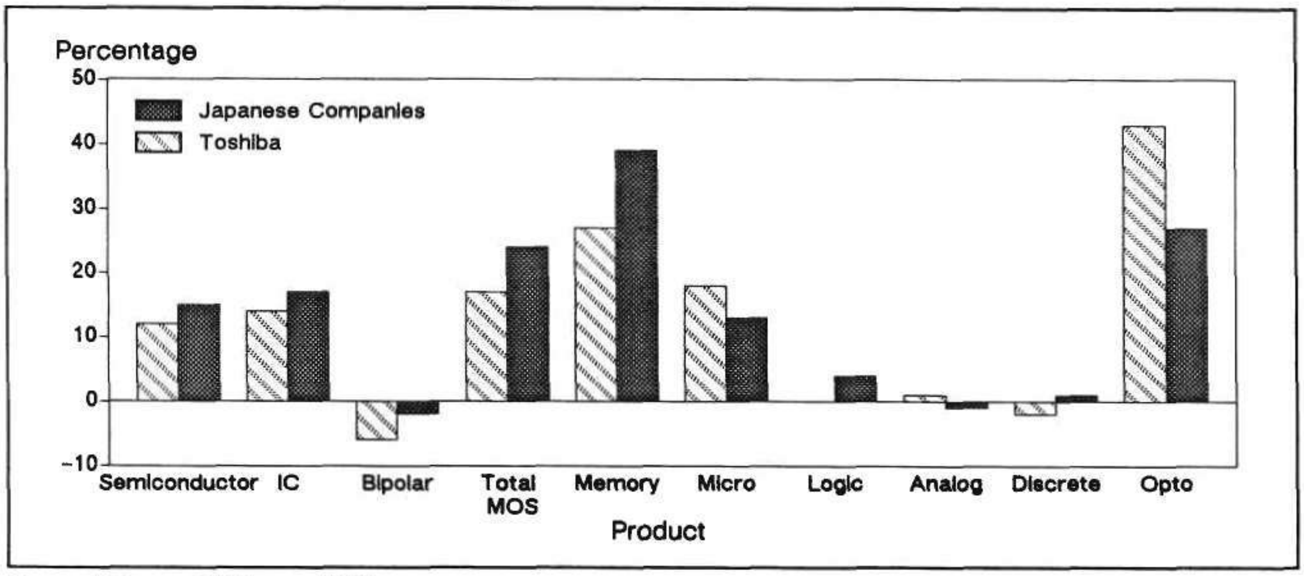
In some instances, Toshiba has decided not to produce its own standard products and has instead

FIGURE 3
Toshiba Growth Rate Compared with Japanese Market



Source: Dataquest (February 1991)

FIGURE 4
Toshiba Growth Rate Compared with Japanese Companies



Source: Dataquest (February 1991)

signed foundry agreements with several chip set vendors including Chips & Technologies. The company is enjoying significant volumes in production of chip set products for other companies on a foundry basis.

Memory

According to Dataquest's preliminary estimated worldwide market share ranking, Toshiba retained its number one position in the MOS memory market in 1990, followed by NEC. In 1989, Toshiba was the worldwide leader in MOS memory production with a 27 percent share of the market. NEC was second with a 17 percent share.

In addition, Toshiba was the number one DRAM supplier with an 18.5 percent share of the market. NEC was next with a 12.8 percent share. Toshiba has been the number one supplier of DRAMs since 1987. The company was also among the top 10 worldwide SRAM suppliers in 1989.

Perhaps the key ingredient to Toshiba's success in the worldwide memory market is its strong international marketing strategies. Because NEC controls a large portion of the Japanese memory market, a strong international presence is necessary for Toshiba's success in the remaining memory market. As NEC dominates the Japanese DRAM market, Toshiba dominates the rest of the worldwide DRAM market. Part of this international strength comes from the company's large number of subsidiaries. Toshiba is well vertically integrated on an international scale. In addition, the company has a very aggressive new product development strategy. Toshiba was among the first companies to sample the 16Mb DRAM.

Analog

In 1989, Toshiba was the world's leading supplier of analog ICs. Preliminary 1990 Dataquest estimates, however, indicate that the company has slipped to second in market share behind Philips, which vaulted up from the number four position. The driver of Toshiba's analog business is consumer electronics applications. Although Toshiba is not particularly strong in standard industrial analog ICs, it is the number one worldwide supplier of consumer-specific ICs. A portion of Toshiba's output supplies internal demand, but most of the production supports other manufacturers of consumer electronics products. Much of Toshiba's analog IC production goes into consumer audio and video products. In addition, the company has a growing presence in the data-processing segment of the electronic equipment industry, particularly in disk drives. As personal telecommunication products take off, Toshiba may enjoy higher sales of data converters and telecom-specific ICs. The company was the number five manufacturer of power ICs in 1989 as well. The particular applications for these devices include consumer audio and video, automotive electronics, and electronic data processing. Toshiba is an application-oriented company, which explains its low market share in standard commodity analog products.

Toshiba was also the number two supplier of optoelectronic products and number one in discrete devices in 1989. Most of the company's optoelectronic sales were CCDs for camcorders and laser diodes for CD players. Consumer audio and video products also have a high discrete content.

Microcomponents

According to preliminary market share estimates, Toshiba was the number six worldwide supplier of microcomponent products in 1990 behind Intel, NEC, Motorola, Hitachi, and Mitsubishi garnering 4.5 percent market share. Toshiba's market share ranking is unchanged from 1989. In addition, the company was the world's number two supplier of 4-bit microcontrollers, trailing only NEC and holding 13.1 percent of the market.

Toshiba's basic strategy in the microcomponent arena has been to second-source existing microprocessor products from two major vendors, Motorola and Zilog. Toshiba's 8-bit microcomponent products are derivatives of the Zilog Z80 family of microprocessors, and the company's 16- and 32-bit offerings contain the Motorola 68000-series core. The company's 4-bit products are generally Toshiba designs, although some are derivatives of National Semiconductor or Rockwell products. Toshiba acquired a license to the Z80 to convert the NMOS Zilog part to a CMOS device. In addition to second-sourcing the Z80, Toshiba quickly spun off a number of application-specific standard products incorporating the microprocessor. This strategy proved very successful.

In exchange for DRAM technology, Toshiba also gained rights to Motorola's 32-bit MPU technology. In addition to second-sourcing Motorola's 68000 family of MPU's (through the 68020 generation), Toshiba used the 68000 core to develop peripheral controllers such as the TMP68301 laser printer controller. Toshiba's penetration of the MPU and MCU markets has been very good. The company employs an aggressive product development and marketing strategy, and it has paid off.

Toshiba recently announced its entry into the PC logic chip set market. In January 1991, the company unveiled a 486-based MCA chip set for applications in high-end desktop computer systems. The 4-chip family (which comprises a 5-chip set) was designed by Micral, an independent affiliate of Groupe Bull, and will be manufactured and marketed by Toshiba. Toshiba is the second major semiconductor supplier to enter this very competitive market in the past four months, the first being National Semiconductor with 286- and 386-based AT offerings. Toshiba's strength in process technology should make it a formidable competitor in this fast-growing segment of the PC logic chip set market.

Dataquest Analysis

Like many large Japanese semiconductor suppliers, Toshiba Corporation possesses a high degree of vertical integration. This characteristic is probably the primary factor in the success of its semiconductor operation. Given that 46 percent of the corporation's $29.6 billion revenue in 1989 was derived from the sale of information systems and electronic devices, the company's internal demand for semiconductors is obviously high. The corporation's large revenue base allows it to support significant investment in its semiconductor development program. In absolute terms, Toshiba, along with Hitachi, is one of the two largest Japanese investors in semiconductor capital spending. In 1988 and 1989, the company spent in excess of $600 million on capital improvements (see Table 2). The company spent 14 percent and 13 percent, respectively, of its total semiconductor revenue on capital investment in 1988 and 1989.

Toshiba also is a well-diversified semiconductor supplier (see Figure 1). The company's semiconductor growth rate in 1989 equaled the 12 percent rate posted by the industry as a whole. In terms of revenue growth rates for specific product segments, Toshiba outperformed the rest of the industry in the microcomponent and optoelectronic segments (see Figure 2). The only market segment in which Toshiba exhibited significantly slower growth in 1989 was MOS memory, which recorded an industry-wide growth rate of 40 percent. Although Toshiba had the largest increase in MOS memory revenue in the industry in absolute terms, several other manufacturers, including Matsushita, Motorola, SGS-Thomson, Samsung, and Siemens posted growth rates in excess of 40 percent. Because of the volatility of the current semiconductor memory market, and because such a large portion of Toshiba's revenue derives from memory sales, Dataquest believes that it is important for Toshiba to continue to push memory product development cycles while using its manufacturing strength to capitalize on opportunities in other product markets such as ASICs and microcomponents.

Dataquest's preliminary 1990 worldwide market share estimates indicate that Toshiba remained within $100 million of overtaking NEC for the number one position in total semiconductor market share. In fact, the estimates indicate that the gap between the revenue figures of the two companies has shrunk. Toshiba's dominance in the memory market is clearly a major competitive factor. If the company can continue its success in penetrating foreign markets and build upon a strong foundation in the ASIC and microcomponent markets, it is entirely conceivable that the 1991 worldwide market leader will be Toshiba.

Phil Mosakowski

Dataquest
a company of The Dun & Bradstreet Corporation

Research *Bulletin*

TRIQUINT/GBL MERGER CONSOLIDATES GaAs IC MARKET SHARE

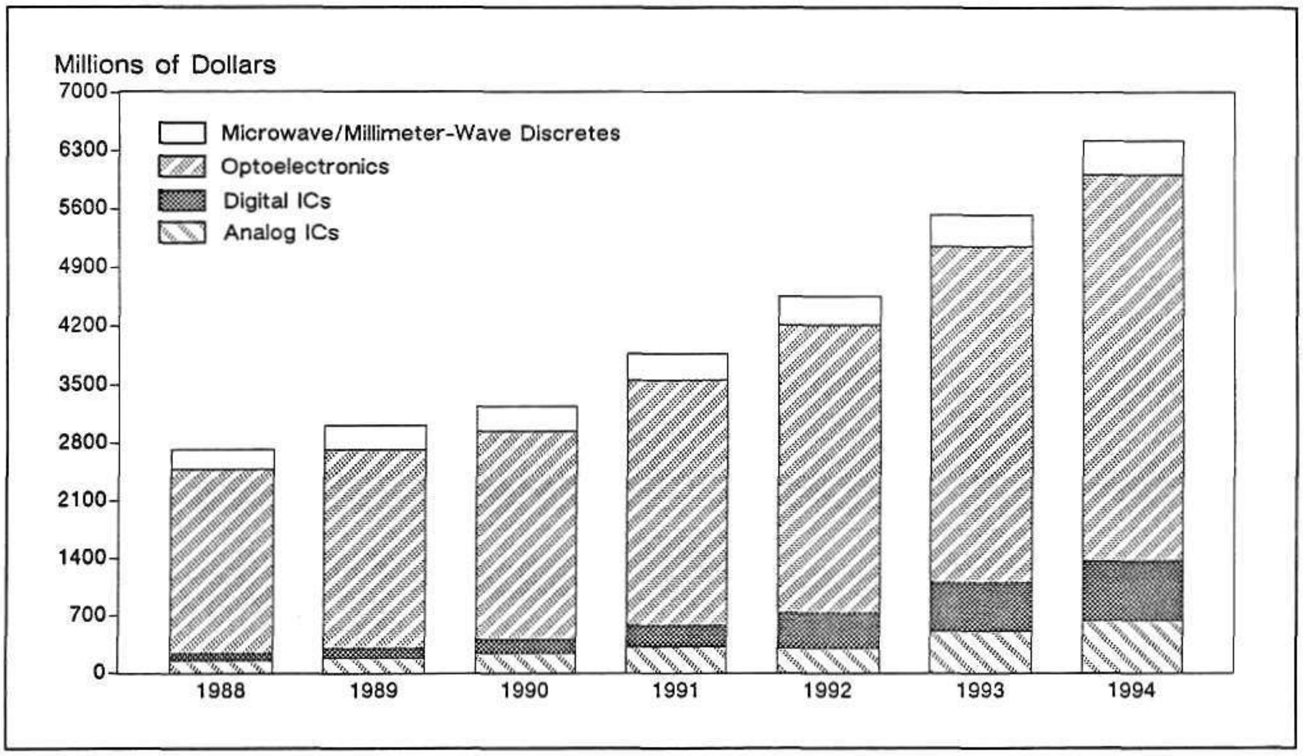
SUMMARY

On January 24, 1991, TriQuint of Beaverton, Oregon, and GigaBit Logic (GBL) of Newbury Park, California, signed a letter of intent to merge. The resulting entity, which will be called TriQuint Semiconductor, Inc., will become the world's largest supplier of gallium arsenide (GaAs) integrated circuits (ICs). The TriQuint/GBL merger occurs at a time when Japanese competition in the GaAs business has been rapidly growing. The merger, which will be finalized on March 31, 1991, consolidates market share in the fastest-growing segment of the GaAs market and gives the United States a leadership position in GaAs digital ICs—for now. This newsletter provides a review of the TriQuint/GBL merger in the context of Dataquest's current outlook for GaAs market growth.

THE COMPANIES

TriQuint, a subsidiary of Tektronix, was founded in 1985. The company specializes in analog GaAs ICs and high-frequency IC packaging

FIGURE 1
Estimated Worldwide GaAs Semiconductor Merchant Consumption (Millions of Dollars)



Source: Dataquest (February 1991)

SIS Newsletters 1991 PMT

0009355

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

and is the leading supplier of GaAs ASICs produced on multiproject 4-inch GaAs wafers. TriQuint is also the major GaAs wafer foundry for Pacific Monolithics and Gazelle. TriQuint's 1990 revenue was approximately $18 million.

GBL was founded in 1981 and specializes in GaAs digital ICs (digICs), including ASICs. GBL is notable for having the industry's only extensive catalog of digICs, including SRAMs, logic, MUX/DEMUX chips, and interface circuits for optoelectronic systems. GBL also operates a major GaAs IC foundry and was the first company to convert to 4-inch GaAs wafer production. Until recently, GBL's biggest customer was Cray Research, to which it supplied annual shipments of custom digICs at an estimated peak value of more than $5 million. GBL's revenue for 1990 was approximately $12 million.

Market Share Advantage—For Now

The new TriQuint Semiconductor has a combined work force of 265 employees and a customer base exceeding 600 companies. With combined 1990 revenue of $30 million, the TriQuint/GBL entity is currently operating at a run rate of approximately $2.5 million per month. Dataquest expects the new company to ship in excess of $40 million in 1991. Although this may not seem like a windfall business, it does represent roughly 8 percent of Dataquest's estimated worldwide merchant consumption of GaAs IC devices, not including nonrecurring engineering (NRE) charges. If one includes Vitesse Semiconductor in this market share estimate, the top two U.S. suppliers may well account for about 15 percent of the worldwide merchant market for GaAs ICs in 1991.

As shown in Figure 1, GaAs ICs made up less than 13 percent of the total worldwide GaAs semiconductor market in 1990. In terms of growth, however, digICs represent the most significant segment. Between 1989 and 1994, Dataquest believes that the analog (including microwave) IC device segment of the GaAs market will have a compound annual growth rate (CAGR) of nearly 34 percent, while the digital IC device portion will grow at roughly 50 percent. U.S. suppliers will also have the "home-field advantage" in that the largest regional market (in terms of merchant consumption) for digital ICs will be in the United States throughout this period.

The new TriQuint Semiconductor (and other U.S. GaAs suppliers) will need all the market share advantage it can muster: Both Japan and Europe are making major investments in GaAs. Worldwide growth in digital ICs will be sparked by the Asia/Pacific region, with merchant consumption growing at a CAGR of 80 percent between 1989 and 1994. Dataquest expects Fujitsu to capture a significant portion of worldwide market share in the future, leveraging from its dominant positions in emitter-coupled logic (ECL) ASICs and ECL RAMs and from its acquisition of U.K.-based ICL's computer and Vitesse's submicron E/D MESFET ASIC technologies.

Michael J. Boss
Gene Miles

Dataquest
a company of The Dun & Bradstreet Corporation

Research *Newsletter*

WILL INDUSTRY ECONOMICS DEFY "MOORE'S LAW"?

"In the long run, financial pressures may force semiconductor companies to slow down the pace of technological development."

—Dr. Gordon E. Moore
Dataquest's 1987 Semiconductor Industry Conference

SUMMARY

Dataquest believes that the semiconductor industry is facing a slowdown in the historical pace of integrated circuit (IC) price/performance improvements. The factors affecting this slowdown have less to do with technical limitations than with the costs of overcoming them. As the semiconductor industry enters the final decade of the 20th century, it faces the critical question of whether the cost of continuing its improvements in device complexity will set the deciding limits to future declines in the cost per function of semiconductor ICs.

A slowdown in IC price/performance improvements has enormous implications: Such a slowdown could ultimately slow the rate of semiconductor market growth, lower the industry's return on investment, and reduce technical improvements because of reduced R&D spending. The net result of diminished price/performance improvements could well be the lengthening of product life cycles in leading-edge devices—a phenomenon that would in turn have a profound impact on the electronic systems industry! The best analogy of this situation is that of a vicious circle taking the form of a tightening noose.

This newsletter is the first in a series that explores global industry issues. This first installment reviews the basic tenets underlying "Moore's Law" and examines cost issues that Dataquest believes are fundamentally altering the price/performance dynamics of the semiconductor industry.

MOORE'S LAW REVISITED

The electronics industry's notions of price/performance improvements were best defined almost three decades ago, when Intel Corporation's cofounder and chairman of the board, Dr. Gordon E. Moore, observed that the "complexity of integrated circuits has approximately doubled every year since their introduction, (and) *cost per function has decreased several thousandfold*" (author's italics). Dr. Moore's observation has become a generally accepted semiconductor industry canon known as "Moore's Law." Over a nearly 20-year period from the introduction of the first planar transistor to the mid-1970s, the semiconductor industry achieved a nearly 800-fold increase in device complexity, which Dr. Moore attributed to exponential progress in the following areas:

- Die size—In a 20-year period, IC die size for the most complex integrated circuits increased by a factor of 20.
- Linewidth—During the same period, reductions in linewidth and space improved by a factor of approximately 32.

In combining these factors, Dr. Moore was able to account for an overall 640-fold increase in device complexity, leaving a factor of about 100 to account for. This factor, according to Dr. Moore, was "cleverness"—the contribution of circuit and device advances to the achievement of higher device density. "It is noteworthy," Dr. Moore observed, "that this contribution to complexity has been more important than either increased chip area or finer lines."

OF TECHNOLOGY AND CEREAL PRIZES

Moore's law, it may be argued, is the most fundamental observation of how the semiconductor

SIS Newsletters 1991 PMT
0009475

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

industry has added value during the more than 40 years since the invention of the transistor. It is the basis for bit-density improvements in semiconductor memories, gate-count improvements in logic devices, and the basic explanation for how an industry can deliver miracles on a timetable basis. The semiconductor industry has made possible the fact that consumers worldwide have an unshakable expectation that electronics products will continuously deliver greater functionality and performance at lower cost. Equally important, Moore's Law has been the basis of profitability (however marginal at times) for an industry that appears perpetually poised to cannibalize itself. The fact that a leading-edge device such as the 4Mb DRAM can drop from a price of $460 to less than $10 in a six-year period fuels, through increased application, a level of demand that to some degree offsets such drastic erosions in price.

A powerful example of price/performance improvements in the semiconductor industry—one that moves us from the realm of abstraction to consumer reality—is the liquid crystal display (LCD) electronic watch. In 1975, the LCD watch represented electronics industry state of the art in a number of areas—the electronic timing semiconductor chip, the CMOS processing that made it possible, LCD technology, the small lithium battery, and the quartz crystal oscillator. Less than 20 years later, these very technologies are being delivered as a plastic giveaway in a box of breakfast cereal. Not only that, all of these impressive technologies of 1975 are now routinely manufactured at low cost in Asia and assembled in mainland China at a likely cost of less than 60 cents. The plastic watch case may be as much of a cost factor as the semiconductors it contains!

WHERE ARE THE LIMITS?

Although the semiconductor industry has granted the same veracity to Moore's Law that one might accord to Newton's Third Law of Motion, it must be remembered that Moore's Law is essentially an observation of the dynamics of an industry based on *past* performance. Numerous industry leaders, including Dr. Moore himself, have cautioned against an extrapolation of device complexity trends through a strict linear progression based on Dr. Moore's insight of three decades ago. In short, there are limits beyond which Moore's Law cannot logically apply. At Dataquest's 1987 Semiconductor Industry Conference, the coinventor of the integrated circuit, Jack Kilby, commented that such a straight-line extrapolation of device complexity to the year 2027 would suggest a range of 100 billion to 10 trillion transistors on a 12-inch square chip—at a price of $3 per chip!

The mind-boggling impossibility of Jack Kilby's extrapolation appears obvious even to an industry accustomed to enormous technological strides. During the 1987 conference, Dr. Moore identified a more fundamental limit to silicon-based semiconductor technology when he observed that progress in dimension reduction, the most important aspect of the industry's technological progress, "doesn't show any signs of abating until we reach a physical limit probably near 0.1-micron"—a limit that the industry will most likely encounter 20 years from now.

In an update of his original analysis 30 years ago, Dr. Moore observed that packing efficiency in ICs had progressed by a factor of four between 1959 and the mid-1970s. At that time, however, he observed, "I am inclined to suggest a limit to the contribution of circuit and device cleverness of another factor of four (improvement) in component density." With cleverness diminishing as a chief contributor to device complexity, Dr. Moore speculated that the slope of the Moore's Law complexity curve could slow to a doubling of complexity every two years rather than every year. Although this has not yet proven to be the case, there are clearly limits to how far the industry can go in improving such factors as defect density and yield.

THE PRICE OF THE FUTURE

While acknowledging the technical challenges of following Moore's Law into the submicron era, one must also acknowledge that the history of the semiconductor industry is replete with examples of overcoming technical limitations. However, there are laws other than those of physics that affect the future pace of the semiconductor industry's price/performance improvements. A greater obstacle to the continuation of Moore's Law may be the law of economics—a law more harsh in its effects on companies than any they may face in the R&D lab. Put another way, a question facing the industry is: "Which do we run out of first, cash or creativity?" The economic forces arrayed against Moore's Law have to do with the price of industry progress: the costs of designing, marketing, and manufacturing leading-edge ICs. Some of the most fundamental cost issues currently facing the semiconductor industry are reviewed in the following paragraphs.

Lithography Discontinuity

In a recent meeting with Dataquest semiconductor analysts, Dr. Moore expressed his current doubts that industry progress toward the limits of device physics would proceed unabated. His earlier conviction that dimension reduction could follow its current exponential slope until it reaches the 0.1-micron level has been tempered by a concern that the industry will encounter serious obstacles in getting past the 0.35- to 0.25-micron range, the feature size requirement for production of 64Mb and 1-gigabit DRAMs! Production manufacturing of circuits with 0.25-micron geometries will be feasible, from Dr. Moore's current perspective, only if it can be done with optical lithography technology. The industry faces an enormous discontinuity at the point that optical lithography is abandoned. The issue, however, is not so much the technical achievement of manufacturing devices with feature sizes below 0.25 micron; it is the cost of doing so given the investments that will have to be made in the technological alternatives to optical lithography.

Design Costs

Dataquest believes that design cost, whether measured by per bit, transistor, or gate, now costs about one-fortieth of what it cost in the early 1970s. Numerous factors lie behind this tremendous progress, most of these having to do with the switch from physical layout and "hand analysis" to computer-aided design (CAD) advances in schematic capture, auto-routing, and simulation. On the other hand, chip density has increased 2,000-fold in the last 20 years, making the cost of design higher on a per-device basis. As a rule of thumb, design and/or development costs have gone up with the square root of density despite the offsetting benefits of CAD technology. Look at the history of microprocessor development: In the past decade, according to Intel, development costs rose from $25 million for the 8086 to $250 million for the 80486. As a whole, Dataquest estimates that design costs have risen 45 times during the last two decades.

Manufacturing Costs

In the near future, Dataquest sees a number of process trends that threaten to drive up the per-wafer cost of semiconductor manufacturing. The most critical of these are as follows:

- An increased number of mask steps—from 5 for a 16K device to between 25 and 30 for a 64Mb DRAM.
- An increase in interconnect levels—1Mb SRAMs, 4Mb SRAMs, and 16Mb DRAMs will use two levels of metal. ASICs, which lead interconnect technology, will have four or five levels of metal.
- An increase in the number of process steps—each interconnect level involves many deposition and etch steps and drives up process complexity as well as requiring expensive equipment. On average, the total number of process steps per wafer will increase from 200 for the 1Mb DRAM to approximately 800 for the 64Mb DRAM.
- The increase in process complexity will cause a decrease in wafer throughput, resulting in lower factory productivity. In addition, increases in process complexity will mean higher work-in-process inventory costs.

Marketing Costs

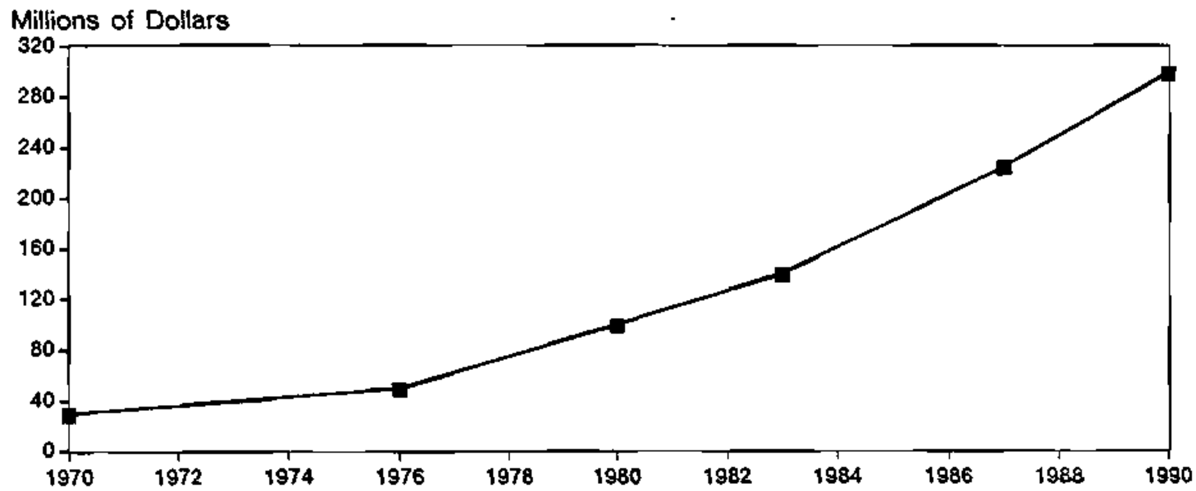
The costs associated with marketing ICs have increased as a function of the increase in market size and the industry's movement to worldwide markets. Dataquest estimates that the former accounts for about an 8 times increase in marketing costs and the latter about a 3 times increase—or about 25 times altogether. Increasing competition among suppliers at the applications level will tend to push these costs up still further.

Wafer Fab Costs

According to Dataquest's Semiconductor Equipment, Manufacturing, and Materials Service (SEMMS), the cost of a state-of-the-art fab has risen from $30 million in 1970 to $300 million today, as illustrated in Figure 1. Equipment costs for a single station routinely exceed $1 million and are increasing rapidly. As a result, process equipment costs have risen from 40 percent of the total fab cost to approximately 70 percent.

Based on discussions that SEMMS analysts have had with several semiconductor manufacturers in Japan and the United States, the cost estimates

FIGURE 1
Building plus Equipment Costs for a High-Volume Fab Line



Source: Dataquest (February 1991)

for a 64Mb DRAM fab range from $500 million to as high as $1 billion. Assuming the more conservative end of this range, we would still be looking at fab costs rising at a compound annual growth rate (CAGR) of 15 percent from 1990 to 1996 compared with a CAGR of 12 percent from 1970 to 1990. With both fab financing and fab productivity becoming equally critical, a slow ramp in production would be disastrous to suppliers both in terms of carrying cost and market prices. If this was true in the past, it will be more so in the future.

THE LIMITS OF PRODUCTIVITY

Up until now, the semiconductor industry has been doing a remarkable job of meeting the manufacturing challenge of increasingly complex devices with increased productivity. Clearly, the industry has responded to manufacturing complexities and costs with increases in die and wafer size and improvements in device yield. At Dataquest's 1987 Semiconductor Industry Conference, Dr. Moore happily remarked that the semiconductor industry had exhibited "the ability to improve products in all dimensions simultaneously by making them smaller with essentially no trade-offs."

A number of factors have contributed to the industry's success in continuing its dramatic price/performance improvements. CAD, for one thing, has not only enabled the industry to design significantly more complex products with greater efficiency but also to model "real-world" conditions of advanced wafer manufacture without incurring all of the attendant learning-curve costs. The industry has also witnessed a qualitative shift in technology development toward zero defects in the sense that defect elimination is occurring more rapidly than new generations of technology are turning over. As a result of improvements in defect density, there have been corresponding improvements in yield and therefore in process complexity (in terms of the number of mask levels) and wafer size.

Nevertheless, there are limitations to this progress as well. As Dr. Moore observed four years ago, "as the defect density is reduced to a tenth of a defect per square centimeter or lower, the yield approaches 100 percent." Although the industry has made great gains in improving average yields from 20 percent to better than 80 percent, there simply is not another factor of four left in yield improvement. Thirty years ago, Dr. Moore noted a limitation to increases in die size: "Extension to larger die size depends principally upon the continued reduction in the density of defects...(and) their density can be reduced as long as such reduction has sufficient economic merit to justify the effort." The operative words in this statement are *economic merit.*

PAYING THE PIPER

With the industry reaching some serious limits in the ability of productivity gains to offset rising wafer capital and processing costs, it is clear that chip costs will rise. The consequence of this increase will be a marked slowdown in the rate of price/performance improvement. Historically, data show that when costs (and prices) stop falling, they do so rather abruptly. This is true because of the compounded effects of slower market growth, lower return on investment, and reduced technical improvements resulting from reduced R&D spending—less market, less investment, less opportunity.

The semiconductor memory market is already showing signs of slower growth, at least as measured in compounded annual bit growth. From 1980 to 1985, compounded bit growth in semiconductor memories proceeded at a 114 percent annual pace. Between 1985 and 1989, Dataquest observed a slowdown in the rate of bit growth to 62 percent. For the time being, the market is continuing its 60 to 70 percent growth rate, but we believe that growth will be far slower in the future.

This forecast does not imply that the market will not continue to grow in dollar terms; the semiconductor market will see healthy growth in the foreseeable future. Dataquest does expect, however, that product lifetimes will lengthen and new product introductions—generation turnover—will come slower. As a speaker pointed out during a speech at the 1990 Dataquest Semiconductor Industry Conference, "For 20 years I have been a proponent of the industry's experience curve. No longer. Moore's Law is dead or dying. This will be plainly evident in two to three years." The critical questions now before the industry concern the consequences of a slowdown in the rate of price/performance improvement and how the industry might adjust to these consequences. This adjustment will be the subject of the next installment in this newsletter series.

Michael J. Boss

Dataquest
a company of The Dun & Bradstreet Corporation

Research *Bulletin*

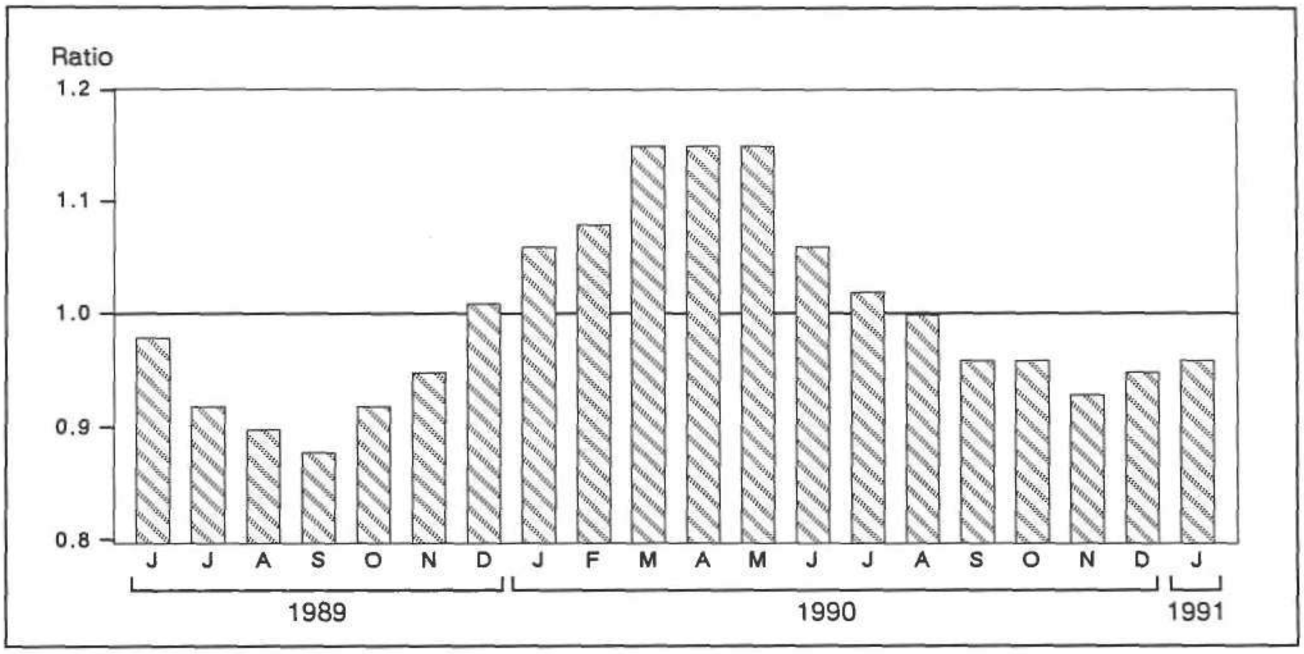
U.S. SEMICONDUCTOR BOOK-TO-BILL REPORT AND ANALYSIS—JANUARY 1991

BOOK-TO-BILL RATIO

The levels of orders booked and shipments billed to the U.S. semiconductor market in January fell 2.8 and 3.6 percent, respectively, compared with December 1990. As a result, the book-to-bill ratio rose from 0.95 in December to 0.96 in January, 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 January decreased 2.8 percent to $1,107 million from December's $1,139 million (see Figure 2). January orders are 8.5 percent lower than October's $1,209.5 million (the last beginning-quarter month). In addition, January 1991 bookings are 10.2 percent lower than January 1990's $1,233.0 million level. Three-month average billings decreased 3.6 percent to $1,158.6 million from December's $1,202.0 million. Actual billings to the U.S. semiconductor market in January were $1,101.4 million, a 7.6 percent decrease from December. In addition, January billings are 8.7 percent lower than October's $1,206.7 million and 4.3 percent higher than the level recorded in January 1990.

FIGURE 1
U.S. Market Book-to-Bill Ratio
(June 1989 to January 1991)

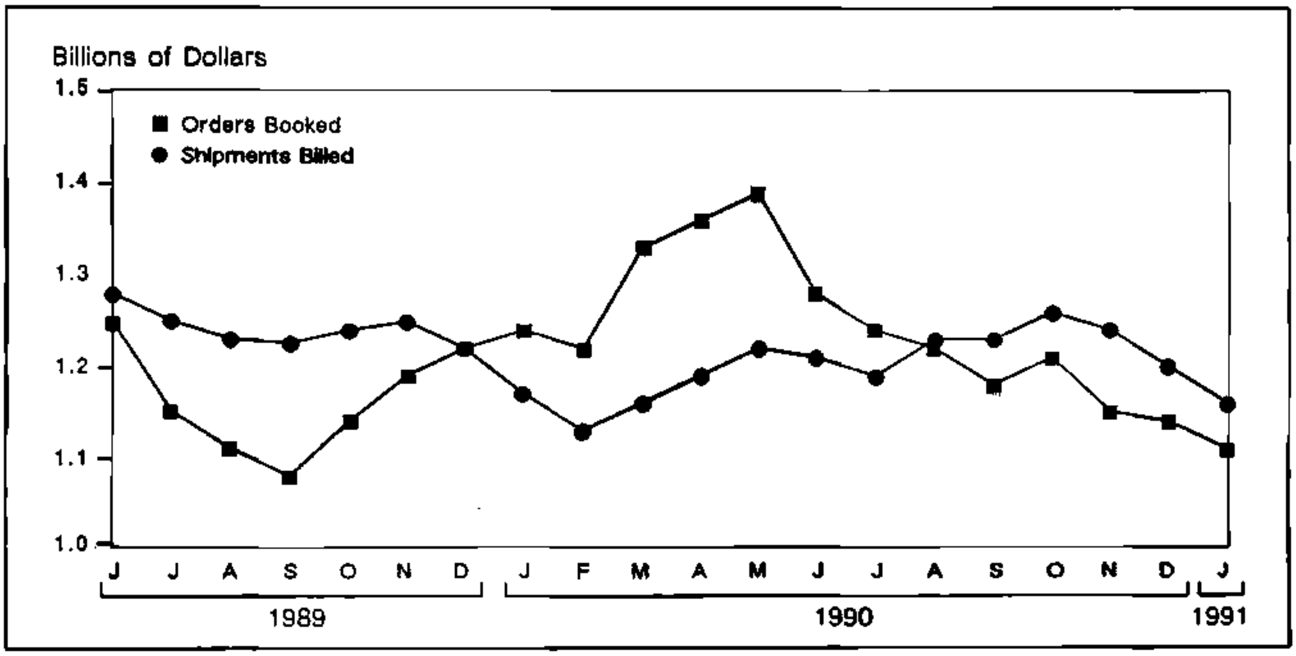


Source: WSTS, Dataquest (February 1991)

0009494

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

FIGURE 2
Three-Month Average Orders and Shipments
(June 1989 to January 1991)



Source: WSTS, Dataquest (February 1991)

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 increased to 21 and 31 days, respectively. Semiconductor buyers maintain a positive system sales growth outlook, predicting an average 3.7 percent growth during the next six months. This is the third consecutive month in which respondents predicted positive growth in the next six months, following a revised January prediction of 6.9 percent. Semiconductor procurement managers expect the semiconductor order rate to decrease by 13 percent, however, in February on a month-to-month basis. This negative growth expectation was anticipated following a strong 39 percent growth prediction for January as systems suppliers replenished semiconductor stock after year-end inventory write-downs.

According to a recent Department of Commerce (DOC) report, on a three-month moving average, shipments of computers and office equipment increased by 1.8 percent in December, although average bookings fell during the same period. Actual shipments and bookings for the month of December, however, were quite strong, increasing 49 and 24 percent, respectively, over the November average. Such high growth rates are typical for December, and the continuation of this trend is encouraging. The market for communications systems exhibited similar characteristics in December, posting growth in three-month and actual shipments and bookings.

DATAQUEST CONCLUSIONS

The Persian Gulf war is influencing the U.S. semiconductor market. The quoted procurement surveys for January and February were taken approximately two weeks prior to and two weeks after the start of the war, respectively. As a consequence, the January results may be slightly inflated while the February numbers may be artificially low. As is any forecast, the survey of semiconductor buyers is affected by the current business environment.

At this point, availability is not a problem, despite managed supply in some particular market segments. Even with the slightly higher inventory level (31 days) and an increase in the actual/target inventory differential of users, the semiconductor market has lost little of its ability to benefit quickly from a sudden increase in semiconductor demand. Dataquest expects overall semiconductor bookings to be down slightly in February, considering the softer systems outlook and the fact that February is a short month.

Phil Mosakowski

Dataquest
a company of
The Dun & Bradstreet Corporation

Research *Bulletin*

MACRONIX FAB: A TRENDSETTER IN TAIWAN?

OVERVIEW

On February 6, 1991, Applied Materials announced that it had received a multiple system order from Macronix International in Taiwan worth over $6 million. The equipment ordered, which includes Applied's Precision 5000 CVD and Precision Etch 8300 systems, will be used to equip Macronix's new fab in the Science-Based Industrial Park in Hsinchu. Macronix is one of several companies—including Acer/TI, Hualon, MOSel, TSMC, Vitelic, and Winbond—building new semiconductor production capacity in Taiwan. Under current development plans, Macronix's new fab will be one of the larger fabs to come on-line in Taiwan in the next two years. This bulletin examines details of Macronix's new fab and gives an overview of the current wafer fab situation in Taiwan.

MACRONIX ADDS SUBMICRON CAPACITY

When completed, Macronix's Hsinchu fab will be capable of between 20,000 and 30,000 6-inch wafer starts per month using 0.6-micron CMOS technology. The company intends to complete the facility in three phases. In the first phase, expected to be completed this September, Macronix plans to spend $80 million to equip the facility to run 8,000 wafers per month using 1.0- to 1.2-micron technology. In 1992, the company hopes to complete phase two of the program, converting to 0.8-micron technology and boosting production to 16,000 wafer starts per month. Capital expenditure through phase two is expected to be $80 million. By the end of 1992, Macronix hopes to be using 0.6-micron technology. At completion, which is expected to occur in 1993, the new fab will have cost an estimated $250 million and will be processing between 20,000 and 30,000 wafers per month.

The company expects to bring up its process using EPROM production. In addition, the new facility will likely manufacture other products for Macronix International and its U.S. affiliate, Macronix Inc., including ROMs, PC chip sets, UARTs, graphics chips, and microperipherals such as fax/modem and LAN controllers. The company has also expressed plans to use some of its capacity to seek foundry contracts that enable future strategic alliances.

FINANCING

In 1990, Dataquest estimates that Macronix International Corp. and its North American affiliate Macronix Incorporated achieved combined semiconductor sales of $13 million. The company also recently completed two rounds of funding. Approximately one year ago, Macronix raised $32 million in equity funding from a number of investors led by Hambrecht & Quist. Recently, Macronix completed a second round of funding that totaled $48 million. In addition, the company has received a significant loan from the Bank of Communications in Taiwan. Dataquest speculates that other corporate investors may be involved, judging by the high price tag of such a state-of-the-art facility.

DATAQUEST ANALYSIS: TAIWAN UPDATE

Dataquest continues to monitor Taiwan's historic attempt at becoming a first-class semiconductor manufacturing base (see ASETS newsletter 1990-05, entitled "Taiwan's Drive for Wafer Fabrication"). Taiwan's performance in 1990 was very disappointing, however, and Macronix seems to be setting itself apart from other manufacturers. Cutthroat price hacking and lack of original product development finally caught up with many companies. Although Macronix is known to be the last

SIS Newsletters 1991 PMT

0009507

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

company to secure land in the Hsinchu Science-Based Industrial Park, its fourth quarter target to begin phase one manufacturing surpasses its competitors' goals.

Macronix's strategy to finance, construct, and operate a semiconductor business in Taiwan mingles the company's familiarity with North American management and Taiwanese flexible competitiveness. The company's management philosophy is firmly rooted in American principles despite the fact that most of its decision-makers are Taiwanese. Yet its knowledge of Taiwan's dynamic financial environment and the importance of relationships has enabled initiation of the Taiwanese fab. Furthermore, Macronix has built credibility by designing its own multistory facility that is unique within the park. Before operations begin in approximately the fourth quarter of 1991, Macronix will have sent all of its senior engineers from Silicon Valley to Hsinchu to conduct American-style training. Despite its Taiwanese engineering roots, Macronix considers itself an American company and will focus on the North American market. Most importantly, Macronix has chosen to focus on its EPROM business. Several companies in Taiwan were hit hard because their mainstream products were shared by their Hsinchu neighbors, which discounted unrelentingly.

DATAQUEST CONCLUSIONS

Dataquest is impressed by the progress rate of Taiwan's semiconductor industry. The availability of capital, government support, and guidance, as well as Taiwan's talented engineers, have propelled the science park in Hsinchu forward. Macronix's latest developments help affirm that disappointments in 1990 will not inhibit the industry's determination to achieve first-class manufacturing.

Dataquest believes that developing a semiconductor manufacturing *culture* in Taiwan will occur more slowly than will its financial and technical capability. We believe that future progress is threatened by many companies' emphasis on short-term product volume (e.g., bimonthly) rather than long-term profitability. In order to gain market share in a highly competitive local market, companies cut prices to ensure volume and are unable to plan ahead. As a result, the semiconductor culture has neglected investing in developing in-house product development capability for the sake of monthly sales.

Dataquest continues to emphasize that the semiconductor market is globalizing at an unprecedented rate. Although a few companies are floundering for focus in Taiwan, others have found success in developing their *own* niche products. We believe that Macronix is one example of a Taiwanese company that has distinguished itself by adopting a more global market view and implemented investments that strive for profitability and product proliferation in the long run.

Daniel Heyler
Phil Mosakowski

Dataquest
a company of The Dun & Bradstreet Corporation

Research *Newsletter*

QUARTERLY SEMICONDUCTOR COMPANY RESULTS

INTRODUCTION

Dataquest regularly reports on semiconductor company financials 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 November-through-December time frame. This information is compared with the corresponding 1989 time frame and shown in millions of dollars unless otherwise indicated. Figures 1 and 2 show the percent change on a quarter-to-quarter basis for aggregate company revenue and net income, respectively, from the fourth quarter of calendar year 1989 through the fourth quarter of 1990. Descriptive summaries of quarterly performance highlights are provided for the companies listed in Table 1.

COMPANIES

Adaptec

For its third fiscal quarter, Adaptec reported net income of $1.5 million on revenue of $30.5 million. Third-quarter revenue was 5 percent higher than revenue for the corresponding quarter one year ago. The company cites a weakened world economy that is impacting system and peripheral manufacturers as a factor affecting Adaptec's latest quarterly results. The company also stated that it has had to create an inventory reserve for a significant portion of its older-generation AT controllers to address the accelerating industry transition to embedded controller solutions.

Advanced Micro Devices

Advanced Micro Devices (AMD) recorded a loss of $43 million in its fourth fiscal quarter that ended December 30. Revenue for the quarter was $265.9 million, a 7 percent decline from the $485.3 million recorded in last year's fourth quarter. The company's net income was affected by a nonrecurring charge of $27.7 million related to the loss of a patent infringement suit filed by Brooktree Corporation. For the first time in the company's history, sales of CMOS products exceeded sales of bipolar products. During the fourth quarter, AMD began operations in its Submicron Development Center and started shipping flash EPROMs, 4Mb EEPROMs, and MACH PLDs.

Altera

Altera announced that it achieved net income of $3.6 million on sales of $21.2 million during its fourth fiscal quarter that ended December 31. These figures represent increases of 18 and 31 percent, respectively, over those recorded during the same quarter a year ago. Altera continued to be supply-constrained during the quarter, which limited revenue growth. The company reports that demand remains strong for its MAX 5000 products and exceeds its foundry capacity in the San Jose, California, fab. Altera looks forward to bringing the Cypress, Texas, fab on-line in the first quarter to begin removing supply limitations.

Burr-Brown

For its fourth fiscal quarter that ended December 31, Burr-Brown announced record sales of $48.3 million, an increase of 21.6 percent over the corresponding quarter one year ago. Net income for the quarter was $672,000 compared

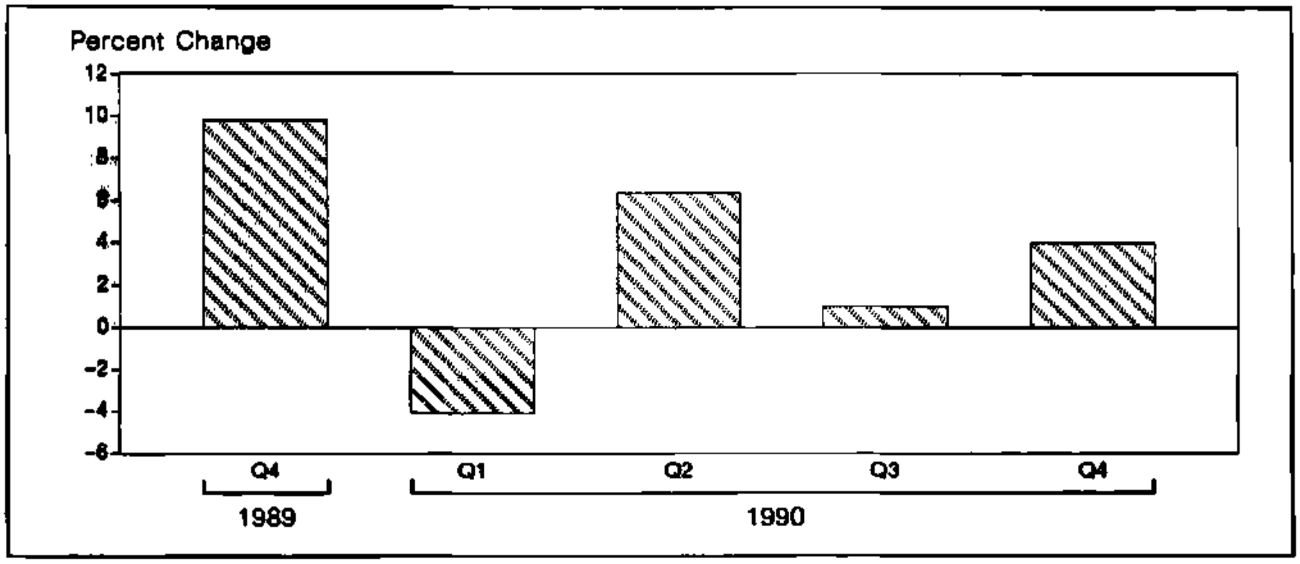
Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398 / (408) 437-8000 / Telex 171973 / Fax (408) 437-0292

TABLE 1
Quarterly Financial Summaries for Selected Semiconductor Companies
(Millions of Dollars, Unless Otherwise Indicated)

Company	Latest Quarterly Revenue	Percent Change	Latest Quarterly Income	Percent Change
Adaptec (Dec. 28, Q3)	30.5	5	1.5	-61
AMD (Dec. 30, Q4)	265.9	-7	43.0	NM
Altera (Q4)	21.2	31	3.6	18
Burr-Brown (Q4)	48.3	22	0.7	-57
Chips & Technologies (Q2)	61.0	-18	-273K	NM
Cirrus Logic (Q3)	37.0	56	4.9	14
Cypress (Q3)	63.0	24	8.2	1
Dallas (Dec. 30, Q4)	25.7	19	3.6	22
IDT (Q3)	48.2	-7	256K	0
Intel	1,000.0	17	163.9	34
International Rectifier (Q2)	63.5	17	6.8	3,300
Lattice (Dec. 29, Q3)	14.4	42	2.0	4
Linear Technology (Dec. 30, Q2)	22.3	24	3.8	55
LSI Logic (Q4)	184.3	33	-45.5	NM
Maxim (Dec. 30, Q2)	18.0	37	2.4	34
Micron (Nov. 29, Q1)	80.3	21	-9.3	NM
Motorola (Q4)	2,930	11	109.0	-17
National (Nov. 25, Q1)	427.4	3	3.5	46
SEEQ (Q1)	12.3	0	-1.6	NM
Texas Instruments (Q4)	1,759.0	2	-56	NM
VLSI Technology (Dec. 29, Q4)	86.0	7	1.3	-54
Weitek (Q4)	10.6	-25	381K	-80
Western Digital (Dec. 29, Q2)	230.0	-13	-98.5	NM
Xilinx (Dec. 29, Q3)	26.3	111	4.3	121

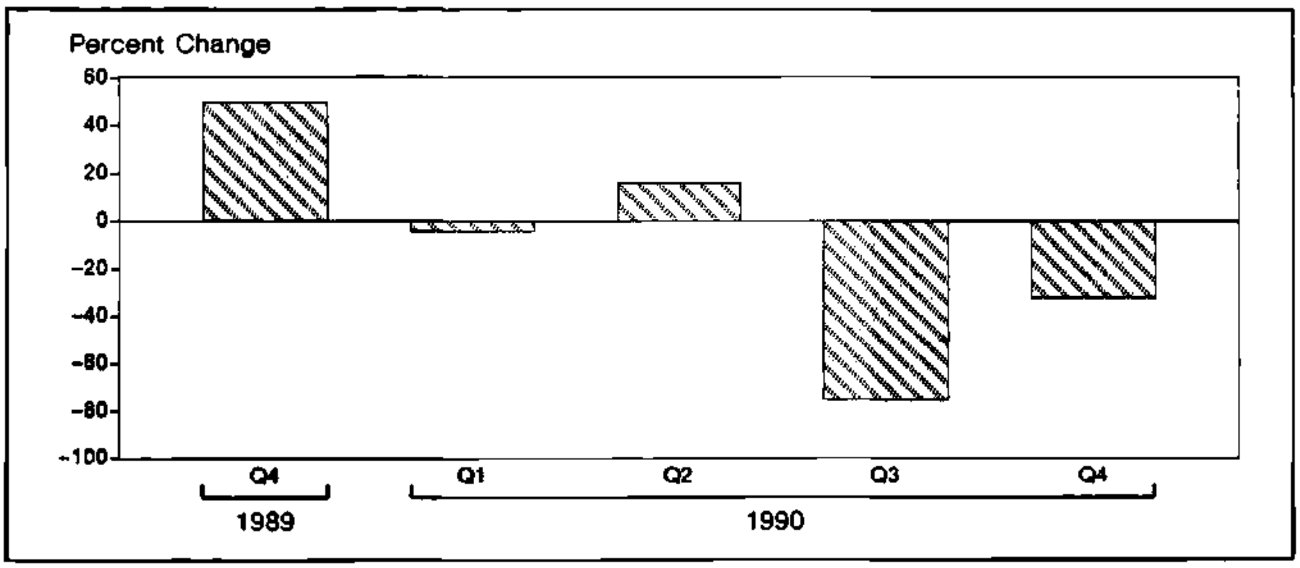
NM = Not meaningful
K = Thousands
Source: Company Literature

FIGURE 1
Aggregate Company Revenue



Source: Dataquest (March 1991)

FIGURE 2
Aggregate Company Net Income



Source: Dataquest (March 1991)

with $1.6 million a year ago. Operating income for the year was lower than the company's target because of process problems in its wafer fab, new quality procedures being implemented during the latter portion of the year, an underutilization of new capacity, and increased strategic spending in sales, marketing, and product development.

Chips & Technologies

For its second fiscal quarter that ended December 31, Chips & Technologies (Chips) reported a net loss of $273,000 on sales of $61 million. Second-quarter results compare with net sales of $74.4 million and net income of $8.9 million for the same period one year ago. The company attributed the second-quarter loss to several factors, including declining average selling prices (ASPs) in Chips' more mature product lines and difficulty meeting customer demands for certain products. In addition to developing leading-edge chip set products that offer enhanced features and higher levels of integration, Chips has directed part of its R&D spending toward developing new technologies to address emerging new markets. These markets include multimedia, software accelerators, and graphics controllers for color video graphics array (VGA) flat panel displays.

Cirrus Logic

Cirrus Logic announced revenue of $37 million for its third fiscal quarter, an increase of 56 percent over revenue in the third quarter last year. Net income for the quarter was $4.9 million, a 14 percent increase over the same quarter a year ago. Demand for the company's PC AT mass-storage products remained strong during the quarter, with excellent growth in Japan for the company's SCSI products. In addition, demand for the company's new CL-GD610/620 liquid crystal display VGA chip set has increased as more companies introduce laptop and notebook computers.

Cypress Semiconductor

Cypress announced that revenue for its fourth quarter was $63 million, a 24.1 percent increase over last year's fourth quarter. In addition, net income for the quarter was $8.2 million, up 1.2 percent from the quarter one year ago. Cypress also announced annual net income of $33.2 million on revenue of $225.2 million, representing increases of 8.2 and 13 percent, respectively, compared with figures for last year. Cypress reports strong growth in five of its seven product lines, with outstanding growth at its Ross Technology and Aspen Semiconductor subsidiaries. Because of record bookings for the year, the company's backlog increased despite record shipments.

Dallas Semiconductor

Dallas reported that net sales for 1990 were a record $100 million, a 22 percent increase from the $82 million achieved in 1989. The company also reported record net income for 1990. Totaling $13.8 million, the figure represents a 24 percent increase over the $11.1 million recorded in 1989. In the fourth quarter of 1990, Dallas also achieved record net sales and net income. Net sales were $25.7 million, a 19 percent increase from the $21.5 million reported in the corresponding quarter a year ago. Net income for the quarter was a record $3.6 million, a 22 percent increase compared with $2.9 million in the fourth quarter of 1989. The company reports that its outlook for continued sales and net income growth remains positive for 1991.

Integrated Device Technology (IDT)

IDT reported net income of $256,000 on revenue of $48.2 million for its third fiscal quarter that ended December 31. The company's quarterly revenue compares with revenue of $51.6 million during the same period one year ago. The company reports difficulty ramping up Fab 3, its new six-inch, sub-half-micron, Class 1 fab facility. IDT believes that the problem has been solved and expects to commence volume shipments this quarter.

Intel

Intel announced that revenue for 1990 totaled $3.9 billion, an increase of 25 percent from the $3.1 billion recorded in 1989. Net income rose 66 percent in 1990 to $650 million from $391 million in 1989. For the fourth quarter of 1990, the company achieved revenue of $1 billion, a 17 percent increase from $895 million a year earlier. In addition, net income increased 34 percent to approximately $164 million from $123 million in the comparable quarter a year ago. In response to increased sales of 32-bit PCs, Intel nearly doubled shipments of its 386 and 486 microprocessors in 1990. Intel reports that 46 percent of the company's revenue came from sales to customers outside North America. The company reports that it again plans to increase capital spending "aggressively" in 1991. According to Dataquest's preliminary market share estimates, Intel was the fastest-growing company among the world's top 20 semiconductor manufacturers in 1990.

International Rectifier (IR)

For its second fiscal quarter that ended December 31, International Rectifier reported revenue of $63.5 million and net income of $6.8 million. Compared with results from the comparable quarter last year, these figures represent increases of 17 and 3,300 percent, respectively, in revenue and net income. A one-time charge of $1 million was taken against costs associated with planned restructuring of the company's power products operations. Second-quarter orders were 11 percent above year-ago levels, and both orders and shipments set second-quarter records for the company.

Lattice Semiconductor

For its third fiscal quarter that ended December 29, Lattice reported revenue of $14.4 million, a 42 percent increase over the $10.2 million posted in the same period a year ago. Net income for the quarter was $2 million, an increase of 4 percent over the $1.9 million posted in the comparable period last year. The company reported a slowdown in orders in certain business segments caused by the current economic downturn. Despite the difficult economic environment, the company achieved a 19 percent pretax margin.

Linear Technology Corporation

Linear Technology reported net sales of $22.3 million and net income of $3.8 million, both company records, for its second fiscal quarter that ended December 30, 1990. Compared with last year's second quarter, the company achieved increases of 24 and 55 percent, respectively, in revenue and net income. Linear Technology attributes the record results to the penetration of its products into the products of both new customers and the newer-generation products of its existing customers. The company continues to set records despite the current economic slowdown.

LSI Logic

LSI Logic reported a net loss of $45.5 million on revenue of roughly $184 million for its fourth quarter that ended December 31. Revenue for the quarter was up 33 percent from the $138 million recorded in the fourth quarter a year ago. The company's net loss included a restructuring charge of $44 million. The restructuring includes changing the focus of the company's U.K. facility from a high-volume CMOS wafer fab to a low-volume analog/digital manufacturing and engineering support facility. It also involves the write-off of the goodwill related to the 1988 acquisition of Video Seven. For fiscal year 1990, LSI had a net loss of $33 million on revenue of $655 million compared with a loss of $25 million on revenue of $547 million in 1989.

Maxim Integrated Products

For its second fiscal quarter that ended December 30, Maxim reported record sales of $18 million, a 37 percent increase in revenue compared with the same quarter a year ago. In addition, the company reported net income of $2.4 million, a 34 percent gain over the $1.8 million in the like quarter in fiscal 1990. This figure marks the 19th consecutive increasingly profitable quarter for Maxim. The company reports that its new product productivity has been bolstered by increasingly greater contributions from its fab. Currently, 60 percent of Maxim's wafer requirements are served by the facility. The company anticipates a military/883 certification in upcoming months, which will allow Maxim to realize its potential in the military market.

Micron Technology

Micron reported net sales of $80.3 million for its first fiscal quarter of 1991 that ended November 29, 1990. This compares with revenue of $66.5 million for the corresponding quarter a year ago. The company recorded a net loss of $9.3 million for the quarter compared with net income of $43,000 for the same quarter last year. Micron's financial performance continues to be affected by declining prices in the company's principal markets. The company is encouraged by its increasingly diversified product line, its strengthening cost position, and the growing number of applications using additional memory.

Motorola

For its fourth fiscal quarter that ended December 31, Motorola reported revenue of $2.93 billion, an increase of 11 percent over the same period a year ago. However, the company suffered a 17 percent decline in net income, down to $109 million. For the year, Motorola recorded net income of $499 million on sales of $10.88 billion. Motorola's semiconductor sales increased 13 percent in 1990 to $3.4 billion as the company gained market share in every major region of the world. Demand increased in most major product categories, led by digital signal processors, fast SRAMs, MCUs, MPUs, and CMOS gate arrays.

National Semiconductor

National announced that net income for the company's second fiscal quarter that ended November 25, 1990, was $3.5 million. This amount compares with net earnings of $2.4 million in the second quarter of fiscal 1990. Sales for the quarter were $427.4 million, a 2.5 percent increase from the $416.8 million recorded in the corresponding quarter a year ago. Results for the quarter include a $2.4 million credit, reflecting the reversal of certain restructuring charges connected with the closure of the company's Danbury, Connecticut, plant. In its report, the company states that the "significant improvement in operating performance in this quarter, compared to the first quarter of this fiscal year, reflects the benefits resulting from the restructuring activity which the company undertook this past August."

SEEQ Technology

For its first fiscal quarter that ended December 31, SEEQ reported revenue of $12.3 million and a $1.6 million net loss. In the first quarter a year ago, the company reported a net loss of $1.1 million on revenue of $12.3 million. SEEQ's revenue increased by approximately $1.2 million from the previous quarter and losses were reduced during the same period. The company attributes the improvements to increased usage of low-cost state-of-the-art wafer fab foundries to supply SEEQ's products. During the first quarter, approximately 30 percent of the company's products were manufactured by its strategic partners.

Texas Instruments (TI)

For the fourth quarter of 1990, TI recorded a net loss of $56 million on net revenue of $1.8 billion. For the year 1990, the company had a net loss of $39 million on revenue of $6.6 billion, compared with net income of $292 million on $6.5 billion in revenue a year ago. Operating results for the company's semiconductor operations were substantially lower than in 1989, primarily as a result of lower prices for memory devices coupled with higher depreciation and R&D investments. Fourth-quarter financial performance in semiconductors declined sharply relative to the same period in 1989 because of lower prices in memory and bipolar logic products.

VLSI Technology

VLSI reported net income of $1.3 million on net sales of $86 million for its fourth fiscal quarter that ended December 29. Revenue for the quarter rose 7 percent compared with the same quarter a year ago. The company also reported annual revenue of $324.8 million for 1990, a 13 percent increase over 1989. However, VLSI recorded a net loss of $12.7 million in 1990 compared with a net income of $506,000 last year. The company reports that new orders during the fourth quarter were broad-based and reflected a 30 percent increase over third-quarter bookings.

Weitek

Weitek reported revenue of $10.6 million and net income of $381,000 for its fourth fiscal quarter that ended December 31. Revenue and net income declined from $14.2 million and $2 million in the fourth quarter of 1989. For 1990, the company reported revenue of $57.8 million and net income of $7 million, representing increases of 17 and 2 percent, respectively, from 1989 figures.

Western Digital

Western Digital reported a net loss of $98.5 million on revenue of $230 million for its second fiscal quarter that ended December 29, 1990. In the same period a year ago, the company recorded net income of $8.6 million on revenue of $265.6 million. The second-quarter loss includes a one-time charge of $66 million related to a previously announced restructuring plan. The company reports that the restructuring plan directly impacted the company's operating results because it made some fundamental changes in the way it conducts business. The restructuring involved refocusing the company's marketing channels more on OEMs and a few strategic resellers and streamlining the company's business operations, including the closure of a board manufacturing plant in Puerto Rico. In addition, the company has reduced its worldwide employee head count by 7 percent since October 1990.

Xilinx

For its third fiscal quarter that ended December 29, 1990, Xilinx reported revenue of $26.3 million, an increase of 111 percent from the $12.4 million posted in the corresponding period a year ago. Net income for the quarter was $4.3 million, up 121 percent from $2 million in the same quarter last year. Xilinx has reported increased revenue and operating income for 13 consecutive quarters. During the December quarter, Xilinx introduced its third generation of FPGAs. The company reports continued strong demand for its products, but it cites the current economic slowdown as a major contributor to its slowing growth rate—from 25 percent revenue growth on a quarter-to-quarter basis in the September 1990 quarter to 14 percent growth in the current quarter.

Phil Mosakowski

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

RECENT START-UPS DEVELOP NEW PRODUCTS, TECHNOLOGIES

INTRODUCTION

During the 1980s, the semiconductor industry spawned over 170 start-up companies. More than one-half of the start-ups formed in the 1980s were started in the first five years of the decade. The period of 1983 to 1985 was particularly strong in terms of start-up activity. In 1983, 37 new companies were formed, followed by 30 in 1984 and 23 in 1985. In the latter half of the decade, however, the number of start-ups per year declined as competition in niche markets increased, venture capital funding declined, and general business conditions became increasingly challenging.

In the past year, however, several small start-ups have emerged with new financing, products, and technologies (see Table 1). These private companies have introduced products ranging from PC logic chip sets to nonvolatile memory devices capable of storing analog signals. Following Table 1 are brief profiles of each of the companies listed in the table.

THE COMPANIES

Benchmarq

Founded in 1989, Benchmarq has developed IC and module products designed for applications in portable and power-sensitive electronic equipment. The first products from the company include a processor management unit (PMU) family, which consists of single-chip solutions

TABLE 1
Recent Semiconductor Start-Ups

Company Name	Location	Product(s)
Benchmarq	Dallas, TX	Memory, micros
C-Cube Microsystems	San Jose, CA	Video-compression ICs
Crosspoint Solutions	Santa Clara, CA	FPGAs
Cyrix	Richardson, TX	Math coprocessors
Elite Microelectronics	San Jose, CA	PC logic chip sets
Information Storage Devices	San Jose, CA	Analog storage devices
InfoChip Systems	Santa Clara, CA	Data compression ICs
Nexel	Santa Clara, CA	Cache controllers
OPTi	Santa Clara, CA	PC logic chip sets
QuickLogic	Santa Clara, CA	Programmable ASICs
Styra	Carrollton, TX	PC logic chip sets
Teraplex, Inc.	Champaign, IL	MISC MPUs

Source: Dataquest (March 1991)

SIS Newsletters 1991 PMT

0009580

providing MPU supervision and battery-backed SRAM to allow power-sensitive systems to intelligently and deliberately power down and recover after power loss. In addition, the company produces battery-backed SRAM modules and nonvolatile controllers that protect standard CMOS SRAMs against data loss due to power failure by write-protecting the memory and automatically switching to a backup battery. Benchmarq, which has received venture capital funding from L.J. Sevin, Ben Rosen, Berry Cash Southwest Partnership, and Dietrich Erdman, anticipates the introduction of additional product families throughout 1991.

C-Cube Microsystems

C-Cube was founded in 1988 by Edmund Sun, founder of Weitek, and Alexandre Balkanski, cofounder of Diamond Devices. To date, the company has received $20 million in funding from venture capital and corporate sources including Hambrecht & Quist, JAFCO America Ventures, and Kubota Ltd.. The company has developed an image-compression processor, the C-Cube CL550, which is capable of the compression and decompression of motion video at 30 frames per second. The single-chip processor fully implements the proposed Joint Photographic Experts Group (JPEG) standard for image compression. C-Cube has targeted the device for applications in color copiers and fax machines, professional video systems, digital photography, video conferencing, and image databases. Image-compression technology will also be a key enabling technology for HDTV equipment. The compression of video images facilitates easier transfer and storage of data in high-performance television and desktop systems.

Crosspoint Solutions

Formed in 1989 by executives from Samsung, Integrated CMOS Systems, National Semiconductor, and VLSI Technology, Crosspoint Solutions has developed what it believes is a unique approach to field programmability in gate arrays. The company believes that its proprietary cell and routing architecture, coupled with a unique interconnect technology, gives it a significant advantage over other field-programmable gate array (FPGA) implementations. In June 1990, Crosspoint completed its first round of equity funding, led by ASCII Corporation, raising $6 million. In October, the company signed a strategic alliance agreement with Performance Semiconductor. Under terms of the agreement, Performance provides its advanced PACE III process and manufacturing services and serves as an alternate source for Crosspoint's new generation of FPGAs.

Cyrix

Another 1988 start-up, Cyrix was formed to design, develop, and market math coprocessors for 32-bit desktop computer systems. Cyrix's FasMath coprocessor is a high-performance, floating-point unit that supports Intel's 80386 microprocessor. The company's competitors include IIT, Intel, ULSI, and Weitek. Cyrix recently filed an antitrust claim for relief from what it believes is an anticompetitive campaign by Intel to keep Cyrix's products out of the market. Subsequently, Intel filed a patent infringement claim against Cyrix. Cyrix claims, however, that its coprocessor is a wholly original design. Cyrix was founded by Jerry Rogers and Tom Brightman and has received venture capital financing from Berry Cash Southwest Partners, Interwest Partners III, Sevin Rosen Bayless Borovoy, and Sevin Rosen Bayless Partners.

Elite Microelectronics

Elite was founded by two former employees of Chips & Technologies, Peter Hsieh and Van Chang, who now serve as president and vice president of CAE, respectively. While at Chips & Technologies, Mr. Hsieh served as director of advanced products. The company was established in 1989 and markets logic chip sets for AT-bus PCs. The company's first product, introduced in November 1990, is the Eagle chip set for 80386-based PCs, which is offered in both 25- and 33-MHz versions. Elite Microelectronics has received $3.5 million in venture capital from a number of investors including Idanta Partners. In January 1990, Chips & Technologies filed a lawsuit against Elite for alleged misappropriation of trade secrets, breach of contract, interference with contractual relationships, and unfair competition. The two companies have since settled out of court, agreeing to have an independent inspector visit Elite's facilities periodically to assure Chips & Technologies that Elite has not used any of Chips' trade secrets in developing Elite's products.

InfoChip Systems

InfoChip Systems was founded in November 1988 by Dr. Kai Yiu and Dr. Bob Woo to design, manufacture, and market information-compression products for the PC and workstation markets. The company's first products include a lossless data-compression chip for random access data storage. In addition, the company offers a board-level product based on the compression IC, offering transparent data compression/decompression for hard and floppy disks. InfoChip claims that the product can increase total data storage capacity by a factor of three. Both the IC and board products are based on lossless or noiseless data compression technology, a recoding methodology in which decompressed data are an exact reproduction of the original data, and no error is allowed. Lossless compression is required for any computing in which data integrity is essential, including data processing, CAD, and desktop publishing.

Information Storage Devices (ISD)

ISD is a three-year-old start-up in San Jose that has developed the technology to produce analog storage ICs. The floating-gate technology that is the basis of the company's analog storage device is similar to that used in digital EEPROMs. ISD believes that its product has widespread application possibilities in consumer products and is initially targeting personal communications equipment, including pagers, cellular telephones, and answering machines. The company has raised approximately $2 million in venture capital to date, led by two venture capital groups—Associated Venture Investors and Applied Technology Investors. The company is operating as a fabless semiconductor supplier, contracting wafer fabrication to Atmel and Sanyo.

Nexel

Nexel is a privately held company that was founded in 1990 by S.Y. Kuo, Kent Marshall, Mike Raghavan, and Wes Sage. The company currently has two products under development. The first product, the SY380SX, is a cache memory controller designed to improve the performance of Intel 80386SX systems. The second product is a single-chip cache controller with the same core as the SY380SX, designed to enhance the performance of 80286-based systems. Nexel also plans to introduce four additional products for 386SX, 386DX, 486, and SPARC systems in the next two years.

OPTi

Founded in January 1989, OPTi's charter is to provide precision-crafted VLSI to enable PC OEMs to build top-of-the-line, technically superior PCs. The company's founders include a number of Chips & Technologies veterans. OPTi's current product portfolio includes AT-bus logic chip sets for 80386SX- and 80486-based systems. Future products are expected to include chip sets that support the full line of Intel microprocessors and the EISA and MCA bus standards. Like all of the other start-ups listed in this newsletter, OPTi operates as a fabless company, contracting its wafer fabrication to a number of foundries.

QuickLogic

QuickLogic (formerly Peer Research) was founded in 1988 by John Birkner, H.T. Chua, and Andrew Chan to develop a new architecture and process technology combining the time-to-market advantage of programmable ASICs with the speed, low power, and design flexibility benefits of masked devices. While at Monolithic Memories, the three founders worked on the development of the original PAL devices. In September 1990, David Laws, former vice president of marketing for Altera, was appointed president and chief executive officer of the young company. Although QuickLogic has yet to introduce its first products, it has closed its first round of venture capital funding. Investors include Sequoia Capital, Sutter Hill Ventures, Technology Venture Investors, and U.S. Venture Partners.

Styra

Styra, located in Carrollton, Texas, was founded in November 1987 by Lynn Reed, formerly of SGS-Thomson. The company's first product is a drop-in replacement for Chips & Technologies' NEAT chip set. Dubbed the high-speed enhanced AT (HEAT) Styraset, the new product has been positioned to compete with the Chips & Technologies products with smaller die sizes and lower prices. The competing products support Intel's 80286 microprocessor architecture. At last report, Styra, which has received funding from a single, undisclosed venture capital source, was sampling its HEAT chip set.

Teraplex, Inc.

Teraplex has developed what it calls a minimum instruction set computing (MISC) microprocessor that is expected to run 70 mips. The company's president, Philip McKinney, was the director of product development and marketing at ThumbScan Inc. Teraplex has licensed its MISC design to Atmel in exchange for design and fabrication capability. Atmel will provide design support and layout at its Chesapeake Design Center and fabrication and testing at its Colorado Springs, Colorado, facilities. Atmel will also pay an unspecified license fee and royalties for eventual production rights to the MISC device. Volume production is scheduled for May 1991. To date, the company has received $2 million in venture capital from Advanced Analytics, the state of Illinois, and other individual investors.

DATAQUEST ANALYSIS AND CONCLUSIONS

The number of start-ups that have emerged in the past year indicates that the slump in start-up activity that occurred in the late 1980s may be over. The companies identified in this newsletter are exploring a wide variety of new technologies and products. PC chip set suppliers continue to emerge, although there are signs that this market is ripe for consolidation. Data-compression technology is likely to be a key technology driver in the 1990s. In addition, the analog storage device introduced by ISD appears to be a revolutionary technology with an endless variety of potential applications. Furthermore, Dataquest is not aware of any other companies with products that may compete with ISD's.

One factor that should offer significant advantages over several start-ups of the early 1980s is the fact that none of the companies discussed herein will operate its own fab. This will allow the young companies to concentrate on product development and marketing without worrying about filling capacity, ramping up a new process, or paying millions of dollars for capital equipment. Dataquest recognizes fabless semiconductor operation as a major strategic trend in the 1990s. Dataquest expects the next wave of start-ups to include companies developing FPGAs, data and image compression ICs, neural network and fuzzy logic ICs, and graphics enhancement devices. The next generation of start-ups will be driven by laptop computers, multimedia, HDTV, and desktop workstations.

Phil Mosakowski

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

SEMICONDUCTOR PRICE/PERFORMANCE: A REPORT FROM THE DRAM FRONT

SUMMARY

In a recent newsletter entitled "Will Industry Economics Defy Moore's Law?" Dataquest analysts highlighted factors that we believe will lead to a slowdown in the historic rate of price/performance improvements in leading-edge semiconductor devices. This newsletter explores the degree to which those factors apply to the DRAM business and the possible implications for the electronics market as a whole.

Based on Dataquest research and the experiences and projections of a number of leading suppliers, it seems clear that leading-edge DRAMs in the megabit era will no longer be able to continue along the same learning curve observed in previous generations. Put simply, the price per bit of commodity memory will no longer decline as fast as it has in the past. Given the importance of ever-decreasing memory costs to the evolution of the PC industry as well as to other segments of the electronic equipment business, this prediction may seem ominous. However, Dataquest believes that although DRAM manufacturers will continue to deliver their historic 4x improvements in bit density per DRAM generation, life cycles will be longer, and DRAM devices will no longer be as inexpensive on a per-bit basis at the megabit and gigabit densities.

The good news is that the "new world order" in DRAMs will create a more stable environment for producers and consumers alike. This stability, however, will come at the price of further industry consolidation. This newsletter discusses a number of issues pertaining to DRAM price/performance, including the following:

- Factors affecting DRAM cost per die
- The evolution of wafer size increases
- DRAM market elasticity and future growth
- The implications of the above for semiconductor manufacturers

THAT WAS THEN; THIS IS NOW

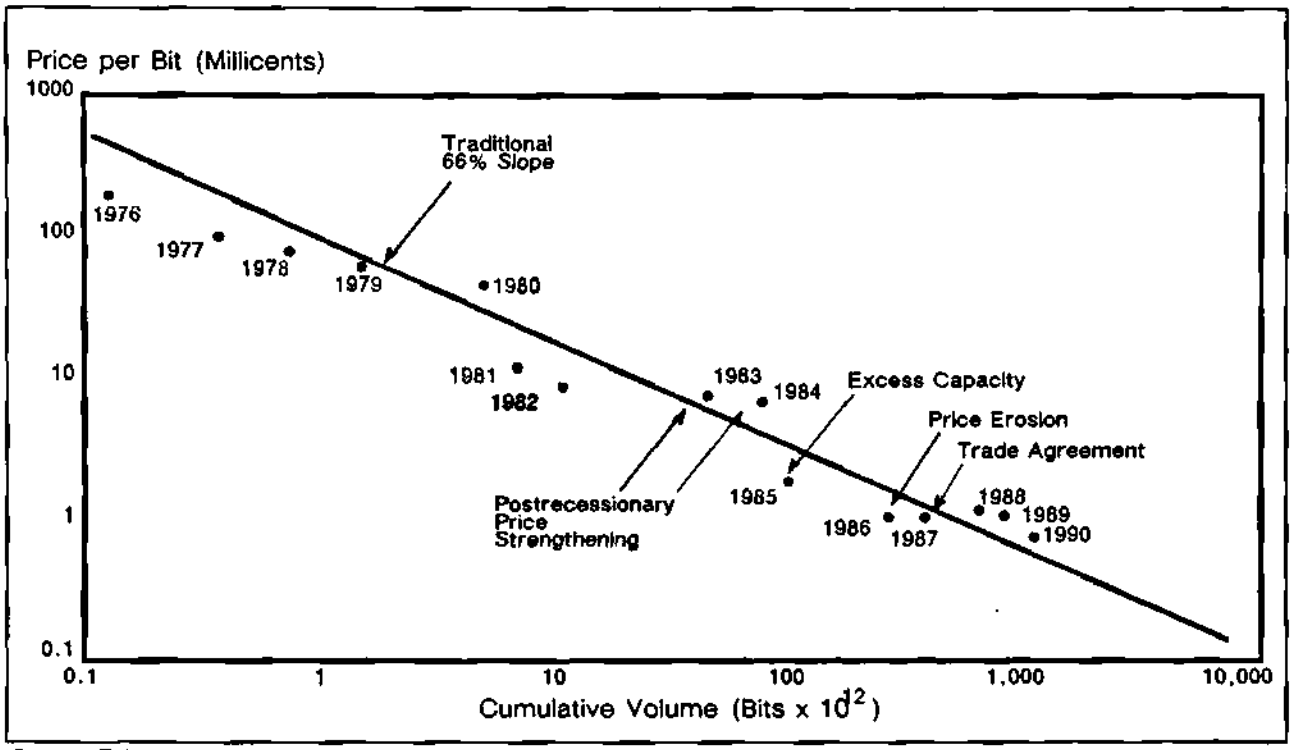
During Dataquest's 1990 Semiconductor Industry Conference, Fujitsu America Vice President David Sear estimated that, in the past few years, price-per-bit reductions helped drive memory demand at a quarterly compound growth rate of 20 percent. Historically, the cost of semiconductor memory has fallen dramatically since the introduction of the 1K DRAM. Figure 1 shows the historic price experience curve for DRAMs, which, in spite of industry booms, busts, and the occasional political intervention, has maintained a historic slope of 66 percent. This figure also supports a Dataquest model of DRAM price/shipment history over the past five years, which basically illustrates that a doubling of volume on a per-bit basis leads to a 35 percent reduction in price.

As the industry makes the transition from megabit to gigabit memories, Mr. Sear and a number of major DRAM suppliers are wondering if price reductions can continue at their past rates. A slide presented at the conference by Dr. Tsugio Makimoto, director and general manager of the Semiconductor Design and Development Center of Hitachi Ltd., illustrates that, although technical limitations pose challenges to DRAM density improvements, the first hurdle the industry will face has to do with "bit-cost saturation"—the flattening of the industry's historic price/performance curve. Dr. Makimoto's slide is recreated in Table 1.

SIS Newsletters 1991 PMT

0009732

FIGURE 1
DRAM Price Experience Curve



Source: Fujitsu America

TABLE 1
Fundamental DRAM Limits

Device Issue	Geometry Limit (Microns)	Limiting Factor
Cost	0.3-0.2	Bit-cost saturation
Performance	0.2	Access time saturation
Reliability	0.1	Breakdown by tunneling effect
Manufacturing		
Yield	0.1	Yield limit by fluctuations
Lithography	0.1	Optical lithography limit
	<0.1	e-beam or x-ray lithography

Source: Hitachi Ltd.

THE COST-PER-DIE BATTLE: SIZE VERSUS DENSITY

Based on the observations of major DRAM suppliers, a number of factors emerge that will contribute to Dr. Makimoto's observation of bit-cost saturation. These factors basically have to do with increases in the cost per die of high-density DRAMs. Basically, the industry is experiencing a discontinuity between the pre- and post-megabit era of DRAM densities.

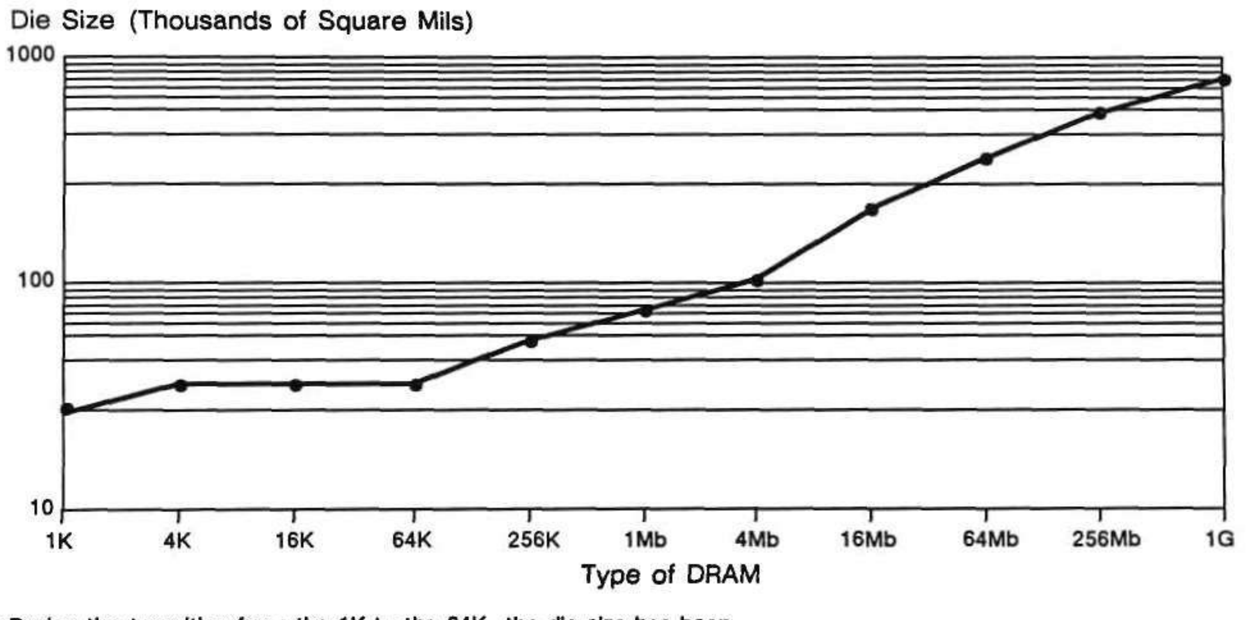
To understand this discontinuity, one should note that during the transition from the 1K to 64K DRAM, die size remained fairly constant at about 25,000 square mils. However, although die size remained constant, density effectively improved by a factor of 64! To begin with, from the 1K to 64K DRAM, processing resolution went from 10 microns down to 5. Density improvements were also propelled by what Dr. Moore has referred to as the "cleverness" factor: the evolution from the 3-transistor cell to the 1-transistor cell, the evolution from double polysilicon to triple poly, the use of stacked capacitors, and so on.

Since the 256K DRAM, however, the combined improvements in device cleverness and reductions in scaling have not been enough to hold down increases in die sizes, which have been taking place at an ever-expanding rate. In continuing the 4x density improvements per DRAM generation, Dr. Makimoto points out that although finer geometries will contribute two-thirds of the improvements, larger chip area will contribute one-third. Put another way, pattern size will get smaller by a factor of about 60 percent, contributing to a density improvement of 2.8 times per DRAM generation. Chip area, however, will increase 1.4 times per generation. Extrapolating on these observations, Figure 2 illustrates that between the 256K and the 1Gb DRAM, we will see a 4,000 times improvement in density, but it will be accompanied by a 20 times increase in die size.

To further aggravate matters, the experiences of major DRAM suppliers indicate that improvements in defect density are not keeping pace with increases in die size. As a result, the maximum potential die available per wafer will continue to decline per generation of megabit DRAM devices. The combined effects of larger die and slowing improvements in defect density are resulting in fewer die per wafer, further contributing to increased cost per die. In the past, end users have enjoyed ever-decreasing costs for successive DRAM generations. This was especially true between the 1K and 64K DRAM generations. Comparing die cost trends since the introduction of the 1K DRAM, Mr. Sear points out that the 64K was 70 percent of the cost of a 1K, even though it had 64 times the number of bits. The ratio with the 256K was not quite as good, being only 83 percent—and from here it continued to climb. At the 1Mb level, die cost compared with the 1K reached 140 percent because the die size grew faster than all the techniques that could be used to control it. The 1Mb DRAM, therefore, clearly marks the transition to a new die cost curve and a slowdown in the rate at which the price per bit will decline.

Figure 2

DRAM Die Size Trends: Actual and Projected Die Sizes of Each DRAM Generation



- During the transition from the 1K to the 64K, the die size has been relatively constant at 25,000 square mils.
- Since the 256K, the die size has been increasing at an ever-expanding rate.

Source: Fujitsu America

WAFER SIZE: THE CAPITAL EQUIPMENT TRUMP CARD

The trump card that manufacturers can, of course, play in stemming the tide of die cost increases is to shift to larger wafer sizes. The competitive advantages of moving to a larger wafer size is obvious from the following example offered by Mr. Sear: from a 5-inch wafer, which costs about $300, a manufacturer can yield 300 DRAM units given a 40,000-square-mil die. By moving to a 6-inch wafer, however, a manufacturer can get approximately 450 units at a wafer cost increase of only $100. Therefore, although the potential cost of a 40,000-square-mil die produced on a 5-inch wafer is about $1.00, the cost will decline to $0.89 using a 6-inch wafer.

The downside to this cost-reduction strategy is that each wafer size upgrade involves large capital investments to support. Nevertheless, switching from 6- to 8-inch wafers will be a necessity, albeit an expensive one, in improving the number of die per wafer in the 4Mb and 16Mb DRAM generations. Unfortunately, this improvement will once again begin to decline with the advent of the 64Mb device. If the industry is going to keep from being totally outdistanced by die costs, memory suppliers will have to completely switch to 8-inch wafers beyond the 4Mb DRAM generation and switch to 10-inch wafers beyond the 64Mb DRAM. Currently, there is little 8-inch capacity in the world today and no 10-inch capacity. This lacks spells a massive capital investment ahead!

OTHER IMPERATIVES

Cost per die, however, is not the only imperative driving the move to larger wafer sizes. Increased output that can be gained from using larger wafers will be necessary just to outweigh increases in the capital costs associated with them. The current industry trend in the relationship between initial fab costs and capacity (measured in millions of square inches of silicon produced) has been analogous to the situation in die cost trends. Dataquest found that the initial capital cost of a state-of-the-art fab (facility and equipment) between 1970 and 1987 rose from $30 million to $225 million. During this same period, typical fab capacity rose from 70 million square inches of silicon per month to 565 million—a rate of increase slightly exceeding the growth rate of initial fab costs. As a result, the ratio of initial fab cost to monthly square inch capacity decreased from $422 per square inch to $398 per square inch—a decrease of 6 percent. This decrease was accounted for by both a doubling of the number of wafers a fab could produce and a doubling of the wafer size. From 1970 to 1987, wafer size doubled from 3 to 6 inches, and wafer capacity also doubled from 10,000 to 20,000 wafers per month.

Since 1987, however, initial fab costs for 6-inch wafer fabs have continued to rise while capacity has remained constant, resulting in an increase in the ratio of initial fab costs to capacity to $522 per square inch. Along with the concern over cost per die, semiconductor manufacturers will have to continue to increase wafer diameters in order to slow the rise in initial fab cost per square inch of silicon capacity. For 4Mb DRAMs, SEMMS analysts estimate that initial facility and equipment cost per square inch of capacity in a 6-inch wafer fab is over $500 per square inch. Making the switch to 8-inch wafers will lower this cost to under $400 per square inch. In terms of cost per die, the Dataquest DRAM manufacturing cost model supports Mr. Sear's observations by demonstrating that semiconductor manufacturers able to maintain yields and move to larger wafer sizes will have a tremendous cost advantage over competitors that have stayed with smaller wafers.

For these reasons, Dataquest expects to see 10- or 12-inch pilot lines announced in the mid-1990s, with widespread use of 12-inch wafers occurring around the turn of the century. Because it takes six to seven years to develop a new process, companies that expect to remain competitive must today be looking beyond the 8-inch wafer. The price of this transition will be considerable. According to Dr. Makimoto, the costs of producing 1 million DRAM devices have nearly doubled with each DRAM generation since the 64K: from $18 million with the 64K, to $35 million with the 256K, $70 million for the 1Mb, $120 million for the 4Mb, and an estimated $210 million for the 16Mb!

REDEFINING ELASTICITY. . .RETHINKING GROWTH

In his speech at the 1987 Semiconductor Industry Conference, Dr. Gordon E. Moore acknowledged that "greater density at lower relative cost could not alone spur technological development over the long run because declining device prices would threaten the industry's profitability. Technological progress has also required expanding markets." From Dr. Moore's point of view, only through doubling the amount of electronics in the world each year could the semiconductor industry afford to offer smaller dimensions and higher functionality at lower relative prices. "Essentially," Dr. Moore stated, "economies of scale have allowed us to continue advancing the technology."

As a benefactor of the global electronics business, the characteristic pervasiveness of the semiconductor industry (marked by growth rates that exceed those of the markets it serves) can be attributed to the fact that the industry not only creates markets through invention but expands them through its ability to offer greater performance at lower cost. Based on Dataquest's observations, a 35 percent decrease in price per DRAM bit results in a doubling of unit volume. Clearly, with the introduction of the 1Mb DRAM, the fundamental economics of silicon-based memories have changed. A price reduction/learning curve of 80 to 85 percent might be more likely than the 70 percent seen in the past.

But does it necessarily follow that a fundamental change in DRAM price/performance curve will result in a less elastic market and therefore slower growth? This question depends partly on how one defines growth. Using the bit price model worked out in Dataquest's consulting group, going from a 35 percent decrease in price to a 15 percent decrease would, theoretically, result in a roughly 40 percent increase in unit volume—a far cry from the doubling of unit volume associated with a 35 percent decrease. By charging 85 percent of original cost instead of 65 percent, however, the dollar value of the DRAM market will still grow at a 20 percent rate versus the 30 percent associated with more aggressive price erosion.

THE MEMORY MARKET: BIGGER AND MORE DIVERSIFIED

Whatever actual change takes place in memory price per bit trends during the next decade, the consensus among major suppliers is clearly that it cannot be business as usual. It is, however, highly unlikely that this new world order of high-density memory will slow memory at the systems level. Although we forecast the worldwide electronic equipment market to grow at a compound annual growth rate of 8 percent during the next five years—a far cry from historic levels—this modest growth rate will result in a worldwide market of $1 trillion in 1995! And this market will continue to be hungry for memory. Dr. Makimoto believes that by the year 2000, worldwide per capita consumption of memory will rise from 160 kilobits (Kb) to 8Mb (based on a population of 6 billion)—about 50 times today's level.

It is likely that we are seeing the tip of the iceberg of memory demand. Regarding the PC, we can certainly identify continued growth in memory requirements being fueled by such advances as high-resolution graphics, digital video technology, and CD-quality sound. More importantly, these performance improvements are driving the evolution of the PC from a terse computer syntax to a user-friendly interface involving increasingly complex software. Quoting Mr. Sear: ". . .software designers—for the last five, possibly eight, years—never thought about the amount of memory the software was going to use. In fact, I believe that they treated memory as though it were infinite in size and zero in cost."

Perhaps as important as the growth in sheer demand for semiconductor memory will be the diversification of that demand and the opportunity it will create for manufacturers to address more value-added applications. The era of gigabit memory will coincide with the era of the 1 giga instruction per second (GIPS) processor. Hitachi's opinion is that this GIPS processor should allow for applications such as real-time language translation machines. Application-specific memory requirements will include PSRAMs (as an SRAM alternate), VRAMs (for graphics), field memory (for TV and graphics), and frame memory (for high-resolution video). All of these types of products, with their various speed grades, organizations, and packaging options, should lengthen the life cycle of each generation of DRAM. In addition, memory density and cost per bit should create a solid-state disk market by the late 1990s.

The extent to which today's DRAM suppliers may be rearranging their product mix and marketing strategies was reflected in a recent presentation to Dataquest analysts by NEC. Based on a figure illustrating the future product mix in the year 2000, NEC showed only one-third of its MOS memory revenue coming from commodity DRAMs—the rest would come from application-specific DRAM products. Hitachi talks of the future "Magic" chip—the combination of high-density DRAM memory and logic on the same piece of silicon.

DATAQUEST CONCLUSIONS: REAL (RICH) MEN HAVE FABS

However the DRAM market changes during the next 10 years, one aspect that will remain constant is the primary qualification for participation: lots of cash. What *will* change, however, is the legendary volatility of the commodity memory business—and therefore the profitability of participating in it. The reasons for this change are probably apparent from the issues discussed in this newsletter and are listed as follows:

- As cash outweighs creativity in the DRAM business, the industry will consolidate further.
- The slowing of price-per-bit erosion will help preserve average selling prices.
- The politics of DRAM trade will make it less likely that the industry will be buffeted by cartel-like behavior or the purchasing of market share through dumping.
- Even as the commodity end of the business continues to be competitive, more diversified memory products will help bolster overall margins for suppliers.
- The integration of logic and memory in DRAMs and the possible lengthening of generation life cycles will extend the useful life of a memory fab and lower the costs of its depreciation.

Another advantage that will accrue to remaining in the DRAM business is the strength it will lend to a company's submicron manufacturing capability—and whether a company produces gate arrays, microprocessors, or DRAMs, it will be doing so at the submicron level if it plans to be at the leading edge.

Michael J. Boss
Len Hills

Dataquest
a company of The Dun & Bradstreet Corporation

Dataquest Perspective

Semiconductors *Worldwide*

Products, Markets, and Technologies

Vol. 1, No. 1 **August 19, 1991**

Market Analysis

Executive Summary: Programmable Logic Devices

1990 Market Overview

Although representing the smallest portion of the ASIC market, the PLD market is receiving much attention because of the growth opportunities it represents. The dynamics of this market are such that the traditional bipolar PLD market continues to decline, whereas CMOS PLDs continue to make inroads. In 1990, the CMOS portion of the PLD market grew so rapidly that it had almost caught up with the bipolar market segment. CMOS PLD revenue amounted to $405 million in 1990, compared with bipolar's $423 million. This year—1991—represents the crossover point when CMOS revenue will overtake bipolar. This trend is reflected in Figure 1, which shows the split between CMOS PLD revenue and bipolar PLD revenue during the past five years.

Supplier Profile

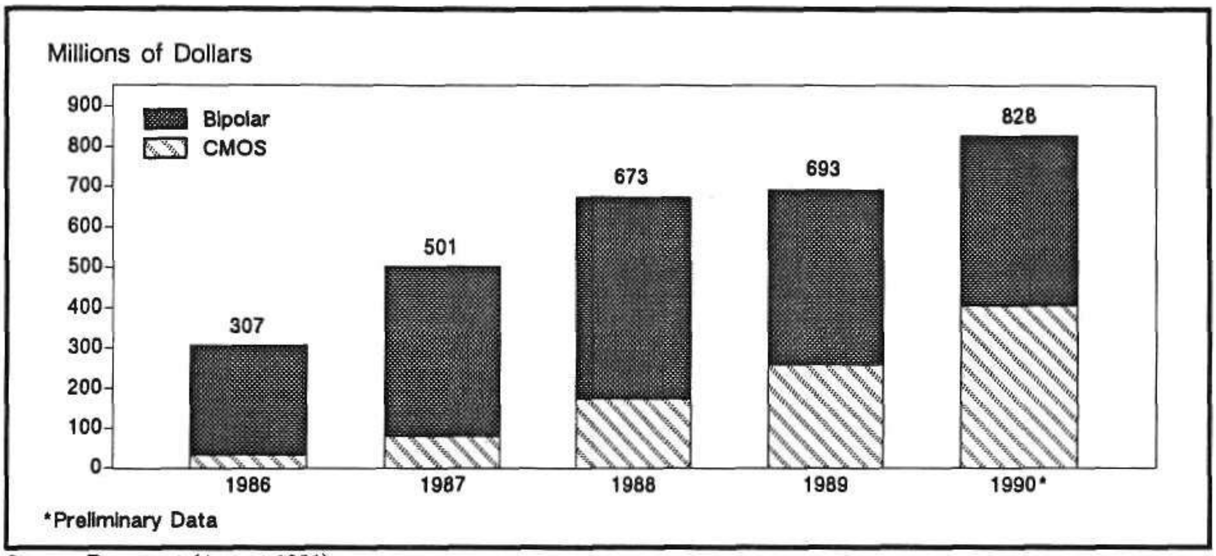
By virtue of their very large bipolar PLD portfolios, Advanced Micro Devices (AMD) and Texas Instruments (TI) retained their number one and two positions in the worldwide PLD market in 1990, with revenue of $291 million and $120 million, respectively. However, the most impressive growth came from the smaller companies, the majority of which participate only in the CMOS segment of the PLD market. The CMOS market comprises both simple PLDs (SPLDs) and complex PLDs (CPLDs), with the highest growth coming from the latter segment. Xilinx was the number one supplier to the CMOS PLD market in 1990 (as shown in Table 1) with its field-programmable gate array (FPGA) offerings. Altera and Lattice, which ranked second and third in the CMOS market, are prominent suppliers of simple CMOS PLDs and also offer (or will be offering) complex PLD products.

North American Application Overview

In 1990, North America accounted for 59 percent of worldwide consumption of PLDs. In the U.S. PLD market of nearly half a billion dollars, consumption was almost equally divided between CMOS and bipolar devices. Table 2 shows how that consumption was distributed over the major application markets, in terms of both process technology and device complexity.

Analysis to date has focused on the revenue side of the market, which pegs the revenue

Figure 1
Estimated Worldwide PLD Revenue (1986-1990)



Source: Dataquest (August 1991)

Table 1
Estimated Market Share Ranking
(Factory Revenue in Millions of U.S. Dollars)

1990 Rank	1989 Rank		1989 Revenue	1990 Revenue	Percent Change	1990 Market Share (%)
1	2	Xilinx	44.0	84.0	91	20.7
2	1	Altera	59.0	78.0	32	19.3
3	4	Lattice	31.0	62.0	100	15.3
4	3	Cypress Semiconductor	36.0	42.0	17	10.4
4	5	Advanced Micro Devices	27.0	42.0	56	10.4
6	6	Intel	23.0	30.0	30	7.4
7	8	Actel	7.0	21.0	200	5.2
8	7	National Semiconductor	8.0	7.0	-13	1.7
8	9	Atmel	5.0	7.0	40	1.7
10	13	International CMOS Technology	3.0	6.0	100	1.5
11	12	SGS-Thomson	3.0	5.0	67	1.2
11	NM	Gould AMI	0	5.0	NM	1.2
13	10	Seiko Epson	4.0	4.0	0	1.0
14	15	Texas Instruments	1.0	3.0	200	0.7
14	NM	GEC Plessey	0	3.0	NM	0.7
16	14	Philips	2.0	2.0	0	0.5
17	NM	Ricoh	0	1.0	NM	0.2
17	NM	Toshiba	0	1.0	NM	0.2
17	NM	AT&T	0	1.0	NM	.2
20	NM	Plus Logic	0	0.5	NM	0.1
20	NM	Rohm	0	0.5	NM	0.1
NM	11	Samsung	4.0	0	-100	0
NM	16	Exel	1.0	0	-100	0
		All Others	0	0	NM	0
		North American Companies	245.0	388.5	59	95.9
		Japanese Companies	4.0	6.5	63	1.6
		European Companies	5.0	10.0	100	2.5
		Asia/Pacific Companies	4.0	0	-100	0
		Total Market	258.0	405.0	57	100.0

NM = Not meaningful
Source: Dataquest (August 1991)

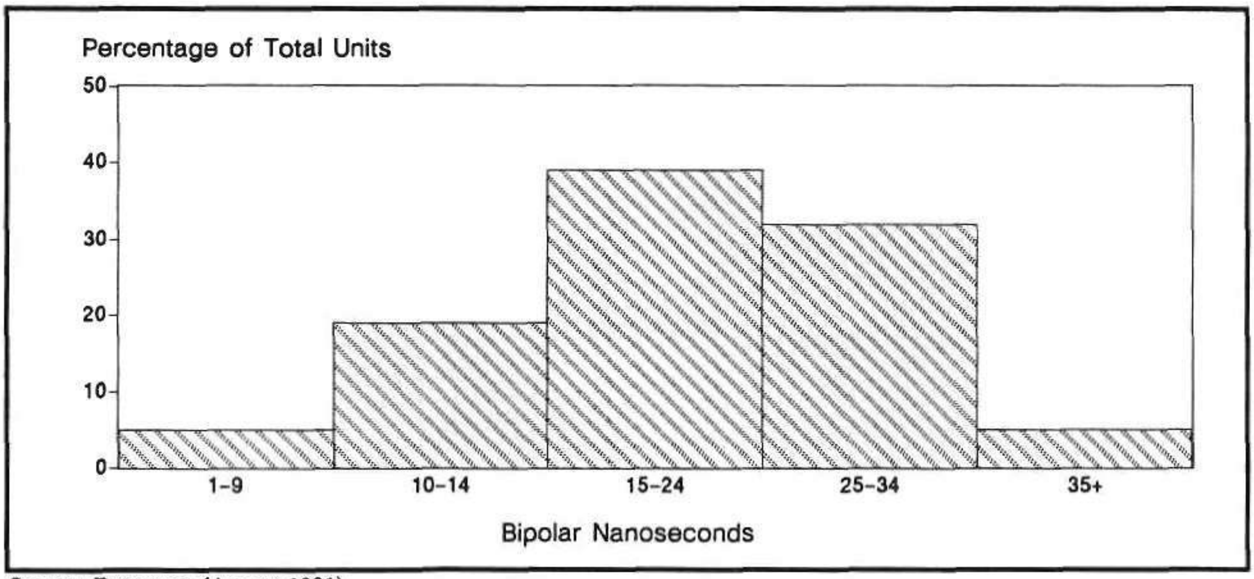
Table 2
North American 1990 PLD Consumption by Application (Percent of Dollars)

	Bipolar	CMOS	SPLD	CPLD
Data Processing	61.3	44.1	56.0	40.7
Communications	24.7	28.8	27.2	24.6
Industrial	6.2	13.5	7.6	18.6
Military	6.2	11.3	7.6	12.9
Transportation	0.8	1.1	0.7	1.6
Consumer	0.8	1.2	0.8	1.6
Total	100.0	100.0	100.0	100.0

Source: Dataquest (August 1991)

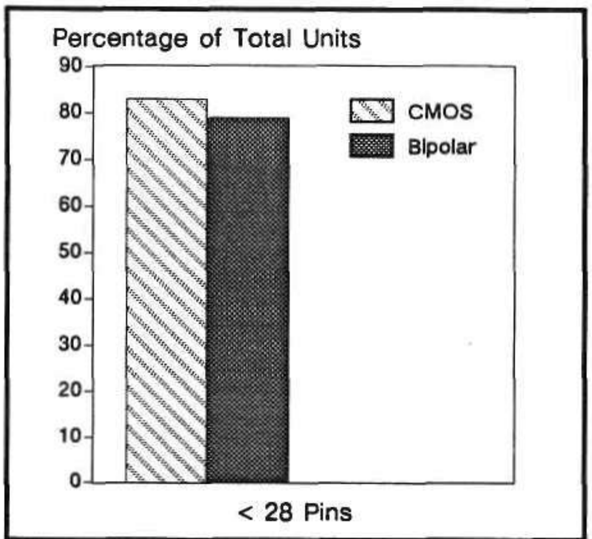
share of bipolar and CMOS shipments almost at parity. However, thanks to a recent Dataquest survey, for the first time we are able to quantify the PLD market in terms of units. The situation with respect to unit PLD consumption is considerably different from the revenue scenario. Unit shipments are overwhelmingly dominated by bipolar ICs, which ship at quadruple the rate of their CMOS counterparts. The figures selected for illustration here depict the distribution of bipolar unit shipments by speed grade (see Figure 2) and the categories in which unit concentration of bipolar and CMOS shipments occur with respect to pin count (see Figure 3).

Figure 2
Estimated 1990 Bipolar Unit Shipments by Speed Grade



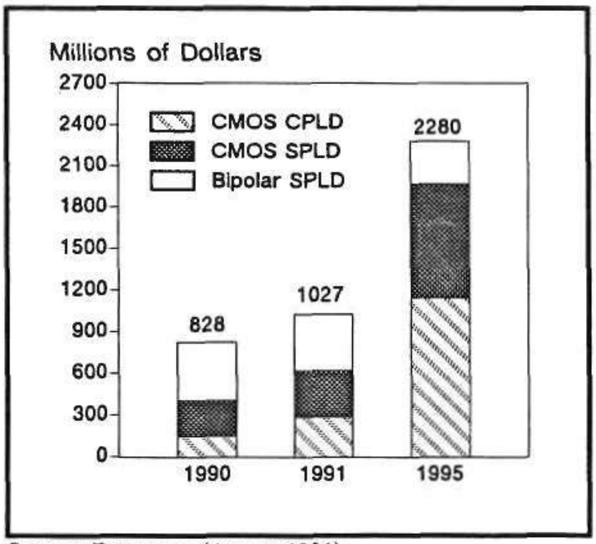
Source: Dataquest (August 1991)

Figure 3
Estimated 1990 Concentration of Bipolar and CMOS PLD Shipments by Pin Count



Source: Dataquest (August 1991)

Figure 4
Worldwide PLD Consumption Forecast (Millions of Dollars)



Source: Dataquest (August 1991)

Dataquest Perspective

Dataquest's outlook for the PLD market remains fairly bullish on the CMOS side while we continue to see the bipolar market decline. Figure 4 illustrates Dataquest's worldwide PLD consumption forecast.

The growth in the CMOS portion of the PLD market is being driven by complex PLDs. This situation presents an opportunity for a host of small companies to offer replacement CMOS parts as well as to enter the market with new and innovative PLD architectures. Complex PLDs represent an emerging market segment with many new suppliers even now entering the fray. In the never-ending challenge to meet time-to-market constraints, PLDs are providing an ideal vehicle and thus are eating away at the low end of the gate array market. As complex PLDs such as programmable multilevel devices and FPGAs increase in density, Dataquest expects them to capture a greater share of the gate array market, especially as they charge down the price learning curve. ■

By Patricia Galligan

Product Analysis

Competitive Analysis of the CPLD Market

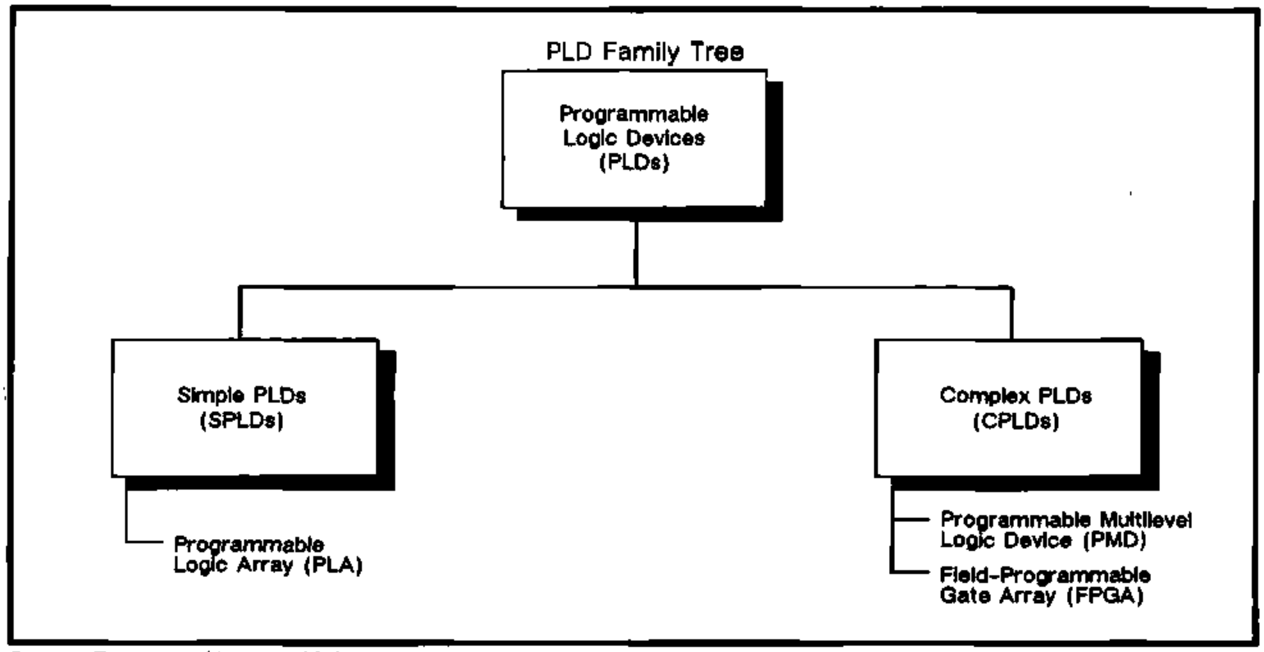
Introduction

Definitions and Distinctions

The preceding executive summary of the PLD market serves as a starting point for the following discussion of the competitive forces at work in this market. High growth experienced in the PLD market is driven by the more complex architectures that we refer to as field-programmable gate arrays (FPGAs) and programmable multilevel devices (PMDs). In order to better understand the analysis section, it is important for the reader to know how Dataquest segments this market, as shown in Figure 1.

Dataquest makes a distinction between FPGAs and PMDs because although these two product categories can target the same applications, their

Figure 1
PLD Family Tree



Source: Dataquest (August 1991)

particular product characteristics (such as predictable timing in the case of PMDs and very flexible logic integration in FPGAs) make each uniquely suited to specific applications. Therefore, both devices may populate a single board, each being used to implement a function for which it is optimally suited.

Key Competitive Forces

In order to assess the prevailing market environment, it is useful to organize the analysis within some kind of context. Therefore, the following basic premises are presented to focus the discussion:

- Supply of the basic raw materials to the industry—A reliable source of silicon is, of course, a prerequisite. Ensuring access to silicon differs depending on whether or not a semiconductor company has a fab. (See further discussion in the section on alliances.)
- Barriers to entering the PLD market—Patents. New entrants must either acquire licensing rights or come up with an original design themselves. (This issue is dealt with in the sections on barriers to entry and the chip set paradigm.)
- Buyers of PLDs—Buyers want to quickly implement some logic functions and are driven by the need to get to market as quickly as possible with a differentiated product. (Please refer to the section "PLDs: Their Place in the Food Chain.")
- Substitutes to be used in place of a PLD—Although there are suitable alternatives such as other ASIC devices or standard logic products, there are no other direct semiconductor substitute devices with exactly the same attributes. Therefore, choosing among possible alternatives requires doing some trade-off analysis. Ever-decreasing product life cycles are driving the trend toward growing CPLD consumption. (See "PLDs: Their Place in the Food Chain.")
- Competition—Whereas the gate array market is dominated by large 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 market is distinguished from other fast-growing IC markets in that, for the most part, it contains small, focused companies with innovative ideas that to date have established the credentials of this market opportunity. (See the section entitled "Balancing Hardware and Software Assets.")

These are the fundamental premises on which our analysis will focus.

Alliances: A Key Supply and Competitive Strategy

Because the CPLD market is in the early phase of development, it is important for small companies with limited resources to get out as far ahead as possible. In order to achieve market share gains early on, most of these companies have successfully employed strategic alliances as cornerstones of their current business plans. As can be seen from Table 1, access to silicon is a major motivating factor for these agreements.

The market is at a critical stage in terms of suppliers positioning themselves for the long term.

Taking a look at the long list of companies vying for market share, it is clear that the market is still in the emerging stage—but the likelihood is that at some stage there will be fallout. Although the market can support several architectures, users cannot invest either the time or financial resources to continually purchase and learn the programming software necessary to keep current with multiple architectures. Therefore, the market is at a critical stage in terms of suppliers positioning themselves for the long term.

Various competitors have taken different approaches to the market. Several companies decided that they have a certain time frame in which to gain the advantage. We believe that they conclude rightly that, as early entrants to the market, the key advantage in their favor is the ability to drive their products into the hands of as many users as possible, thereby saturating customers' capacities to purchase and assimilate competing products. In order to expand their market presence, they are, as small companies, willing to sign up second sources—typically large semiconductor houses—to help drive the momentum of their products. Good examples of this strategy are Xilinx and Actel, the leading FPGA suppliers. These two companies each clearly believed that the risks posed by going it alone versus taking on a partner weighed their strategy more heavily in favor of a partner. Their respective choices represent large companies with financial strength and very credible semiconductor manufacturing capability. The trick from the small company's

Table 1
PLD Licensing Activity

Originator	SPLD	CPLD	Licensee	Agreement Type
Actel		X	TI	Foundry, second source
			HP	Technology license
			Matsushita	Foundry, marketing (Japan)
Advanced Micro Devices	X		National, TI	Second source
	X		Altera, Lattice	Technology license
		X	NM	Sole source
Altera	X		Cypress, Intel, TI	Foundry, second source
	X		Sharp	Foundry
		X	Cypress	Foundry, second source
Atmel		X	Philips/Signetics	Second source
Concurrent Logic		X	TBA	Foundry, second source
Crosspoint		X	Performance	Foundry
International CMOS Technology	X	X	Gould	Foundry, second source
Lattice Semiconductor	X		AMD, National, SGS-Thomson	Second source
	X		Seiko Epson	Foundry
		X	NM	Sole source
National Semiconductor	X		NM	Sole source
Philips Components	X		NM	Sole source
		X	Atmel	Second source
Pilkington Microelectronics		X	Toshiba	Second source
Plessey		X	NM	Sole source
Plus Logic		X	Ricoh	Foundry
		X	Microchip	Foundry, second source
Quicklogic		X	VLSI Tech.	Foundry
Xilinx		X	AT&T	Foundry, second source
		X	Seiko Epson	Foundry

TBA = To be announced
NM = Not meaningful
Source: Dataquest (August 1991)

viewpoint is to ally itself with a powerful partner that will not use its power against the smaller partner but will instead help to grow the market and set the de facto standard. With a cooperative partner willing to contribute, the smaller companies are unencumbered by expensive fabs that must be equipped and maintained; they are free to channel their limited resources into R&D and product development, where their real added value lies and where they are more likely to reap the payoff. In a fast-growing market, it would seem that such an alliance strategy would create a win-win scenario.

Complex PLDs: A Complex Sell

Alternatively, some companies believe that their products will sell themselves on the basis of merit and are proposing to propel their market acceptance on their own. This is a high risk approach. Although it is possible for a company to successfully embark on such a strategy if its product offers significantly higher value, value alone may not be sufficient to assure the company's viability or a potential customer's perception of viability. This reasoning goes back to the product fundamentals. The CPLD architecture is a significant feature in the sale of a product, necessitating a more sophisticated selling approach that takes more time and is more expensive. In addition, the product implements the integration of general-purpose logic, which translates into a large potential market but one that may not be readily identifiable. Product integration and matching applications to a specific product architecture impose on a PLD supplier the requirement of an effective applications engineering staff, which is a benefit many companies believe that they get when they ally themselves with a major partner. The partner helps provide an infrastructure of feet-on-the-street and applications expertise that a small company cannot easily finance or wait to develop.

Barriers to Entry: Patents

The basic patents for the most common type of SPLDs belong to Advanced Micro Devices (AMD). These patents, which AMD acquired when it merged with Monolithic Memories Inc. (MMI), have served as a fairly robust barrier to a massive onslaught of competition in the SPLD arena. Several companies have licenses to use these fundamental designs. The comparatively recent influx of many new participants in the CPLD market stems from innovative new architectures that, likewise, are patented. It is essential for any small company bringing an innovative new design to market to have its patent portfolio securely protected.

The "Chip Set" Paradigm

The complex PLD market is often compared to the chip set market, which experienced phenomenal growth for a few years. This market attracted many newcomers that became casualties in more recent years as a shakeout of suppliers occurred. However, there are some major distinctions between the two product areas. One key difference between CPLDs and chip sets is the CPLD patent protection that precludes an onslaught of competitors just jumping into the market. An ingenious idea launched Chips & Technologies (C&T) into a minor miracle—designing a chip set that provided all the glue logic necessary to support the standard of the IBM PC and compatibles, a volume market. Although at first this strategy was eminently successful, it was clearly a strategy that could not provide C&T with a sustainable competitive advantage over the long term because any company could (and did!) enter the chip set market, designing a product to be compatible with a standard. C&T's chip set was not the standard; it just implemented the standard. The reason start-ups in the CPLD arena tend to be compared to their cohorts in the chip set market, we believe, has more to do with the coincidence that many of these companies are making their way in the semiconductor world without fabs!

PLDs: Their Place in the Food Chain

The basic elements of an OEM's system (see Figure 2)—the memory, analog, and CPU elements—are typically off-the-shelf standard parts. The OEM most often resorts to the logic portion of the system to implement product differentiation.

This is the point at which CPLDs charge onto the scene. Significant advances in density and complexity, in concert with a user-programmable standard product, have fueled the spectacular growth of CPLDs. This combination of features diminishes the user's exposure to risk because the product is a standard part (therefore, no nonrecurring engineering costs) while simultaneously permitting the user to get to market faster with a differentiated product. Because CPLDs offer greater density and more complexity than do their SPLD precursors, they are used as replacements for multiple TTL and PAL devices as well as low-density/low-volume gate array designs. These attributes are driving the tremendous appeal of CPLD devices on both the supply and demand sides of the equation. From the supplier's perspective, where we primarily focus our attention in this analysis, the question is how these advantages can be cultivated to achieve long-term staying power for many of the market participants.

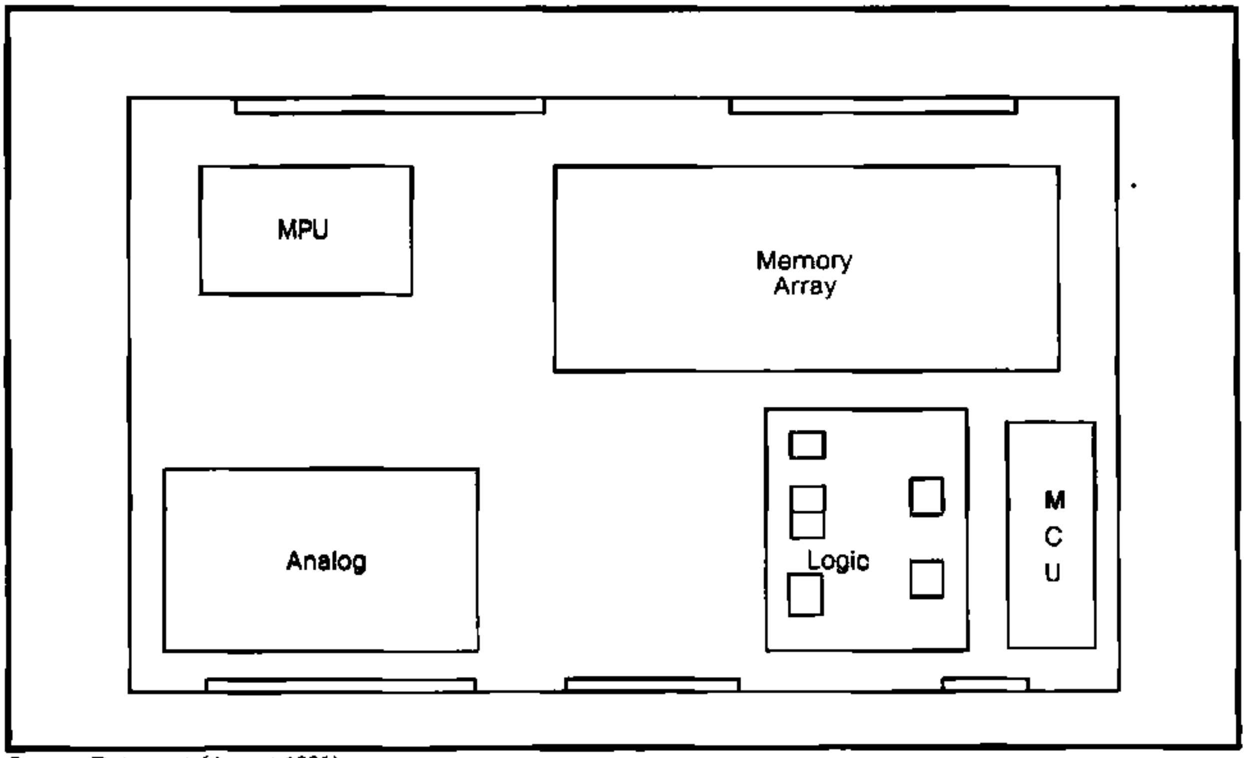
Balancing Hardware and Software Assets

An understanding of some of the product fundamentals as well as the experiences of other products in the semiconductor marketplace is helpful in determining the position of CPLDs in the product continuum and in developing an effective PLD product strategy.

A PLD is manufactured like a standard product, i.e., a commodity product. However, it is unlike other commodity products in that it requires a little more sophisticated sell to the user, something that makes it somewhat resemble the architectural sell of a microprocessor. A significant portion of the added value of a CPLD is derived from its architecture and the EDA tools used to implement a design. This is increasingly true of the most recent complex PLDs.

Currently, the vogue among industry pundits appears to be to denigrate hardware in favor of software, thereby concluding that the path to success means unshackling one's business from the drag affect of hardware. This is a pretty sweeping statement, and it bears some elucidation. What is implicit in this viewpoint is that, although the United States operates at a disadvantage when it comes to labor and capital costs as compared with many of its primary

Figure 2
Diagram of Major System Blocks



Source: Dataquest (August 1991)

competitors from the Far East, the United States still possesses advantages when it comes to software and other technological expertise. When hardware is an open standard, the ability of U.S. companies to compete on cost is adversely impacted. Our contention is that an initial proliferation of hardware supply is necessary to establish the product as a de facto standard. Once that momentum is in effect, protecting one's margins on the supply of the hardware becomes a function of the extent of competition, and the software requirements then assume a greater competitive role in maintaining leadership. The balance between these respective forces is subject to change over time. We believe, therefore, that at this early stage in the product life cycle of a CPLD, the architecture (hardware) and the development tools (software) are both extremely important to the CPLD supplier's market progress. Let's examine this contention a little more closely.

An example to illustrate the importance of hardware is Intel's story of market domination of the IBM PC (and compatibles) world. Its current position (i.e., having a sole-sourced product that serves as the standard other companies build their equipment around) is almost the ideal situation, but it did not start that way. Intel achieved this lucrative status by starting out with a very broad product strategy. In the early days, the company's strategy was to establish its architecture as a standard, and, fortunately for Intel, IBM was instrumental in this. The proliferation of the Intel architecture through licensing of the X86 family to other semiconductor manufacturers created a climate in which the IBM PC-compatible clone makers could access a competitive supply of product, further driving the standard. With the hardware suppliers and the users hooked on a standard, Intel was assured of its architecture's dominance. Having done so, Intel altered its licensing policy to become very exclusive while remaining ahead of the technology curve.

There are limits, however, to how far the Intel analogy can be applied to the CPLD case. Although this example pretty well describes how the Intel microprocessor architecture achieved its unique predominance, such an outcome is less likely for a CPLD architecture. No single PLD architecture is likely to command a critical position in the design of a system to the extent that a CPU does. In the hierarchy of critical components, the PLD will not form the basis on which a whole system design will be conceived. The *raison d'être* of the PLD is to implement random logic; so although an innovative PLD product architecture may provide great value to the system designer, if unavailable, an alternative PLD could be found to replace it.

Another limitation to the Intel analogy has to do with the factors that favor the proliferation of the IBM-PC-compatible standard: the enormous investment made in software by the end users. Although delivered to the OEM in the form of hardware, the Intel architecture provides the ability to preserve the enormous software investments made by an extensive community of end users.

The CPLD market is in the early stage of its evolution, with room for a variety of innovative solutions.

Currently, there are many different CPLD architectures, and new ones are still being announced. Each architecture has different strengths and weaknesses. Once design engineers are introduced to an architecture, unless there are very motivating factors to change, the engineers are most likely to continue working with that architecture because switching to another one incurs the expense of new development tools, more training, and another learning curve. As the user community expands and the investment in software tools is made—in the case of PLDs, development tools—the momentum behind a particular architecture tends to propel it toward a de facto standard. While a CPLD user's investment can be preserved by remaining with a specific CPLD architecture, the scale of this user community (i.e., the system designer) is dwarfed by the PC consumer community. With regard to the scale of user communities in question, it may be more appropriate to compare CPLDs with another product such as microcontrollers (MCUs). In the case of MCUs, there are several different standards coexisting in the market today. Competition tends to center more on performance and cost. However, with respect to prices, MCUs are likely always to be more cost driven than CPLDs because of their high-volume consumption in consumer applications.

Dataquest Perspective

The CPLD market is in the early stage of its evolution, with room for a variety of innovative solutions. What happens when certain products start to emerge as de facto standards and there is consolidation of the players? The demands of the PLD market are such that any successful company must do the following:

- Establish a sturdy foothold in the user community to ensure the company's basic survival
- Continue to increase market penetration in an attempt to create a de facto standard
- Preserve the advantage by helping users find solutions to their problems, thereby establishing both credibility and loyalty
- Have a consistent source of cost-effective silicon
- Continue to add to the product's value and stay ahead of the technology curve

To achieve long-term prosperity, Dataquest believes that PLD suppliers must focus on two major objectives: identification of high-growth end-market applications and identification of specific applications (e.g., state machines, counters, combinatorial logic) where the architecture is uniquely suited. Moreover, it would also behoove the CPLD supplier to look beyond what customers are demanding today and anticipate what they will need tomorrow. In order to offer more application-specific versions of these devices as well as to anticipate future needs, we believe that product planners should refer to a kindred product, i.e., gate arrays (also used to implement random logic), as the most relevant model of comparison. Dataquest's extensive research of the gate array market shows that as gate array densities increase, certain functions tend to be hardwired into the silicon for lower cost and higher performance. Likewise, we believe that as CPLDs move up the density curve, suppliers will modify their pure random logic replacement approach with one that is more targeted at specific application requirements. This leads us to conclude that it is to the CPLD company's advantage to establish its preeminance among competing products by using a strategy that combines added value in terms of architecture (sustainable advantage) and applications with the benefits of a standard product cost-reduction strategy. ■

By Patricia Galligan

Company Analysis

National's New Leader Shares His Vision

The Challenge

At a financial analyst meeting in late July, Gil Amelio, new president and CEO of National Semiconductor Corporation, displayed his inclination for straight talking. He did not equivocate over National's well-known financial woes; instead, he admitted that the numbers spoke for themselves but not reassuringly. He presented a five-year financial history that produced a cumulative loss in excess of $400 million (based on profit/loss before taxes). Dr. Amelio deems this (no doubt the company's creditors concur) to be unacceptable performance and announced his plans to effect a turnaround from this situation.

To explain National's current predicament, Dr. Amelio chose as a starting point his identification of the macro industry trends at work in the semiconductor industry. He sees these trends as essentially twofold: the transition of components into subsystems and the capital intensity of the semiconductor business. One consequence for National is that the company is not just selling silicon, with hundreds of thousands, even millions, of transistors on a chip; the company is selling subsystems. This means closer ties to the customer with much greater opportunities for adding value through software and applications expertise. At the same time, the enormous capital costs associated with running fabs also impose a heavy financial burden on the company.

Early in his presentation, Dr. Amelio asserted that the purpose of sales is to generate gross profits and the purpose of investment is to generate future sales. The basic challenge facing National is the need to optimize the return on equity (ROE), which includes gross profit margins, return on investment, and asset management.

When in Doubt, Reorganize

As one of Dr. Amelio's first actions, the company has already been reorganized to achieve greater market focus. According to the new structure, there are two major business groups: the Communications and Computing Group (C&C) and the Standard Products Group. The organization chart illustrated by Figure 1 depicts products covered in the respective groups. The Fairchild Research Center, listed under Quality and Strategic Operations, will concentrate on research and will develop core technologies to be dispersed into the appropriate business groups. The impetus for separating the business groups in this manner stems from their respective business characteristics, as follows:

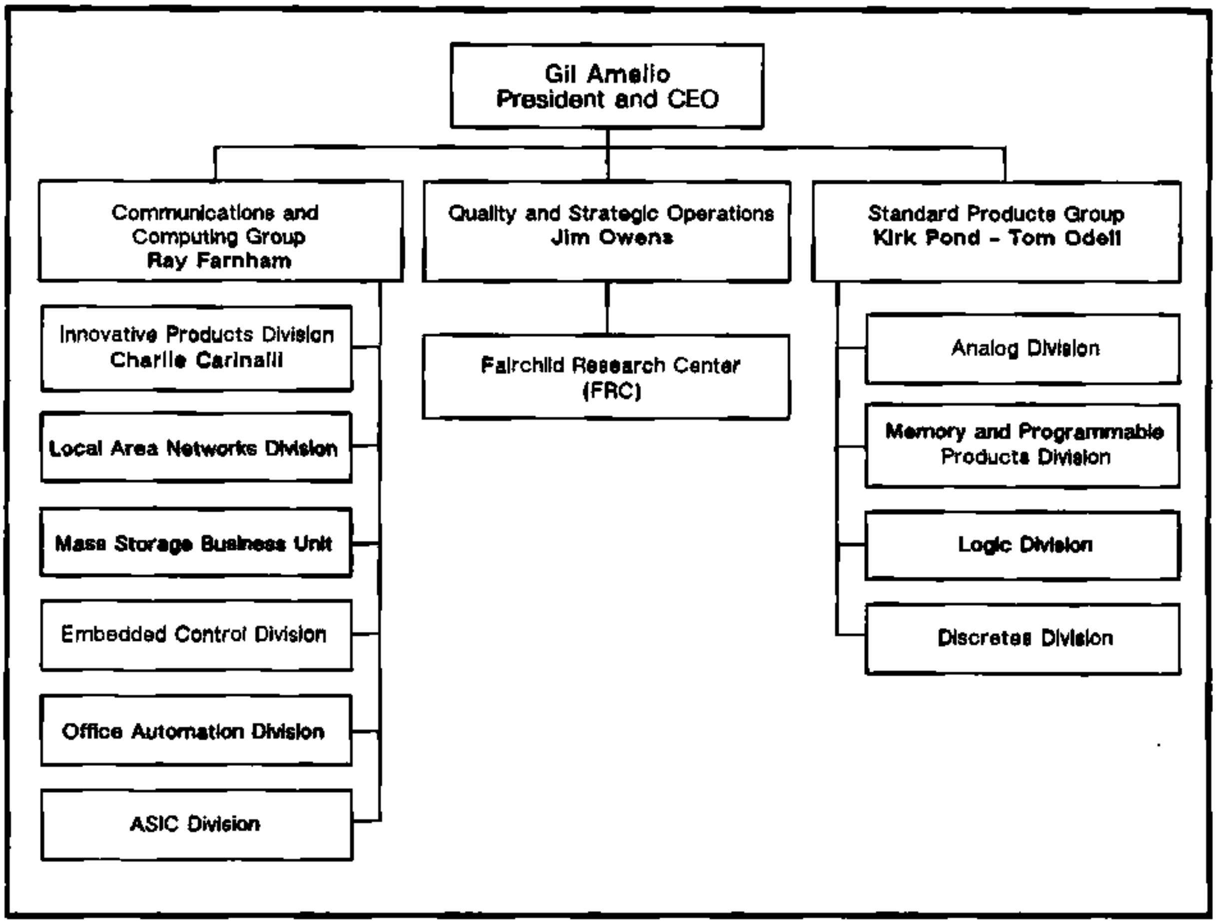
- C&C
  - Higher gross margins
  - Higher R&D outlay
  - Lower asset turns
  - Higher profits required
- Standard Products
  - Lower gross margins
  - Low R&D outlay
  - Higher asset turns
  - More mature assets

The new structure will permit management to measure the performance of the respective areas using the most appropriate measures in each case as well as to balance the company's short-term needs with longer-term direction. According to Dr. Amelio's assessment, the Standard Products Group is targeting the horizontal market; that is to say, it produces standard commodity products suitable for a wide range of applications. Such products offer little by way of added value, are essentially differentiated on the basis of price, and are an easy sell. In contrast, the C&C Group targets vertical markets that require application-specific products. Because of the significant systems and applications expertise needed to do this, these products represent high added value and high margins but also a more difficult sell.

Value-Added Products

In National's quest to become a leading supplier of communications components, the experience that Dr. Amelio brings from his tenure at Rockwell will be a great asset. Prior to joining National, Dr. Amelio served as president of Rockwell Communication Systems since May 1988. He joined Rockwell in 1983 as president of Rockwell's Semiconductor Products Division, a division that had been losing money. However, Dr. Amelio soon turned the division into a break-even entity. In keeping with Dr. Amelio's characterization of the 1990s as the decade of personal communications, it is not surprising to

Figure 1
National Semiconductor Corporation Organization Chart



Source: Dataquest (August 1991)

learn that National's future product focus will primarily be on communications products.

Within the C&C Group, the Innovative Products Division will be focusing on the following:

- Wireless communications
- Advanced communications
- Telecommunications
- Personal computer components

Value-added products from the C&C Group including the following:

- ST-NIC (TM) 10 Base-T Ethernet chip
- RIC 10 Base-T ethernet repeater interface
- Floppy disk controller

Value-added products from the Standard Products Group were identified as follows:

- Simple Switcher
- Customer-defined adaptive braking systems
- FACT "Quiet Series" Logic

Dr. Amelio believes that National's strength in high-performance bipolar and analog will stand it in good stead in wireless communications while advanced communications will draw on the company's mixed analog/digital capabilities. National also has invested in BiCMOS, a process technology that has found applicability particularly in the communications arena.

Dataquest Perspective

Clearly, Dr. Amelio is not a person to shrink from a challenge, and, no doubt, he did not join National to preside over its gradual decline. He seems to have moved quickly to identify problems and solutions, and within a relatively short time frame (five months) to do a credible job of formulating his strategy for the company to present to the world.

Dr. Amelio believes that the company has enough breathing space to allow him to turn it around by implementing lasting changes, not quick fixes.

Some of the company's investments may take a few years to pay off; in the meantime, Dr. Amelio's agenda is to ensure the company's survival. Dataquest believes that he will endeavor to avoid the "mega mistakes" of the past that squandered National's resources to no avail. Reading just a little into his comments that the changes will be ongoing, we might conclude that even more changes may be in store in the future; or there are probably some tough decisions yet to be made. Dr. Amelio believes that the company has enough breathing space to allow him to turn it around by implementing lasting changes, not quick fixes. He referred to National's hidden strengths; he will need to tap those hidden reserves. He also believes that the company can still capitalize on the goodwill of its customers.

In order to explain his vision, Dr. Amelio used the example of the dieter who can lose weight with a crash diet—but may not be as healthy a person afterward and may not be able to sustain the weight loss. His preferred solution would be to change the dieter's lifestyle to habits sustainable for a long-term healthy life. As always, to carry the simile a little further, the proof of the pudding is in the eating. It therefore remains to be seen how successful Dr. Amelio will be in pulling off this turnaround. However, we believe that it is probably in National's best interest that someone—particularly someone with Dr. Amelio's track record—has accepted the challenge that National represents and brings to it both a fresh approach and relevant experience. It is a combination that inspires some confidence. ■

By Patricia Galligan

Quarterly Financial Summary for Selected Semiconductor Companies

Table 1 summarizes the net sales and income disclosures of selected semiconductor companies based on data from quarterly report periods that ended during the May through July time frame. Figure 1 graphically presents the percent change for aggregate company revenue and net income.

Dataquest Perspective

Key points worth noting about the data include:

- Although aggregate revenue growth was modest, net incomes reflect a bleak state of financial affairs.
- In terms of net income, the absolute count of declines versus gains showed that out of the 28 companies covered in the table, 12 experienced declines in net income compared with 16 companies whose net income increased when compared with the year-ago quarterly data.
- Only half as many companies (i.e., 6) experienced a revenue decline as experienced an income decline for the same period.
- Of the top five performers based on a comparison to year-ago net income data, four of those companies appeared among the top five revenue gainers.

When analyzing these data in order to draw conclusions about the state of the U.S. semiconductor industry, caution must be exercised because the two largest companies from a revenue perspective (i.e., Motorola and Texas Instruments) are not pure-play semiconductor companies. Taking both of these companies out of the equation would have resulted in very different results. Revenue for the second quarter would have been reduced by more than half; nevertheless, net income would have increased. The corresponding statistics for revenue and net income calculations compared with the year-ago quarter would reflect increases of 17 and 53 percent, respectively. Although economists at large are heralding the wane of the economic recession, the data presented here are mixed and tend to support a rather less optimistic outlook among the ranks of U.S. semiconductor companies. ■

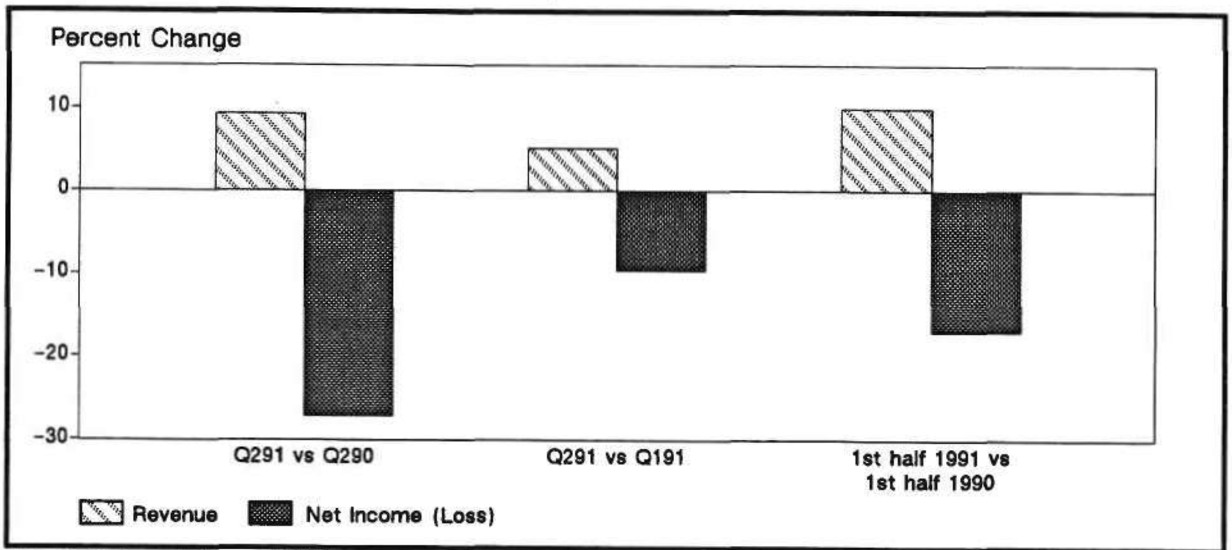
By Patricia Galligan

Table 1
Quarterly Financial Summary for Selected Semiconductor Companies for Quarters Ending in May, June, and July 1991
(Millions of Dollars)

	Latest Quarter Revenue	Percent Change from Year-Ago Quarter	Percent Change from Prior Quarter	Latest Quarter Income	Percent Change from Year-Ago Quarter	Percent Change from Prior Quarter
Adaptec	29.7	-8.3	-3.3	2.3	-48.9	27.8
Altera	26.0	34.7	12.1	4.2	27.3	13.5
AMD	296.8	10.9	8.2	17.3	-393.2	311.9
Atmel	30.5	104.7	-10.0	3.5	926.4	40.0
Burr-Brown	45.9	6.2	-1.3	1.9	58.3	72.7
Chips & Technologies	48.9	-40.1	-12.1	-5.3	-184.1	10.4
Cirrus Logic	40.4	30.3	3.1	5.4	28.6	1.9
Cypress Semiconductor	75.1	39.6	8.7	10.0	17.6	9.9
Dallas Semiconductor	28.5	13.1	3.6	4.1	17.1	2.5
Intel	1,252.7	29.4	10.6	230.8	35.2	16.9
IDT	52.3	6.5	1.0	0.3	15.4	-34.8
Lattice Semiconductor	17.0	2.4	9.7	2.4	-17.2	14.3
Linear Technology	26.4	26.9	8.6	5.0	47.1	13.6
LSI Logic	181.0	13.3	0.4	4.5	-27.4	114.3
Micron Technology	126.8	50.8	34.2	7.0	288.9	-418.2
Motorola	2,814.0	3.6	2.6	119.0	-26.1	2.6
National Semiconductor	444.9	-2.5	15.0	5.6	19.1	12.0
SEEQ Technology	12.7	25.7	5.8	0.062	-101.3	-102.8
Sierra Semiconductor	21.1	37.0	22.0	3.2	412.0	88.2
Silicon General	15.0	-3.8	-5.1	0.539	168.2	3.1
Siliconix	33.9	14.5	7.6	-0.938	-92.7	-37.5
Standard Microsystems	18.1	-12.1	-22.0	-1.8	-437.7	958.8
Texas Instruments	1,686.0	5.9	2.4	-157.0	-1,527.3	190.7
VLSI Technology	109.9	29.9	11.7	4.0	66.7	42.9
Weitek	11.0	-31.3	3.8	0.05	-97.8	-85.3
Xicor	22.5	10.3	8.2	-2.9	-39.6	-25.6
Xilinx	33.2	79.5	11.8	8.3	196.4	43.1
Zilog	27.1	6.7	7.5	2.5	13.6	47.1

Source: Company Literature, Dataquest (August 1991)

Figure 1
Aggregate Company Revenue and Net Income (Loss)
(Percent Change)



Source: Dataquest (August 1991)

Technology Analysis

TAB Gets Serious—At Last

Introduction

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). Moreover, as the semiconductor industry enters an era of high-density interconnect, single-ship solutions will increasingly give way to multichip modules (MCM). A graphical depiction of these trends in packaging is presented in Figure 1.

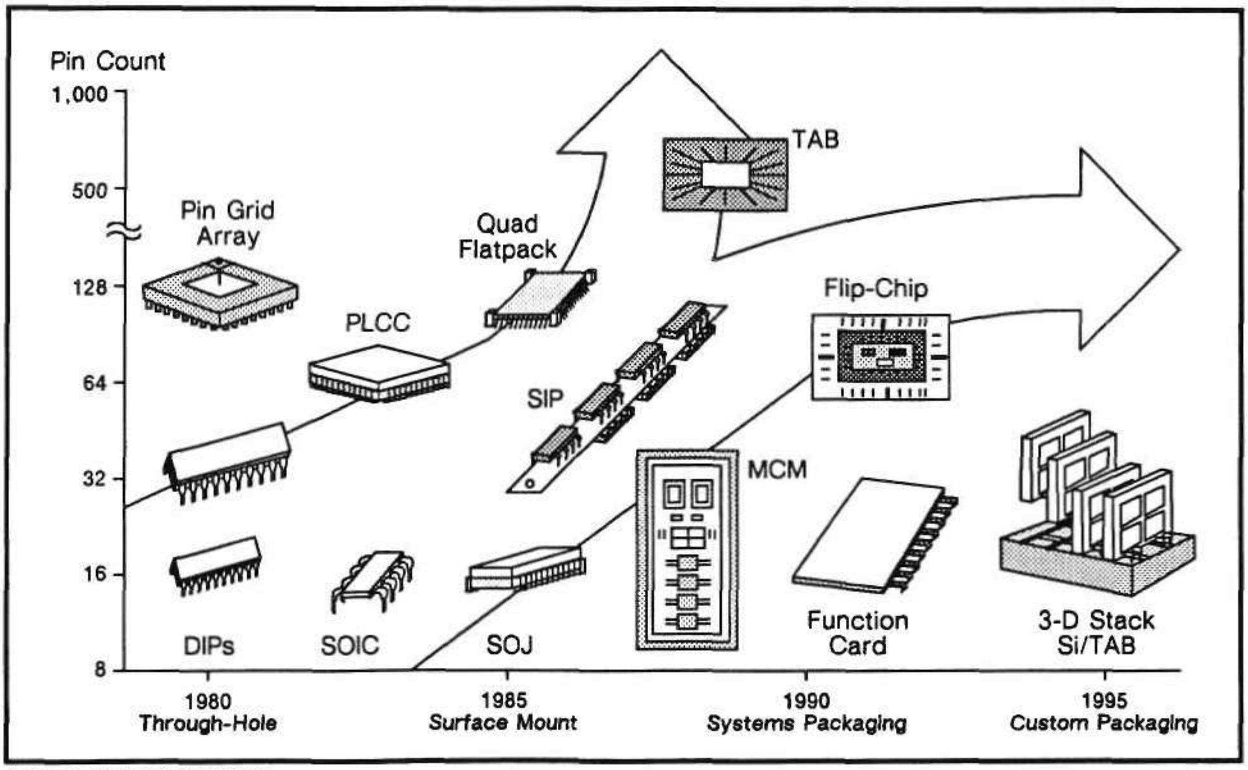
Time for TAB!

For years, analysts have been predicting that TAB packaging was about to explode as the next technology in interconnect, but always it was just around the corner. Well, the "corner" finally appears to be looming—although not for the reasons originally envisioned. TAB is not the low-cost solution for all integrated circuit packaging; rather, it seems to be the preferred solution for the high-lead-count, bond-pad limited die—especially those found today in multichip modules.

TAB: What Is It?

Tape-automated bonding is an electronic interconnect method wherein thin, narrow conductive patterns (usually copper) on a flexible insulating carrier (polyimide or polyester) are bonded to IC dice. This interconnect is made via thermocompression or thermosonic bonding,

Figure 1
Packaging Road Map



Source: Texas Instruments

primarily in reel-to-reel format. In TAB bonding, either the die or tape is usually "bumped." In a more traditional approach, thick metal bumps are added to the chip bond pads, providing an elevated site for bonding. The individual die is positioned under the window of the tape as it unwinds from the reel, and the patterned tape is aligned to the die for bonding.

TAB and MCMs: A Happy Coincidence

Today, TAB is being scrutinized by every IC manufacturer as possibly the main interconnect method for high-lead-count, electrically speedy silicon circuits. Coincidentally, while most companies are now using surface-mounted devices to achieve high-density packaging, they are looking to MCMs as the next technology to achieve even higher densities for specific high-end electronic packages. An MCM can be briefly described as a collection of multiple die arranged in a thin-film multilayer interconnect structure so that the complete assembly functions as a single integrated circuit. Because of TAB's inherent handling and performance benefits, it will be used in MCMs now and in the near future.

The advent of MCMs specifically is driving TAB use in the United States.

Furthermore, the nature of TAB interconnect allows the elimination of one level of interconnect. The shorter connection routes increase signal-transmission speed resulting from the lower inductance, capacitance, and resistance. TAB then becomes a beneficial interconnect method for high-speed applications such as those required by multichip modules.

MCMs require higher I/Os on finer pitch. TAB has the ability to connect closely spaced bond pads. Analysts at MCC in Austin, Texas, have concluded that if the cost of additional silicon area needed for wire bonding is factored in the total cost of an MCM, the cost per I/O could favor TAB at higher pin counts. Advanced Packaging Systems (APS) of San Jose, California, has found that module costs can vary depending on the number of chips per module. For example, a 4-chip MCM works out to be less costly using wire bonding, while a 12-chip MCM is less expensive using TAB.

Recent TAB Developments

Test and Repair

Placing a large number of bare, untested die on an MCM substrate (such as would be the case with wire bonding) is a risky proposition. One questionable or bad die can result in a giant headache of rework and expense. This is where TAB has a benefit over wire bonding, specifically because of MCMs. Because MCMs are too valuable to scrap, they must be reworked. In these high-density interconnect modules, bond pads and chips are very close together. Connecting a die to TAB tape allows testing and burn-in characteristics that might be impossible with traditional packaging technologies such as wire-bonding, molded packages, and chip-on-board. For TAB devices that have been die-attached and soldered, MCC has developed a method to rework them without damaging the substrate or the die. In addition, the flip-TAB method of attachment has become increasingly popular because of its ease of repair and replacement. Pretested TAB chips minimize rework and increase yields.

Supply and Demand

At recent technical conferences highlighting packaging issues—notably, the Third International TAB Symposium (ITAB) and NEPCON West '91—findings indicate that TAB use is increasing in many applications. For example, in 1990, approximately 40 percent of all worldwide TAB was used in liquid crystal display applications, with another 20 percent consumed by smart and memory card applications. Hence, it comes as no surprise that Japan is the TAB leader, accounting for approximately 70 percent of the world's consumption. Sharp is the largest volume user of TAB, followed by Matsushita, Casio, and Hitachi.

Europe is second in TAB use, with TAB used primarily for smart cards and watches and secondarily for automotive and telecommunications applications. The United States lags behind. Hewlett-Packard Company (HP) is the largest U.S. user of TAB—for calculators and printheads. Other users include Digital Equipment Corporation and IBM for computers and Motorola and Texas Instruments for application-specific integrated circuits.

With respect to manufacturers of TAB tape, the data (see Table 1) show that Japan leads the way with the most companies producing tape, outstripping European and U.S. suppliers.

Table 1
Worldwide Tape Manufacturers

Japan	Europe	United States
Shindo Denshi	MCTS	Olin/MESA*
JIS	Cicorel	Cicorel USA
Nippon Mining	EM	Rogers
Casio		Dyna-Craft
Fuji Micro		Semiconductor Connection
Hitachi		Gould-Microbond
Ibiden		
Mitsui Mining		
Shinko		
Sumitomo Metal		
Nitto Denko		

*Up for sale as of June 1991
Source: Dataquest (August 1991)

Materials

In recent times, tape materials have been dominated by the use of high-performance Upilex polyimide. However, Du Pont Company has developed two new polyimide films, Kapton E and K, to compete with Upilex. In addition, Casio has developed tape based on polyester (PET) for low-cost applications. Microconnectors, also from Casio, use anisotropic conductive particles (hollow plastic spheres plated with nickel and gold mixed with smaller, insulative particles) that conduct only when pressure is applied, breaking the insulation and forming electrical contact.

Equipment

One of the biggest changes within the last year relates to the TAB equipment itself. Many companies (see Table 2) have announced availability of production equipment for TAB. Laser bonding equipment is now a reality for both inner and outer lead bonding, with ESI (in conjunction with MCC), Hughes, SMH/Farco, and Panasonic leading the way. Single-point bonding equipment, previously dominated by U.S. manufacturers, is now available from Japanese companies (e.g., Shinkawa and Kaijo Denki).

Table 2
TAB Equipment Manufacturers

Anorad	United States
Automated Tooling Systems	Canada
Disco	United States
ESI	United States
Hughes	United States
Cicorel USA, IMI	United States
Kaijo Denki	Japan
K & S	United States
Matsushita/Panasonic	Japan
Micro Robotic Systems	United States
Shibuya	Japan
Shinkawa	Japan
SMH/Farco	Switzerland
Toray	Japan
Universal Instruments	United States

Source: Dataquest (August 1991)

Technology

Although the number of suppliers seems to have leveled at the moment, the technological innovations have not. Recent advances have been made in TAB tape. Nippon Mining has developed a new rolled-copper process for three-layer tape. The copper is modified with 300 ppm of indium, which gives improved strength and heat resistance and limits anisotropic conditions normally found in conventional rolled-copper tape (tensile strength versus elongation problems). This rolled-copper tape also results in better electrical characteristics and higher resolution compared with electrodeposited (ED) copper. Tape dimensions as small as 60u pitch with 25u lines have been made.

Shifting focus from small to large, Casio has developed a low-cost TAB process for manufacturing calculators. Based on 158mm (yes, about 6 inches wide!) tape, chips are simultaneously processed using multiple placement heads. One could almost liken this to pseudo reel-to-reel flex circuit material.

The use of specialized multimetal tape continues to increase. 3M, Olin, Rogers, Shindo, and Sumitomo Metal are among those offering two-metal layer TAB tape with a ground plane for controlling impedance and reducing crosstalk. Additionally, Rogers has developed three-metal layer tape, with the third layer used as a power plane. This arrangement limits noise associated with simultaneous switching because the power-supply inductance can be reduced.

Many new technologies are in the R&D stage for TAB. Researchers at the University of Berlin have developed a process for bonding 20u pitch bumps. HP has developed a "bumpless" bonding process. Toshiba has developed a microbump process (pseudo flip-chip) on 10u pitch. Matsushita continues to promote its TB-TAB (transfer bump) process, in which bumps are plated on a conductive glass substrate and then transferred to planar TAB tape. This process forms "bumped tape" via thermocompression.

Laser bonding is becoming more widely used, due to its many advantages over traditional thermocompression gang-bonding and single-point thermosonic processes. Bond pad layout and pitch are not limited by tool size or pressure, only by laser-beam size. Changing from one die size to another is not hardware limited but software driven. Damage to the chip is minimized because the bond force is only a few grams. Reliability is increased because the die is subjected to minimal heat. Laser bonding provides the speed of gang bonding (65 bonds/sec.) coupled with the reliability of single-point bonding.

Dataquest Perspective

Finally, the TAB infrastructure is in place. Dataquest believes that LCD applications for TAB will continue to dominate volume use until they are replaced by less expensive methods such as conductive adhesives. The advent of MCMs specifically is driving TAB use in the United States. We expect laser bonding to become more prevalent as lead counts increase and pad pitches decrease. By 1991, TAB will be used in approximately 8 percent of all interconnects. Even contract assembly manufacturers must get into TAB as TAB's chip-on-board benefits continue to drive low-cost systems. ■

By Jim Walker

News and Views

The "News and Views" section is a compilation of recent industry events of significance and is generated by Dataquest's worldwide semiconductor analysts.

DEC to Buy Philips' Information Systems Division

Philips Electronics and Digital Equipment Corporation (DEC) have reached agreement in principal on the sale of most of Philips' Information Systems Division to DEC. The final agreement will encompass the division's activities for financial institutions, small and medium enterprises, image and document management systems, and all related customer service activities. Excluded from the agreement are the dictation systems, the smart card products, PCs, and the manufacturing activities of Philips' Eiserfeld (Germany) plant. The companies also have agreed to explore possible cooperation areas, such as PCs, components, compact disk integration, and multimedia applications. Approximately 7,000 Philips employees will be transferred to DEC. DEC maintains that price discussions have not occurred and that therefore rumors of a price between $250 million and $300 million are somewhat premature.

Intel Update

Following a recent rash of reports of poor second quarter results from distributors, with particular finger-pointing at excess inventories of the Intel 386 as the culprit, Intel executives took great pains at a financial analyst meeting on July 22, 1991, to assuage analyst concerns. Distribution canceled backlog in June but rebooked in July. Intel believes that inventories at its OEM customers are tightly managed. The company has heard no reports of large amounts of inventory at customer sites, and its largest customers have held their orders or even pulled them in.

Gray market prices for the 386DX fell rapidly but have firmed somewhat over the most recent three weeks. Intel will concentrate on what it calls "new wave business" (e.g., the 486 and

386SL). To date, 1 million units of the 486 have been shipped. There are 129 design wins for the 486, split 60/40 in favor of the SX, going mostly into desktop applications. There are 35 design wins for the SL, with about 60 additional projects under consideration. Intel predicts that although demand for the 386SL and SX and for the 486DX and SX will rise in the third quarter, the quarter will be flat. The company's 586 device will sample in mid-1992, with production to follow during the second half of the year. The "P5," code name for the 586, will achieve 100 Dhrystone mips and be compatible with the 386 and 486. With more than 3 million transistors on board, the 586 will include features required for business applications such as instruction cache and pipelining. Other announcements by the company included its intention to have the 486SX redesigned to a smaller die (approximately 20 percent of the die is used for the FPU), and we can expect an announcement this year of a 25-MHz 486SX.

Motorola to Add Complex PLDs to Product List

Motorola has announced that it will field a team to analyze how best it can tackle entry into the fast-growing field programmable gate array (FPGA) market. The company anticipates that its entry product would address the higher end of the spectrum at about 10,000 gates. No design architecture or methodology has been identified, nor has the company indicated if the design will be its own or a licensed product. It seems likely that Motorola might employ an alliance with one of the smaller existing FPGA companies (such as Concurrent Logic, Crosspoint, or ICC) to enter the market as rapidly as possible. Although short on details at this point, the company promises more details before year's end.

NEC Samples 16Mb DRAM in United States

NEC Electronics Inc. announced that it is sampling a new 16Mb dynamic random access memory (DRAM). The devices are manufactured using a 0.55-micron CMOS process and incorporate stacked capacitor storage cells. The products will be available in 70-, 80-, and 100-nanosecond versions and operate at 5 volts with an internal step-down to 3.3 volts. They will include fast page, nibble, static column, and write-per-bit modes. A choice of 2K or 4K refresh cycles is available. Initial organizations include 16Mbx1 and 4Mbx4, and more are planned for early 1992, depending on customer requirements. NEC will provide a range of packaging, including SOJ, ZIP, and TSOP for all versions of the product. The part is available in sample quantities for $300 each, and volume production is scheduled to start in the fourth quarter of 1991. NEC is just completing a 676,000-square-foot, $508 million facility in Roseville, California, which has a 115,000-square-foot clean room. When this fab is fully operational, NEC will have the largest revenue-producing DRAM manufacturing facility in the United States. Dataquest estimates that the fiercely contested 16Mb DRAM market will reach more than $6 billion by 1995.

Siemens May Sell Stake in AMD

Siemens AG advised Advanced Micro Devices (AMD) that it may sell the 8.2 million shares of AMD common stock it now owns. The shares constitute about 9.9 percent of the total 83.3 million shares of AMD common stock outstanding. Siemens purchased the stock in 1977 in two purchase agreements when it was contemplating a joint venture formed in 1977 and subsequently terminated in 1979. Under the agreement, AMD has the exclusive right to negotiate with Siemens to repurchase the stock. If no agreement is reached, Siemens may keep the stock as an investment or sell all or part of it in private transactions or on the open market.

TI/Fujitsu Agree and Disagree on Cross-Licenses

Texas Instruments (TI) announced that it has concluded a five-year worldwide semiconductor patent cross-license agreement with Fujitsu Limited of Japan. However, Fujitsu has decided against licensing the so-called "Kilby" (fundamental IC) patent. Fujitsu asserts that its products do not rely on the technology covered by that patent. Because the agreement does not include TI's Kilby patent, TI will seek damages and injunctive relief by filing suit against Fujitsu in Japan. Fujitsu has responded by announcing its intention to legally clarify the applicability of the patent to its own products. TI stated that the suit for injunctive relief will specify certain products, such as DRAMs, in order to establish the principle that Fujitsu's ICs are subject to the patent. An outcome in TI's favor would probably increase the value of its patent leverage for the next major round of license renegotiations in 1995. The Kilby patent runs until 2001. TI has already successfully negotiated licenses with companies such as Oki, NEC, Toshiba, Matsushita, and Samsung, and the company is pursuing negotiations with 16 or 17 others.

This case represents the first court challenge to TI's Kilby patent in Japan. The Japanese patent office awarded the patent in 1989, some 30 years after its original filing, despite hearing comprehensive objections by virtually all the Japanese semiconductor manufacturers. Fujitsu apparently is not arguing about the validity of the patent but rather the applicability of the patent to its semiconductor manufacturing process. TI claims that Fujitsu is risking a post-litigation rate that will be higher than the prelitigation rate. Other major Japanese suppliers have agreed to TI's terms, so one wonders how likely it is that Fujitsu's manufacturing processes could be so different from the other suppliers' manufacturing processes as to avoid the patent's jurisdiction. At this point, TI is only pursuing legal action in the Japanese arena. Presumably, it is TI's intention to add Fujitsu to its list of contributors and continue to grow its royalty stream, not to start a trade war with Japan by halting the importation of the alleged infringing devices into the United States. In the final analysis, if TI's claim prevails it is inconceivable that Fujitsu would risk either its IC business or its systems business—either of which places the company among the top six vendors worldwide. In TI's most recent quarterly financial results (June 30), the company attributed $74 million of net revenue to royalty payments. It may be a year before the current litigation is resolved and before it could affect TI's royalty revenue. ■

For More Information . . .

On the topics in this issue	Semiconductor Procurement (408) 437-8258
On related subjects	Client Inquiry Center (408) 437-8141
About on-line access	On-Line Service (408) 437-8576
About other Dataquest publications	Sales (408) 437-8246
About upcoming Dataquest conferences	Conferences (408) 437-8245
About your subscription	Customer Service (408) 437-8402
Via fax request	Fax (408) 437-0292

New From Dataquest!

We've Changed Our Format to Meet Your Needs!

When you open this cover, you'll see a **bold new look** for your Dataquest publications. Dataquest is committed to providing you with accurate, timely information on high-technology companies, markets, and industries. We're equally committed to presenting our analysis to you in a consistent, easy-to-use format across all of the industries that Dataquest tracks.

What's Changed?
Chances are, you're inundated with trade journals, business periodicals, and research publications--all of which you have to sift through to find the critical facts and insight you need to stay on top of the competition. Our clients told us that they wanted their Dataquest information to be more timely and easier to use. *And we listened!*

- We've streamlined the number of reference binders per service so that you and your staff can quickly gain access to the specific Dataquest information that you need. Each service now provides two basic binders: a binder of twice-monthly publications called *Dataquest Perspective*, and an organized binder of reference and statistical documents called *Source: Dataquest.* You will also receive a binder for each service segment you elect to purchase.

- We've increased the frequency of our publications to provide you with timely, up-to-date information on major topics and events of interest in your market. *Dataquest Perspective* is a publication that includes a synopsis for each article, and our analysts' assessment of the overall significance of each topic covered. Now you can quickly grasp the impact of major events in your industry.

- We've indexed and cross-referenced our publications to allow you and your staff to save valuable research time when looking for information on a specific topic. A complete, updated index will be delivered quarterly, providing a year-to-date cross-reference by company name and major topic.

- We've designed the total look and format of our publications and reference documents with your needs in mind, so that your Dataquest material will be easier to read, route, and file.

What Will You Find in Your *Dataquest Perspective* Binder?

This binder holds issues of the *Dataquest Perspective,* the multitopic publication that contains in-depth Dataquest analyses. A quarterly index lists the articles by title for your easy reference. *Dataquest Perspective* will have articles in the following areas:

- *Market Analysis*--Provides forecasts, trends, and market share analysis by segments such as products, regions, applications, and distribution channels
- *Product Analysis*--Presents the impact of new products on the industry
- *Company Analysis*--Highlights new activities or organizational changes and provides analysis of strategies, finances, and major product segments
- *Technology Analysis*--Zeroes in on key or changing technology and its impact on the markets and companies in the industry
- *Conferences and Exhibitions*--Identifies trends and analyzes key events at recent conferences and trade shows attended by Dataquest analysts
- *News and Views*--Provides Dataquest's perspective on recent major industry events

What Will You Find in Your *Source: Dataquest* Binder?

Source: Dataquest is an annually updated reference binder in which you'll find the following:

- *Guides*--Documents that clarify Dataquest definitions and methodologies
- *Market Statistics*--Detailed market shares, history, and forecasts
- *Company Backgrounders*--A set of in-depth backgrounders on the top players in your industry. Each backgrounder contains useful information on a company's finances, product line, sales and manufacturing locations, joint ventures, and mergers and acquisitions

What's in the Segment Binders?

If you subscribe to a segmented service, you will receive a binder for each segment of the service to which you subscribe in addition to the *Source: Dataquest* binder. Your segment binder consists of the following:

- *Market Statistics*--Market share and forecasts for detailed product classifications
- *Dataquest Perspectives*--Where you'll file your segment-specific *Dataquest Perspective* publications and the annual index

Dataquest
a company of The Dun & Bradstreet Corporation

Dataquest Perspective

Semiconductors Worldwide

Products, Markets, and Technologies

Vol. 1, No. 2 September 23, 1991

Market Analysis

Executive Summary: The Analog IC Market

1990 Analog IC Market

The year 1990 was a good year for analog ICs, with growth in all regions and all product categories. This scenario is in sharp contrast to 1989 when many of the digital IC segments continued to grow while analog IC segments were flat. The waning growth trend of traditional linear ICs, coupled with a recessionary year for electronic equipment, created an unexpectedly slow market in 1989. In 1990, however, a slightly stronger market, combined with the increasing weight of the more rapidly growing mixed-signal IC segment, pulled the analog IC market up strongly. The 1989 to 1990 period does not point to a general decline in the analog market, but rather it is indicative of the fact that the analog product mix is changing. Part of this change is that the analog market will be less isolated from the fortunes of the fast-growing digital markets than in the past.

Putting 1990 in Perspective

Total analog IC revenue, both monolithic and hybrid, was $10.57 billion in 1990. (Hybrids included in our database are only those hybrid analog ICs that are manufactured by an analog IC supplier. Dataquest's hybrid IC data is not intended to fully represent the total hybrid market.) The total analog IC revenue represents about a 13 percent increase in revenue over 1989's $9.34 billion; however, we must note that the 1990 numbers include some additional revenue for companies not surveyed in previous years. Although it may be accurate, strictly speaking, to say that the total IC market grew in 1990, a change of only 0.8 percent over the prior year reflects an essentially flat market. Measured against the overall IC market, analog ICs performed strongly with a 13 percent gain. A significant average selling price (ASP) decline in commodity linears (largely op amps and regulators) starting in mid-1988 flattened revenue growth in 1989. This rapid ASP erosion slowed in 1990, resulting in a more stable pricing environment and more predictable price erosion. In 1990, commodity linear ICs had both revenue and unit growth but at significantly lower growth rates than in the past.

Figure 1 shows the analog IC sales revenue by product category for 1990. Growth occurred in three main product types—application-specific integrated circuits (ASICs), telecom ICs, and consumer-specific ICs. Two applications markets—telecommunications and consumer—showed continued growth. Some of the product highlights in 1990 were as follows:

- Analog and mixed ASICs registered a 29 percent gain.
- Telecom ICs racked up growth of 18 percent.
- Consumer-specific ICs came in with a 13.8 percent gain.
- Data converters increased 12.1 percent.

Consumer-specific IC consumption returned at a fairly strong 13.8 percent, despite soft demand for consumer end products in North America. Double-digit growth in the telecommunications market, especially in Europe, paced mixed-signal IC growth. A growing European market was amplified by growing strength of European currencies against the dollar. About 9 percent of European growth is attributable to exchange rate growth. Better-than-expected growth in the mass-storage market helped mixed-signal and linear IC growth in this very specialized market segment. Because of this resurgence, many specialty suppliers to the mass-storage market had strong growth in 1990. The data converter market was helped by revitalized digital signal processing (DSP) and controller markets. Unlike the severe price erosion seen in palette digital-to-analog converters (DACs) and digital/audio DACs in 1989, prices fell at a somewhat slower pace in 1990 (aided by a weaker dollar). ASICs, especially mixed-signal ASICs, grew at a very robust rate (more than 30 percent). Although this segment currently represents only 5 percent of the total analog market, ASICs are becoming one of the growth drivers.

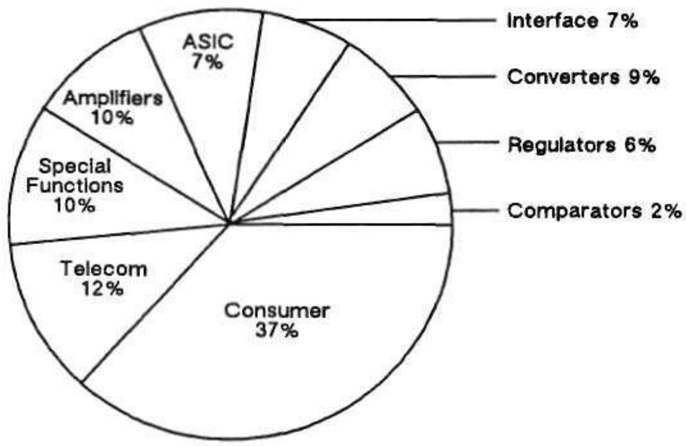
Product Segmentation Scheme

Dataquest's categorization scheme is mainly product-function oriented. This grouping does not always provide the best perspective for viewing the analog IC market. Product perspectives having to do with signal-processing type, power capabilities, or end applications are also important. Although an infinite number of ways exist to segment the analog market, one of the most important alternate views warrants discussion here.

Mixed Analog/Digital ICs

Dataquest considers ICs that mix analog and digital circuitry to be part of the analog segment. To clarify product categorization,

Figure 1
Monolithic Analog IC Revenue by Product Category



Source: Dataquest (September 1991)

Dataquest is focusing on mixed-signal ICs as one of the difficult areas in which more visibility is needed. These products are often reported as MOS logic, MOS SRAMs, or other digital categories. Some of the gain in the mixed-signal product area represents some portion of product reclassification and integration (the integration of an analog and digital chip will sometimes result in increased revenue for analog/mixed-signal products and decreased revenue for digital products) rather than real semiconductor growth. For example, analog and mixed-signal functions integrated into microcomponents increase revenue in those digital categories and create a loss for the analog side.

Mixed-signal products include interface ICs, data converters, motor controllers, mixed-signal ASICs, telecom-specific ICs, and the mixed-signal portion of automotive-specific ICs. Mixed-signal ASICs and telecom ICs combined represent a large market (approximately $3.5 billion in 1990) and lead growth with a forecast compound annual growth rate (CAGR) of 16.7 percent from 1990 to 1995. BiCMOS is emerging as an important process technology for these products.

Linear ICs

ICs that contain no digital logic and are purely analog are classified as linear ICs. These products have analog inputs and outputs and tend to represent the major mature product areas of analog. Dataquest estimates that the market for these devices in 1990 amounted to an impressive $5.7 billion. This product category comprises both high-growth devices such as voltage regulators and weak-growth areas such as commodity amplifiers and comparators. The CAGR for linear ICs is estimated at a respectable 9.5 percent for 1990 to 1995.

Power ICs

The power IC grouping (including Smart Power) traverses many product categories to define a new category meeting Dataquest's definition of a power IC. Power ICs are defined as being able to control 1 or more amps of current, dissipate 1 or more watts of power, or operate with voltages exceeding 100 volts. Meeting any one of these requirements is sufficient to be considered a power IC. This nearly $1 billion market is forecast to have a CAGR of 15.5 percent between 1990 and 1995, and smart power devices are the fastest growing portion of this product group. Smart power is simply the mixed-signal portion of the power IC segment; it is a power IC combining power outputs with logic circuitry.

Markets for Analog ICs

Application Markets

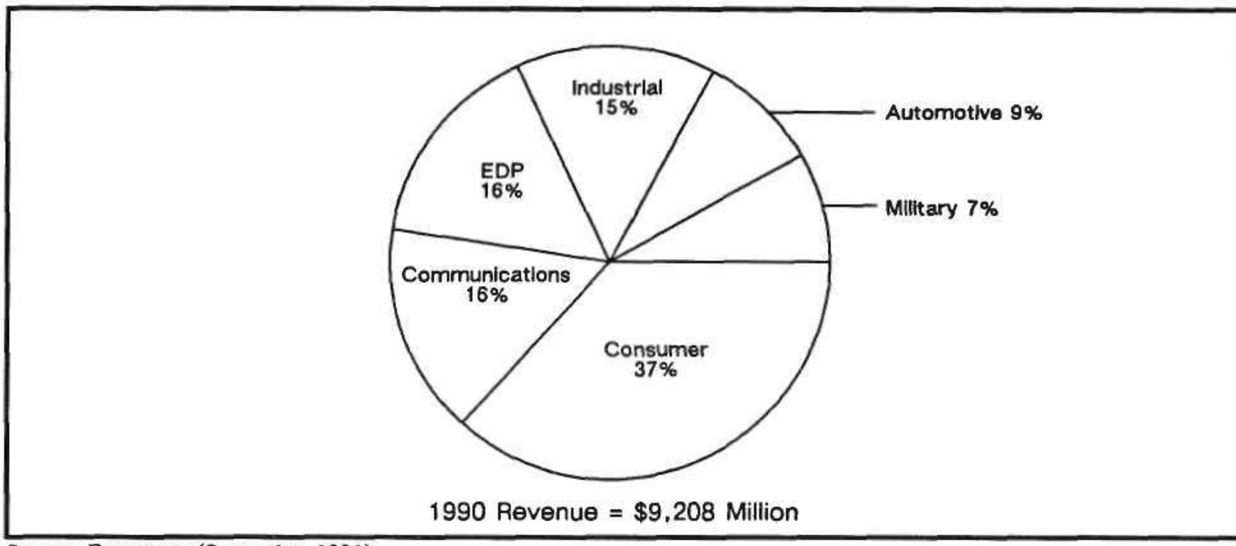
Among the major application markets of data processing, communications, industrial, military, consumer, and transportation/automotive, the consumer market is the largest market for analog ICs, including as it does audio, video, and embedded appliance controls. As all electronics equipment becomes smarter, analog IC content will continue to increase to provide sensory input and control outputs. The consumption of monolithic analog ICs by application market in 1990 is presented in Figure 2.

Regional Markets

The relative size of monolithic analog IC consumption by region is illustrated in Figure 3. The regional markets vary considerably in their consumption of analog ICs.

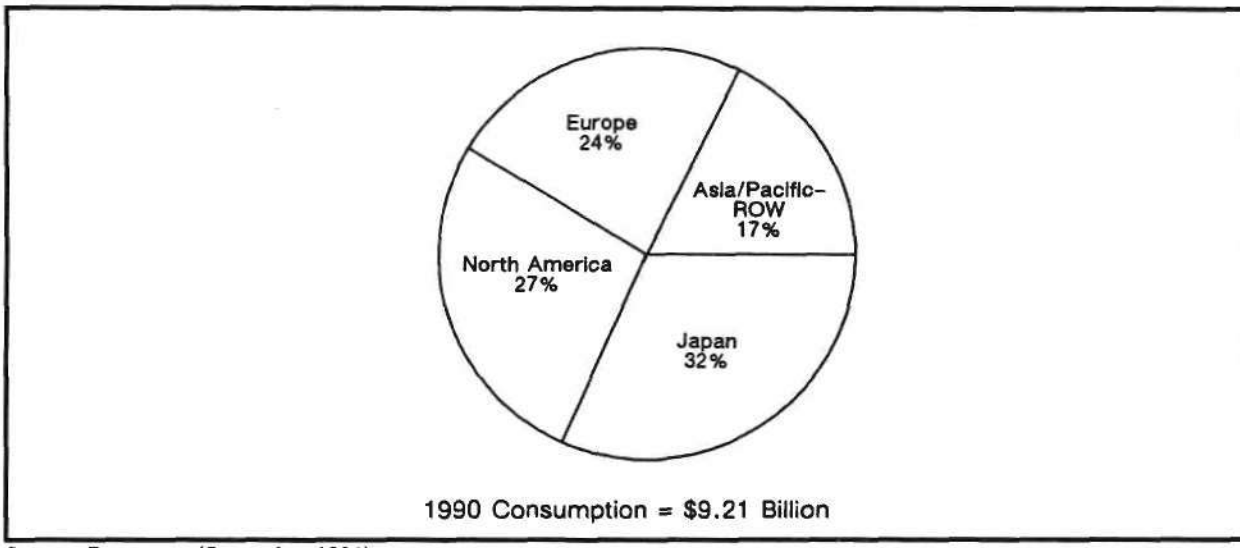
Compared with the other regional markets, the North American market is quite varied in end-use applications. One of its strengths is the computer industry, which helps drive new analog IC applications such as palette DACs for high-resolution graphics and hard disk drive support ICs. Tied into the computer revolution,

Figure 2
Monolithic Analog IC Revenue by Application Market



Source: Dataquest (September 1991)

Figure 3
Monolithic Analog IC Consumption by Regional Market



Source: Dataquest (September 1991)

communications and DSP applications create new markets for analog ICs. The automotive market's analog IC consumption continues to grow. The Japanese semiconductor market is heavily involved in consumer products. Consumer entertainment products are large users of analog ICs. Audio, TV, and camera chip sets are examples of the consumer-specific nature of these products. The emergence of digital-audio and DSP techniques has only served to increase the analog IC content of these products. The Japanese computer market is growing rapidly as a consumer of analog ICs, especially in computer peripheral products such as printers, disk drives, and graphics monitors. The Western European market is quite unique. Rather than a single regional market, it is more like a conglomerate of 15 widely divergent markets. In the aggregate, however, the European market is recognized for its strong telecommunications and consumer product focus. The data processing and automotive markets are showing good growth for the future. Analog IC consumption in the Asia/Pacific-ROW region is heavily focused on consumer and automotive markets.

Forecast

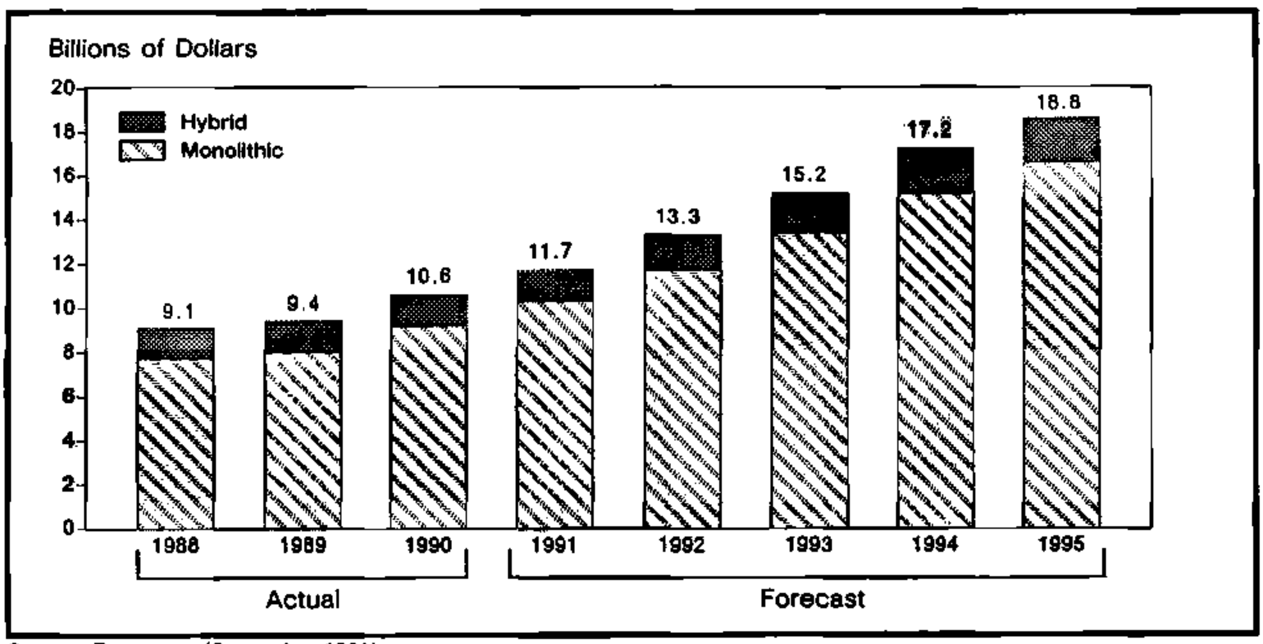
Dataquest expects the worldwide analog IC market to experience a 12.5 percent CAGR between 1990 and 1995, as shown in Figure 4.

Analog ICs are used in many application areas. Although this fragmentation creates problems of its own, it also provides a great deal of stability in the aggregate. We expect moderate growth of 11.4 percent in 1991. This growth is somewhat below that of 1990 because of an expected cooling in the European market and less favorable currency exchange rates. We expect the market to show stronger growth rates in the years following 1991.

Market Drivers

The strongest growth by product segments is expected in mixed analog/digital products such as data converters, ASICs, and telecom ICs. Beyond 1990, consumer electronics will continue to increase the demand for analog circuitry even as digital techniques are employed. "Smart" homes and automobiles require sensors, displays, and analog ICs for signal processing and driving functions. DSP requires the acquisition and digitization of a signal with analog components before digital processing can occur. High-definition television, despite its high profile in the media, is unlikely to contribute much to analog IC growth in the 1990 to 1995 time frame. Standard TV and video products will show moderate growth and will continue to dominate the consumer entertainment market. Hard disk drive support ICs should continue to grow, albeit at a slower pace in the future.

Figure 4
Worldwide Analog IC Forecast



Source: Dataquest (September 1991)

Commodity linears have shown a significant ASP erosion in 1989 and 1990. ASPs for these products have stabilized, but revenue growth will not be strong from 1990 to 1995. Voltage regulators remain an exception because they are needed to power all electronic systems. Integration into higher-level ICs will continue to stunt the growth of commodity analog blocks as the analog segment evolves into more application-specific products. More application-specific products with higher ASPs will offset the ASP erosion seen in 1989 and 1990.

Competitive Analysis

For 1990, Dataquest identified and quantified the analog IC revenue for 103 companies, representing a 24 percent increase in the number of companies in our database (83 were identified in 1989). Many suppliers are involved in the analog hybrid IC market. Note, however, that Dataquest has a limited coverage that tracks only the revenue of analog hybrid ICs supplied by semiconductor vendors. Many small companies purchase unmounted die from chip manufacturers and package them in multiple configurations; these companies are not included in our data.

Most analog IC suppliers are not broad-based vendors. Of the vendors identified in our database, 71 percent participate in four or fewer product categories. Because the categories can be widely diverse and serve vastly different markets, most medium-size and small suppliers tend to focus on selected products and markets. Five companies supplied products in all nine categories shown, (including hybrid ICs). These suppliers are Fujitsu Ltd., Harris Corporation, Mitsubishi Electric Corporation, National Semiconductor Corporation, and Toshiba Corporation—all of which have over $100 million in analog IC revenue. In general, the large suppliers are the top suppliers. Dataquest's top market share rankings for monolithic analog ICs are shown in Table 1. Table 2 lists the top five suppliers by product category.

Analog ICs: Future Directions

Analog ICs serve a collection of niche markets as well as the very large consumer entertainment market. The vendor base for analog ICs is extremely large, totaling 136 companies supplying thousands of different products. The nature of analog competition is changing. The end-equipment markets drive the IC markets. These products are developing a growing appetite for the signal sensing, signal handling, data conversion, interface, and control functions provided by analog ICs. This growth in analog consumption will not necessarily be served by the standard product offerings of today.

The Changes

The traditional, engineering-oriented, small analog IC niche supplier is finding increased competition from larger companies as higher levels of integration and more ASICs are offered. The stable, safe-haven nature of the analog IC market continues to decline, causing traditional niche suppliers to consider the faster-moving consumer, automotive, and data processing markets. The niche segments traditionally offered refuge for small suppliers, and the consumer and automotive applications were dominated by large suppliers. The consumer/nonconsumer division marks a well-recognized delineation between markets dominated by Japanese manufacturers and those dominated by North American and European companies. Moreover, the influx of nominally digital suppliers, along with their proclivity toward digital life cycles and digital pricing policies, will increase competitive pressures substantially in the 1990s.

The Dynamics of Traditional Growth

In the past, analog IC growth has come from the following four areas:

- Market growth in general
- General-purpose products
- Improved performance of existing products, leading to broader applications
- Increased levels of integration for market-specific products

The three product evolution paths of performance, integration, and high-performance/integration lead into markets of varying size, growth rates, and sustainability.

Performance

Performance improvements can make a marginal product a winner or open new design areas for accepted products. In general, performance improvement means that a product already meets general-purpose requirements for a fairly broad application range. Focusing on performance improvements of existing products is characteristic of an engineering-driven niche supplier. Although this strategy serves to carve out a niche protected by technical expertise, it is a conservative approach that tends to leave growth opportunities to other companies.

Integration

Integration provides access to the more significant growth areas in analog. Consumer, automotive, telecom, and PC markets are characterized by a need for analog subsystems combining

Table 1
Monolithic Analog ICs
1990 Worldwide Market Share—Top 20

1990 Rank	1989 Rank	Company	Sales ($M)	Percent Share
1	1	National Semiconductor	590.0	6.4
2	4	Philips	581.0	6.3
3	3	SGS-Thomson	554.0	6.0
4	2	Toshiba	549.0	6.0
5	5	Texas Instruments	458.0	5.0
6	7	Matsushita	410.0	4.5
7	6	Sanyo	395.0	4.3
8	8	Motorola	393.0	4.3
9	9	Sony	363.0	3.9
10	10	NEC	330.0	3.6
11	11	Mitsubishi	314.0	3.4
12	13	Analog Devices	305.0	3.3
13	12	Harris	250.0	2.7
14	15	Hitachi	250.0	2.7
15	16	Rohm	221.5	2.4
16	14	AT&T	197.0	2.1
17	17	Siemens	190.0	2.1
18	21	Silicon Systems	165.0	1.8
19	18	Rockwell	160.0	1.7
20	37	GEC Plessey	147.0	1.6
		All Others	2,385.5	11.6
		Total	9,208.0	100.0

Note: Some columns do not add to totals shown because of rounding.
Source: Dataquest (September 1991)

Table 2
Top 5 Suppliers by Product Category

Rank	Amplifiers	Comparators	Regulators	Converters	Interface	Special Functions	Telecom	Consumer	ASIC
1	National	National	National	ADI	TI	Silicon Sys.	Rockwell	Philips	GEC Plessey
2	NEC	TI	Motorola	Harris	National	Hitachi	SGS	Toshiba	Mietec
3	Harris	Motorola	TI	National	SGS	Mitsubishi	AT&T	Sanyo	AT&T
4	TI	NJR	SGS	Brooktree	Allegro	Philips	AMD	Matsushita	Harris
5	Mitsubishi	Philips	AT&T	Burr-Brown	Toshiba	National	ITT	Sony	Silicon Sys.

Source: Dataquest (September 1991)

maximum in functionality with low cost in an easy-to-use product that often does not need state-of-the-art performance. Mixed analog/digital ASICs provide entry into these markets.

High-Performance/Integration

This path represents a more specific direction for engineering-oriented niche suppliers. Here the product is so market specific that it represents a custom IC or a very close alliance with major customers for this very specific product.

Dataquest Perspective

Analog Prospects: A Mixed Bag

The power of digital number handling has initiated a strong movement toward digital implementation of traditional analog functions. With the advent of mixed analog and digital ICs in both applications-specific standard products (ASSPs) and cell-based custom and semicustom IC configurations, the nature of analog ICs continues to change. DSP techniques have potential to reduce linear IC content in future products. This trend toward DSP is manifested in the rapid appearance of numerous mixed analog and digital ICs such as disk drive support ICs, modem ICs, or fax circuits. Mixed analog/digital solutions are becoming more prevalent, and the value of simple linear functional blocks is waning. Mixed-mode opportunities in the power IC market abound as digital control is combined with analog power drivers. The mixed-signal product area is attracting suppliers that have historically been considered digital and is reawakening the interest of important analog IC suppliers that have let their analog IC lines slip into cash-cow status. ASIC technology has moved to the forefront as an effective means of offering these customized circuits with a fast turnaround time. However, in contrast to digital circuitry, analog has remained very difficult to automate and simulate because of a lack of computer-aided design and simulation tools. ■

By Gary Grandbois, Patricia Galligan

Company Analysis

Texas Instruments: Breaking through Design Barriers

Semiconductor Strategy

This year, the two-day Texas Instruments (TI) Tech Trends Conference (August 28 and 29) focused on what the company is doing to position itself in areas that it believes will drive semiconductor consumption—areas in which TI has expectations as both a component and a systems vendor. It has become increasingly apparent over the last several years that TI's philosophy has undergone some major revisions—namely, that TI has dispensed with the sacred cow of "NIH" (to quote a senior executive at TI) in favor of symbiotic relationships with other companies. The company also is heavily committed to a vision of itself as a worldwide semiconductor supplier. The key elements of TI's semiconductor strategy were outlined by Pat Weber, executive vice president:

- Increase capacity at lower cost of capital
- Ramp submicron CMOS processes
- Provide differentiated products
- Offer design, manufacturing, sales, and support globally
- Have a market-driven focus
- Vigorously protect intellectual property

Leveraging Investment

Clearly, TI has been aggressively adding capacity—primarily through partnerships such as its arrangements with the Italian government, with Acer Incorporated in Taiwan, and with Canon Inc. and Hewlett-Packard Company in Singapore. These relationships serve two fundamental purposes: TI can increase its access to submicron capacity while sharing the investment and risk. TI believes that this approach lets it add capacity at a very competitive cost of capital, which is essential to compete on a global basis in the semiconductor market.

To leverage its capital investments, TI is deploying a strategy that it terms "harmonization." TI believes that through harmonization it will achieve process development cost reductions in the order of 25 to 30 percent while extending the life of its wafer fabs by as much as two times. This new product development method has revolutionary implications. Rather than just design a product for manufacturability, the goal of TI's harmonization program is to design its manufacturing processes such that a high degree of compatibility in equipment sets and process recipes would occur over several different product families. The result of this compatibility would be that each different family can be manufactured on the same equipment set in the fab. TI is focusing on getting DRAMs, logic, and NV memory to be manufacturable on an almost identical equipment set that would achieve compatibility of at least 95 percent. Currently, TI claims that its process recipes for a given technology generation have gone from 10 to 15 percent compatible to a post-harmonization status of 60 to 65 percent compatible. The benefits of such a program are wide-ranging and include increased yields, a lengthening of a fab's productive lifetime, more efficient loading of a fab, and major reductions in product and process development costs. For example, TI believes that its product development costs alone will be reduced by as much as 25 to 35 percent because of harmonization.

Conversion to CMOS

Over the past five years, TI has been transitioning its bipolar capacity to CMOS and BiCMOS.

The company acknowledges that in the mid-1980s it was lagging behind the industry average in terms of CMOS capacity. A mere 8 percent of the company's semiconductor revenue was derived from CMOS in 1986, whereas it expects CMOS to account for approximately 70 percent of its semiconductor revenue by next year. Being a broad-base IC supplier, TI has extensive process technology requirements as reflected by its process technology road map in Figure 1. A new process node is introduced approximately every three years, heralded by the next generation of DRAMs. DRAMs, by virtue of being a high-volume commodity product, are suited to driving both manufacturing and process technologies.

Differentiated Products

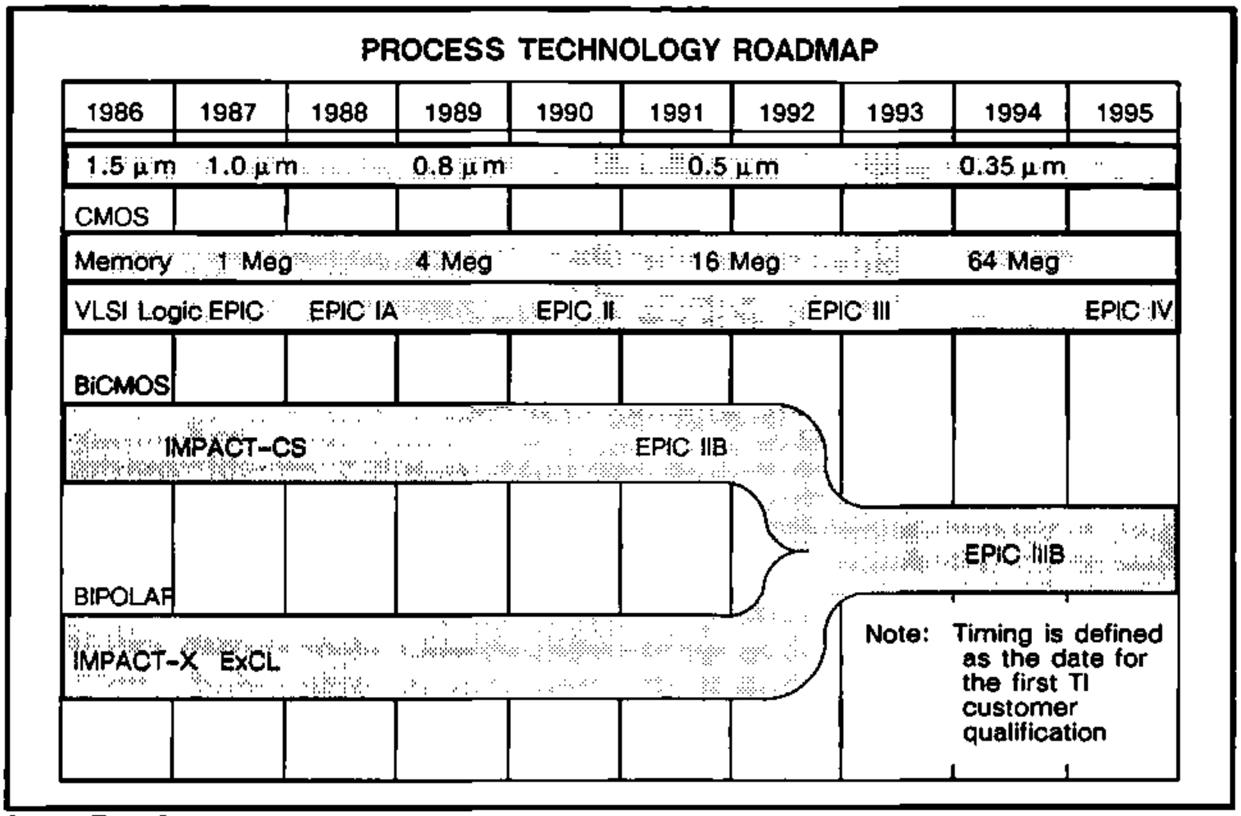
Much of this year's presentations focused on TI's thrust into differentiated products. The company has stated that it intends to grow differentiated applications processors as a percentage of its business so that they will account for more than half its semiconductor revenue by the latter part of the decade. Differentiated products not only offer the prospect of earning higher margins but also increase TI's intellectual portfolio bargaining power.

In a sense, it may also be said that the concept of harmonization finds currency in TI's approach to product development where it is referred to as "reusability." The idea of leveraging existing resources—design, in this case—meshes well with TI's characterization of its products as offering the "look and feel" of ASICs, as illustrated in Figure 2.

This product road map of providing value to its clients through product differentiation also points to TI's ambitious plan of developing process and design technologies that can deliver "ASIC-like" design of multiple functions such as digital signal processing (DSP), linear, microcontroller, and power ICs on a single chip.

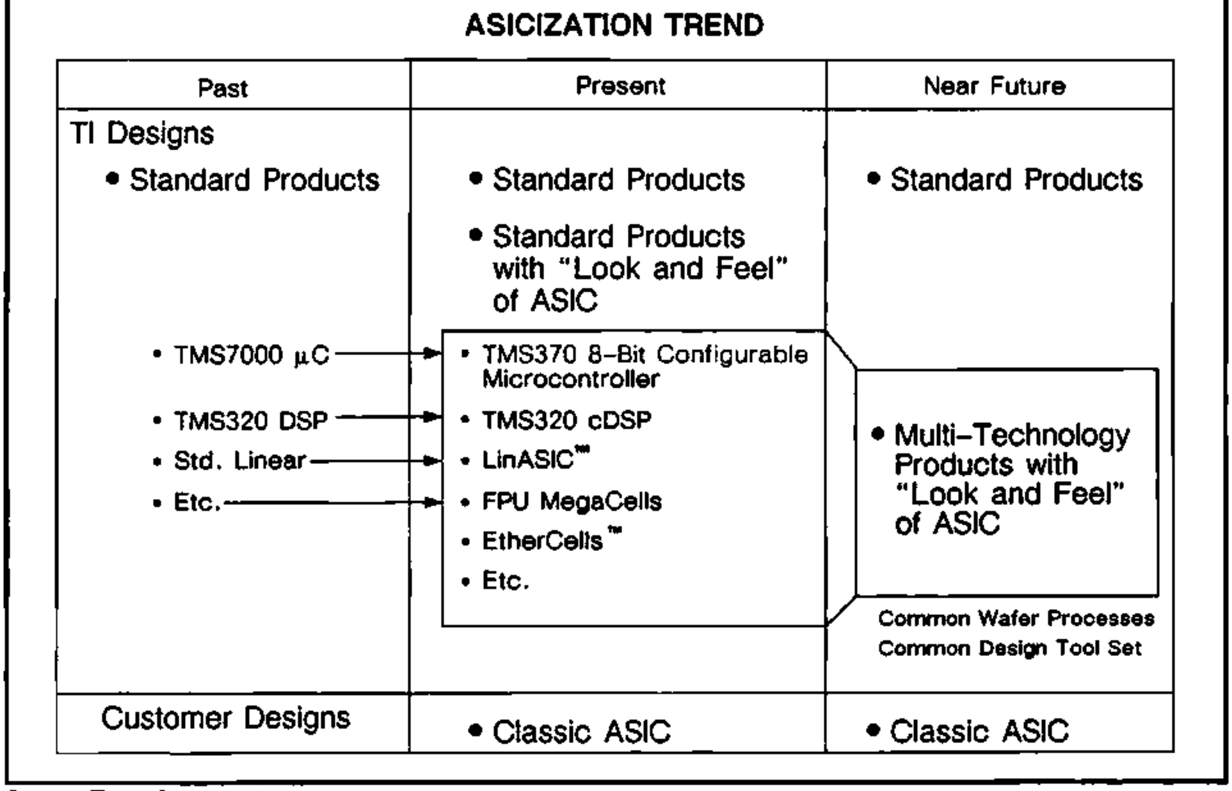
Given limited resources, TI had to decide where to focus those resources. By assessing the prospects of various end-equipment markets,

Figure 1
TI's Process Technology Road Map



Source: Texas Instruments

Figure 2
ASICization Trend



Source: Texas Instruments

the company has developed a strategy to most efficiently target its resources. TI outlined those end-market opportunities that it believes are emerging and developing and how the company's semiconductor product portfolio dovetails into these growth opportunities. Perhaps more than any other single discussion, TI's presentation of its vision of multimedia showcased the scope of the company's entire semiconductor device repertoire, as shown in Figure 3.

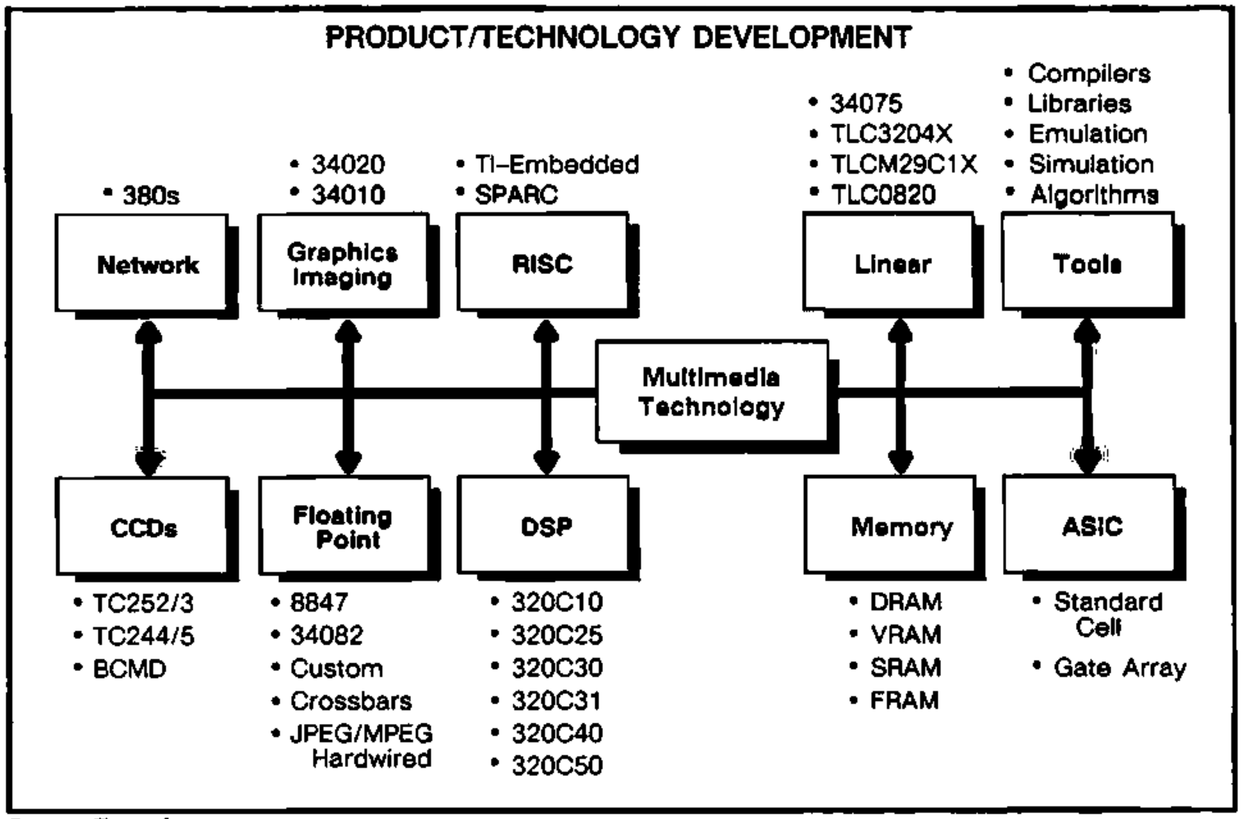
The concept of multimedia encompasses a very broad range of products and capabilities that puts all the pieces together, spanning both computing and communications. These basic building blocks can be combined in various ways to support TI's aspirations in a number of end markets including workstations, personal computers, personal communications, automotive/industrial, and military. Digital signal processing, a market pioneered by TI (in its LSI form) and still owned by TI, is a cornerstone technology to the company's aspirations in multimedia, hard disk drive storage, modems, and 3-D graphics. If today's workstation is tomorrow's PC, then TI's participation in these two markets is fundamental to the company's strategy as a semiconductor supplier. TI has achieved some high-profile wins with its differentiated products, including the following:

- Its DSPs in five of the top six workstation vendors' systems
- A custom MegaCell floating-point unit around which Hewlett-Packard configured 100,000 gates of random logic used in the HP Apollo 9000 Series 700 system
- TGB1000, a BiCMOS gate array that is winning in telecom applications

Packaging: A Gating Factor

The ability to deliver ever greater performance and customization inevitably imposes tremendous demands on packaging technology. TI continues to make substantial investments in this arena. As a significant memory supplier, it is not surprising that TI should be pursuing

Figure 3
TI's Product/Technology Development



Source: Texas Instruments

thin packaging such as is required for memory cards. TSOP (thin small outline package) thickness is currently measured at 1.0mm and is expected to be at 0.5mm by 1992. High-density interconnect structures such as multichip modules are also an area where TI has been active and is working with customers to provide them with such solutions. TI and GE are cooperating on a DARPA-sponsored contract that involves the incorporation of power devices in cavity packages that facilitate customized chip set modules. Companies with extensive ASIC experience, such as TI, often find that, contrary to some of the more optimistic expectations of market pundits who seemed to extrapolate the trend toward ASICs as a future method of integrating every conceivable function into a single device, issues such as cost and time to market are in many cases pointing to multichip modules as a more effective solution.

Think Globally, Act Locally

Competition honors no regional borders. To TI, competing worldwide means being able to support customers wherever they operate worldwide. By the end of 1992, TI will have submicron CMOS wafer fabs in every major market region of the world. TI's Semiconductor Manufacturing Systems (SMS) will provide a crucial link in ensuring that this regionally dispersed capacity is accessible worldwide at the stroke of a key. To curb the escalating cost of manufacturing, TI is implementing a Modular Manufacturing Semiconductor Technology system that will support dynamic planning and scheduling, real-time process control, WIP tracking, recipe downloading, and specification generation and management. TI is clearly acquiring considerable expertise in the area of planning wafer fabs and devising sophisticated computer-integrated manufacturing.

A Market-Driven Company

The imperative to be a market-driven company is evidenced not only by TI's desire to service its customers wherever they are, but also by a new focus on alliances. As more and more systems requirements are embedded in the silicon, the systems customer becomes a more important element in development of differentiated products. In TI's case, global alliances can take many forms ranging from shared investments to shared technology, represented by its relationships with Acer, with Canon and HP, with Actel (FPGAs), with Hitachi (16Mb DRAMs) and with Fujitsu, Hitachi, and Sony (HDTV). Some of TI's "teacher-customer" relationships reflect the value that it sees in working closely with customers like Delco, Ericsson, Hewlett-Packard, Sony, and Sun Microsystems.

Leveraging Intellectual Property

With respect to protecting its intellectual property, TI makes no apologies for aggressively pursuing return on its investments. Clearly, the company is not afraid to commit very substantial resources to building its core capabilities, but TI knows that it cannot afford to do so without reaping the commensurate rewards of such investments. Given the company's very ambitious capital expenditure program, at a time of fairly soft semiconductor demand, TI is making very good returns on its intellectual property (having netted in excess of $860 million in royalty revenue since 1986).

Dataquest Perspective

Several conclusions can be drawn about TI from its recent conference. Certainly, it seems fair to say that there has been a change in many of the company's attitudes. TI has chosen to abandon its former go-it-alone practices in favor of alliances in order to share its risk exposure, to gain increased access to advanced state-of-the art fabs, and to guide product development. The company also seems to be more convinced that the fostering of a more entrepreneurial environment internally will be instrumental in achieving market success. It is cultivating this entrepreneurial approach by working with small companies such as TranSwitch for access to specific product expertise and by giving greater independence to new product groups to operate with fewer large company restrictions such as it did in the case of its field programmable gate array (FPGA) group (modeled on a similar undertaking with its DSP operations).

There is a saying that "necessity is the mother of invention." In applying this idiom to Texas Instruments, it seems that the company is hoping to do more with less, or at least to do more with the same. TI has earned significant financial rewards by pursuing its intellectual property rights. By taking a more all-encompassing approach to the concept of return on investment, Dataquest believes that TI expects to increase the mileage it gets on each dollar invested through, say, its corporate relationships and its harmonization program. TI is aggressively investing in capacity and product development. TI's strategy in the semiconductor industry is clearly one of engagement, and the company is boldly betting that it will number among the leading semiconductor suppliers in the future. In an extremely competitive marketplace where TI's semiconductor competitors have deep pockets, ingenuity and nerve may assume greater importance in weathering out the slow times, to be in position when better times occur. In a year of soft industry demand, TI has its work cut out for it. ■

By Patricia Galligan

In Future Issues

The following topic will be featured in a future issue:

- LAN chips

For More Information . . .

On the topics in this issue .... Products, Markets, and Technologies (408) 437-8642
About on-line access .... On-Line Service (408) 437-8576
About other Dataquest publications .... Sales (408) 437-8246
About upcoming Dataquest conferences .... Conferences (408) 437-8245
About your subscription .... Customer Service (408) 437-8402
Via fax request .... Fax (408) 437-0292

0011364

Please fold and seal your reply card before mailing

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL

FIRST CLASS PERMIT NO. 7279 SAN JOSE, CA

POSTAGE WILL BE PAID BY ADDRESSEE

Dataquest Incorporated
ATTN: Liz Levy, M/S 290-1336
1290 Ridder Park Drive
San Jose CA 95131-9980

SIS-0991

How Are We Doing?

Now that you've had a chance to read through your first *Dataquest Perspective* publication, what do you think of it? We've included a reply card so that you can rate our efforts. We need your feedback so that we can continue to develop and evolve our research documents to meet your needs!

Please take a few minutes to fill in your responses below. Thank you for your feedback!

	Strongly Agree	Somewhat Agree	Somewhat Disagree	Strongly Disagree
This *Dataquest Perspective* format is easier to read than the previous newsletter-style format used.	❑	❑	❑	❑
I prefer the multitopic style of *Dataquest Perspective* to the single-topic style of the research newsletters.	❑	❑	❑	❑
I found the articles interesting and relevant.	❑	❑	❑	❑
The articles contained the appropriate depth of analysis.	❑	❑	❑	❑
Delivery of *Dataquest Perspective* twice a month is satisfactory.	❑	❑	❑	❑

I would rate the overall quality of the *Dataquest Perspective* as:

❑ Excellent ❑ Good ❑ Average ❑ Fair ❑ Poor

Comments or Suggestions:

____

____

I'd like Dataquest to cover these topics in upcoming issues of *Dataquest Perspective:*

____

____

Name: ____________________ Company: ____________________
(Optional)

You may also call and leave a recorded message on the Dataquest Hot Line at (408) 437-7878.

Dataquest
a company of The Dun & Bradstreet Corporation

Dataquest Perspective

Semiconductors *Worldwide*

Products, Markets, and Technologies

Vol. 1, No. 3 **October 21, 1991**

Market Analysis

Primer for LAN ICs

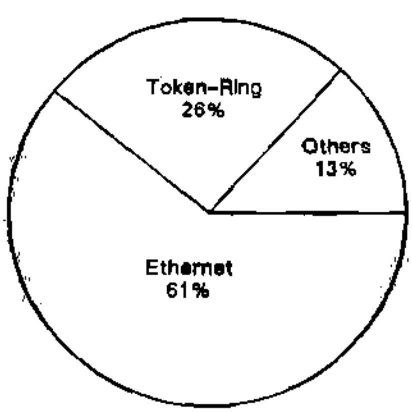
Rapid growth in the PC connectivity arena is continuing to attract suppliers of LAN very large scale integration (VLSI) device solutions. Currently, the LAN market has many permutations of access method, hardware implementation, and media solutions available to it. This multiplicity of possible solutions makes the choice of a networking solution a difficult one for the user. This executive overview will present the current and emerging solutions and discuss some of the issues affecting this market segment.

Forecast

As can be readily seen from the following figure, Ethernet and Token-Ring have become the LAN solutions of choice.

The Ethernet (IEEE802.3) market, which currently accounts for 61 percent of U.S. unit shipments, is forecast to experience healthy growth at 18.8 percent from 1991 to 1995, while continuing to accrue a larger share of the market. Some of the expected growth can be attributed to the development of 10BASE-T, which uses unshielded twisted-pair (UTP) wire, creating more demand for this access method. The workstation environment favors Ethernet as its LAN solution, and most of these companies are embedding Ethernet directly on the motherboard. Although some workstation companies offer Token-Ring as an option, Ethernet is usually included as a standard feature. The 10BASE-T development, along with the endorsement of the workstation market, has given the Ethernet access method a stronghold in the LAN market.

Figure 1
1991 U.S. LAN Forecast



Total Shipments = 4,531K Units

Note: FDDI represents less than 1%

Source: Dataquest (October 1991)

Token-Ring

The compound annual growth rate for the Token-Ring (IEEE802.5) access method in units is forecast at 22.7 percent from 1991 to 1995. Although this is a slightly faster growth rate than that of Ethernet, it does not generate sufficient momentum for Token-Ring to catch up with Ethernet. Currently, the Token-Ring solution is more expensive than the competing Ethernet solution. However, Token-Ring claims inherent intelligent architecture that is automatically included in the solution and may be reflected in the price. A key growth driver for this access method is that IBM in particular is promoting this standard.

FDDI

Fiber-distributed data interface (FDDI) is the high-speed LAN solution supporting up to a transmission rate of 100 megabits per second (Mbps) (ANSI X3T9.5). Traffic on existing networks increases with the increasing transfer of large files incorporating sophisticated graphics, creating a need for a high-speed LAN solution. In early applications, FDDI is employed as a backbone to interconnect existing Ethernet and Token-Ring networks. Many applications have not been feasible on the existing slower-speed LANs, however, and Dataquest believes that FDDI is poised for growth as the high-performance solution. We expect it to have growing market acceptance as prices begin to decline.

Others

Our expectation is that this category will experience a decline as new LAN users focus on widely accepted, open-architecture networking solutions.

Technical Considerations

Ethernet is an access method that allows all users the opportunity to send information across the network at any given time. It has a 10-Mbps transmission rate. Depending on the media type, it is typically a one- to three-chip solution. The UTP Ethernet standard called 10BASE-T has made it possible to shrink Ethernet to a one-chip solution, because the 10BASE-T transceiver does not need to be electrically isolated. However, when using coax media, the transceiver needs to be electrically isolated, making it difficult to reduce the chip set to a single device. 10BASE-T has also enabled Ethernet support to begin driving standards to implement more sophisticated network management in Ethernet. The proposed 10BASE-T hub management standard operates by having nodes communicate to a hub, which allows the hub to command and monitor the network.

Token-Ring is available in two versions, a low-cost 4-Mbps and a 16-Mbps version, depending on users' performance needs. The Token-Ring chip-set solution claims to embody intelligent architecture that is able to provide a high level of built-in network management. This intelligent solution performs such tasks as preventive maintenance through nodes reporting back to the network when a potential problem may be developing.

A Plethora of Media Types

Three types of media may be used with Ethernet or Token-Ring—coaxial (coax), twisted-pair (TP), and fiber-optic media. Each entails different advantages and disadvantages. From the chip vendor's perspective, the task of standardizing the chip set is made more difficult because of the many different electrical characteristics of the three types.

Traditionally, coaxial media have been used when networking an environment. However, they are not very flexible, they are difficult to install in an existing building, and they can become very expensive. Market demand for a one-chip access method solution is complicated by the need to preserve the electrical isolation of the coax driver. This need for isolation in conjunction with the cost associated with installation of coax media may influence the market more toward TP or fiber access methods.

TP has gained momentum because of its flexibility in installation and the lower costs associated with both unshielded and shielded twisted pair (UTP and STP). Ethernet and Token-Ring can use UTP, although Token-Ring is usually associated with STP. When it comes to conversion time, however, there is reason to believe that some users will bypass TP and convert directly from coax to fiber in order to upgrade to much higher transmission rates. Although fiber is still in its infancy, it is forecast to become the high-performance media type as transmission rates with access methods such as FDDI reach 100 to 200 Mbps.

Dataquest Perspective

The majority of LAN access methods are currently implemented into a system through the network interface card (NIC). An NIC is placed in a computer system, and the computer uses the NIC to communicate on the network using a particular access method. As the networking of data processing equipment becomes more common, Dataquest believes that the access method will be embedded directly on the motherboard, bypassing the need for the NIC. Technical workstations, which were developed in a networked environment, had their access method integrated as a standard feature. Some of the major workstation vendors chose Ethernet and currently embed it onto the system's motherboard. The laptop market, which traditionally has not been networked, is another key market for embedding the access method. The increasing miniaturization of laptops is creating pressure to embed the chip set on the motherboard. Moreover, since laptop users transport their systems to networked environments, they may require that a variety of access methods be available.

Nevertheless, before widespread migration to the motherboard occurs, several conditions must be met, including the following:

- Standards that are viable solutions must exist.
- Widespread adoption of one standard or interchangeable standards must exist so that the user is not limited when choosing to embed an access method.
- The chip set needs to occupy as little real estate on the motherboard as possible.
- The cost of the chip set must be low enough that it does not make a significant difference to the buyer in the system cost.

Currently, Ethernet and Token-Ring are both viable solutions. Another possible solution to widespread adoption of Ethernet or Token-Ring would be the development of a dual-access method controller allowing the use of either access method. In fact, in September, Chips and Technologies became the first semiconductor company to claim the distinction of announcing such a product. As is always the case in microelectronics, the driving forces of size and cost of the chip set solutions continue on their relentless downward trend. Dataquest believes that as these conditions are worked out in detail and networking of personal computers becomes the rule rather than the exception, the result will be more PCs sold with an access method directly embedded on the motherboard. ■

By Anna Cahill
Patricia Galligan

Product Analysis

Opportunities and Organizations

Organizational Quicksand

At Dataquest's recent conference titled "Technology Outlook 1995: Opportunities and Organizations," a recurring theme dealt with the all-too-prevalent phenomenon of vibrant high-technology companies whose growth potential is mired in ineffective corporate organizational structures. This topic was addressed from a variety of perspectives, one of which in particular warrants mention here because its message pertains to our semiconductor clients. We would like to take this opportunity to revisit some of the key points of a speech given by Gerald Banks, Director and Principal Analyst for Semiconductors Worldwide, in which he posed a challenge to his audience of senior company executives to right what is wrong with so many existing product-planning processes.

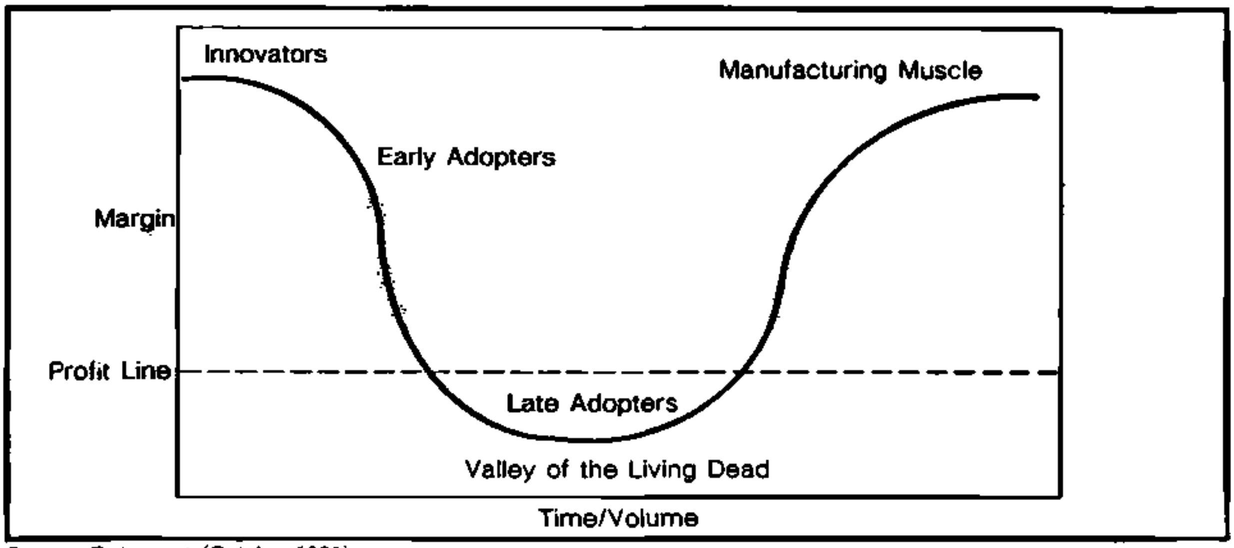
Product Planning: A Misnomer?

From Dataquest's vantage point, there is a high exposure rate to a myriad of product announcements and presentations. Almost inevitably, many of these announcements have similar fundamental flaws—the products rarely contain any significant differentiation, the target market is vaguely defined or overcrowded, and the product is frequently indefensible.

To kick off our discussion, let's review the concept of the product life cycle (shown in Figure 1), with which you are probably only too familiar. When a product is first introduced, the Innovators can typically expect high margins and low volumes. As volume begins to pick up, the Early Adopters jump into the market and cause margins to rapidly decline. Unfortunately, the margins typically fall at a faster rate than manufacturing costs can be reduced; thus, when the Late Adopters jump onto the bandwagon, profits have largely evaporated.

Figure 1 shows the "Valley of the Living Dead." These are the companies that are habitually late to market and do not have the manufacturing

Figure 1
Product Life Cycle



Source: Dataquest (October 1991)

muscle to drive the product into a low-cost, profitable commodity product. These companies are dead, but they just do not know it. At this point, the manufacturing musclemen jump in and turn the product into a cost-driven commodity that can generate profits only if sufficient capital is invested. Our purpose here is to suggest a way not only to avoid the "valley" but to develop defensible product strategies. What is needed is a strategy that allows a company to look beyond any one individual knowledge base and develop product concepts that lead the marketplace rather than trail it.

Strategies

Build in Defense

Each of these "valley" products was undoubtedly a new and original idea; unfortunately, it was not defensible. No key component was sufficiently protected to prevent the copiers from entering the market and eroding margins. In order to extend the value of a product's uniqueness and maintain adequate profit margins, it must be defensible. Gate arrays are a good example of the ultimate semiconductor commodity product. They represent a product with low volume; unique packaging; unique testing; a single customer per design, requiring sophisticated tools; and a difficult, technical sell that has a price-per-gate erosion worse than the price-per-bit of DRAMs! Today's mainstream gate array is not defensible; as a result, it is doubtful that anyone is making money on mainstream gate arrays. Growing a product's potential market rapidly requires alternate sourcing and reasonable price reductions. Through licensing, however, the addition of alternate sources is controlled; with royalty payments, price declines are more palatable. A good example today of a defensible product is a field-programmable gate array (FPGA). Although there are several companies trying to grab a piece of the FPGA pie, the intellectual property of the innovators has yet to be tested. Should the inevitable intellectual property battles not bear fruit for the innovators, the manufacturing musclemen will still have a tough time breaking into this market because it requires a technical sale and this tends not to be the forte of the large commodity-oriented semiconductor giants.

Be Market Driven

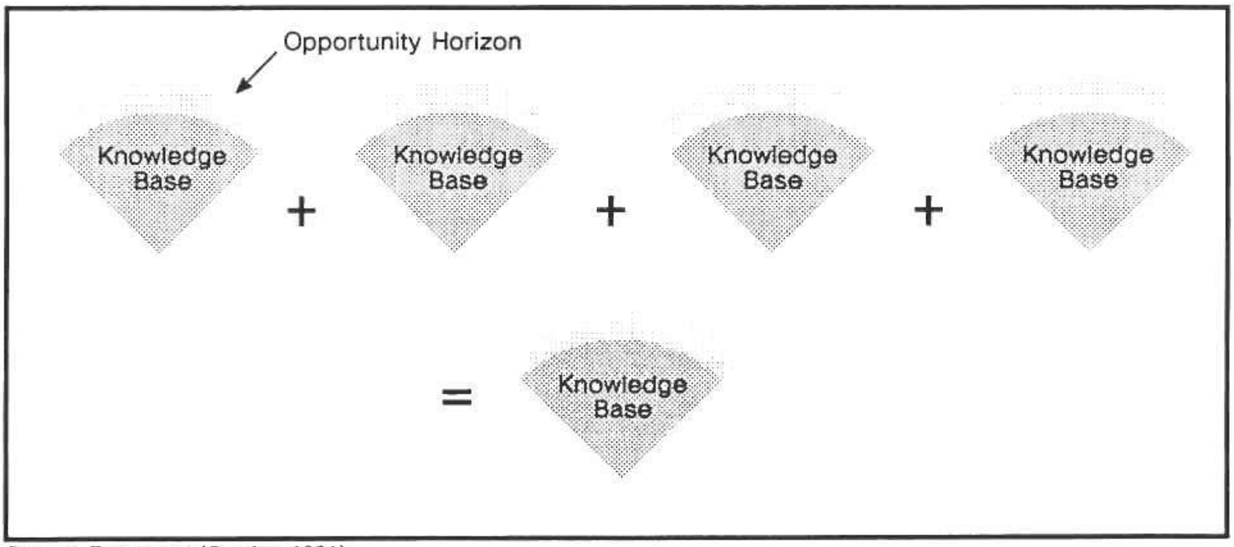
Every company should be market driven. This is not to be confused with marketing driven or, what is equally bad, engineering driven. Most marketeers have a tendency to confuse market driven with marketing driven. Companies should be driven by the market, and marketing should assist in this process.

The main problem here is that when it comes to new and innovative products, the market does not always know best. Simply asking one's customers is not a substitute for the product planning process. First it must be recognized that anything the customer will tell you, the customer will also tell your competitor. Furthermore, in matters concerning such strategic issues as product planning, the customer is not always right. (We are not referring to the day-to-day tactical issues of price, delivery, and service where the customer is king.) The company that relies solely on a customer's product "wish list" will find itself continually chasing the pot of gold at the end of the rainbow. It helps to know what the market needs were yesterday and what they are today, but only if this trend analysis is used to predict what will be needed tomorrow. This means staying ahead of the customer—not following. In order to stay ahead, you do need to talk to the leading-edge systems manufacturers, which are not necessarily the largest; but more importantly, you have to expand the knowledge base of your product planners.

Knowledge Base versus Future Outlook

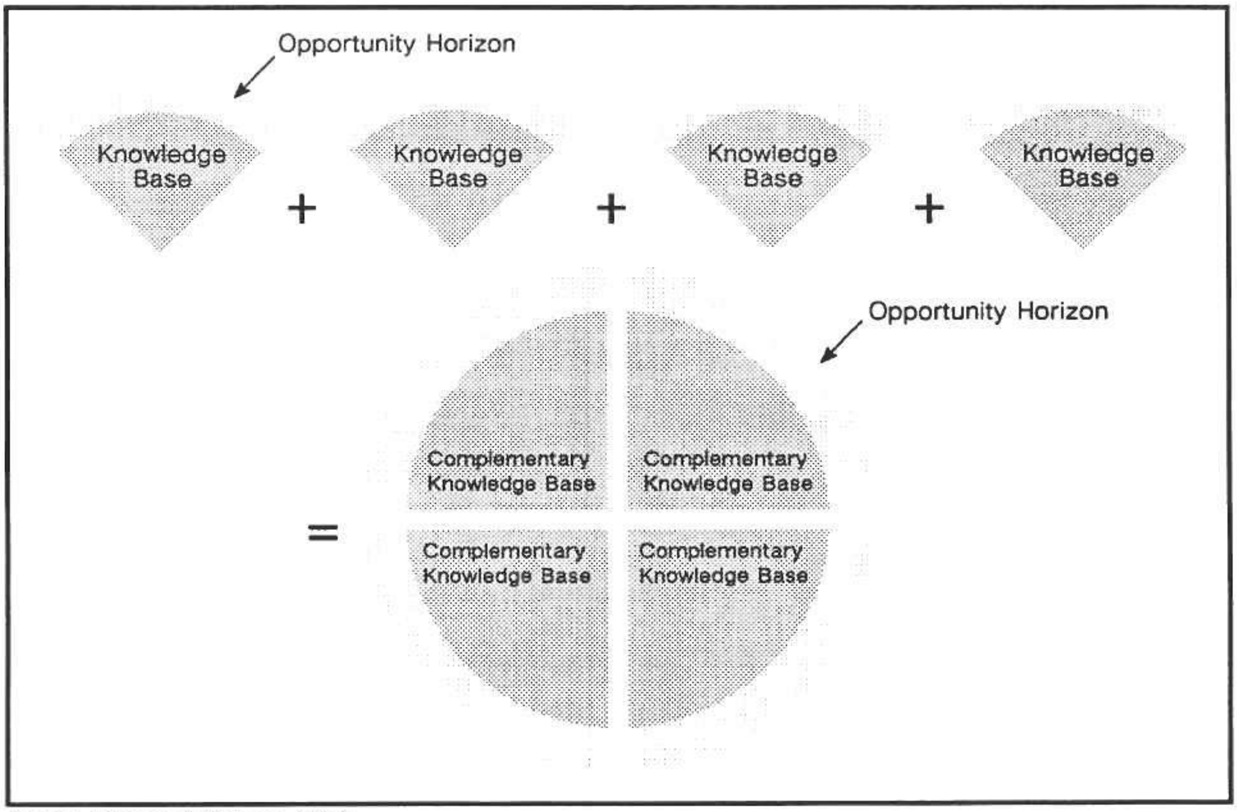
So how can a company differentiate itself against multitudes of competitors that have a similar knowledge base and are looking at the same marketplace? Our position is predicated on the premise that we all have a knowledge base, or set of experiences, that lets us look a little beyond the opportunity horizon. The broader the base, the farther we can look. Therefore, to expand our vision, we need to broaden our knowledge base. However, not only is it common for the burden of product planning to reside entirely within the domain of marketing, but most marketeers believe that this is as it should be. Hence, although the marketing group ostensibly has access to other groups within the company, effectively it operates in isolation. If the people chartered with product planning rarely solicit help or input from anyone outside of their own group, then assembling four people (or five or any number of people) with similar knowledge bases does not multiply the knowledge of the base by four (or five or whatever). In fact, it only creates a consensus among the same knowledge base, and it may even effectively reduce the group's overall knowledge because of miscommunication between the various members. This concept is illustrated in Figures 2 and 3.

Figure 2
Many People—Similar Knowledge Bases



Source: Dataquest (October 1991)

Figure 3
Complementary Knowledge Bases



Source: Dataquest (October 1991)

Dataquest Perspective

In summary, we believe that the following three basic lessons have broad applicability:

- Product ideas born from one head, or one group, rarely gain the broad base of internal support needed to make the product a success.
- A product idea is useless if the product cannot be manufactured for a profit.
- For long-term growth, the end product must be defensible.

All three points are important, but the one dealing with product ideas born of one mind is the cornerstone of the three. To have an effective product planning process, a company must be leveraging all of its resources. The process must take into account all of the company's core competencies. Marketing typically makes up something less than 10 percent of a company's organization; so why confine the product planning process to such a limited circle? Therefore, the imperative for effective product planning is to build a team that represents the core competencies of the corporation. A team made up of complementary knowledge bases not only expands the team's future outlook but makes the total greater than the sum of its parts. Buy-in has been built into the process as has manufacturability. The fact that the core competencies of the corporation have been brought together to solve a problem increases the likelihood that basic intellectual property with which to protect the product's position in the marketplace can be identified. This teamwork forms the basis of a successful and defensible product offering.

Although these truths may seem elementary, based upon our review of product announcements from many companies, we respectfully submit that most product planning groups are in urgent need of an overhaul. Putting together a well-balanced product planning team is the most difficult and most important task of any management team, and we urge senior executive management to take an active role in this key to their company's future success. By building a product planning process that leverages the core competencies of a corporation, that corporation will greatly enhance its ability to evade the "Valley of the Living Dead" in favor of long-term profitability. ■

By Gerald Banks
Patricia Galligan

Company Analysis

Snapshot of the Top Five Semiconductor Companies

Dataquest's 1990 semiconductor market share rankings list the five leading semiconductor suppliers worldwide, as follows:

- Number 1—NEC Corporation ($4,898 million)
- Number 2—Toshiba Corporation ($4,843 million)
- Number 3—Hitachi Ltd. ($3,893 million)
- Number 4—Motorola Incorporated ($3,694 million)
- Number 5—Intel Corporation ($3,171 million)

Interestingly, the rankings of the top four semiconductor companies have remained unchanged since 1987. For each of these five companies, we will note other important 1990 rankings; show their semiconductor revenue by product and by region; and chart their performance against the industry's (see Figures 1 through 15).

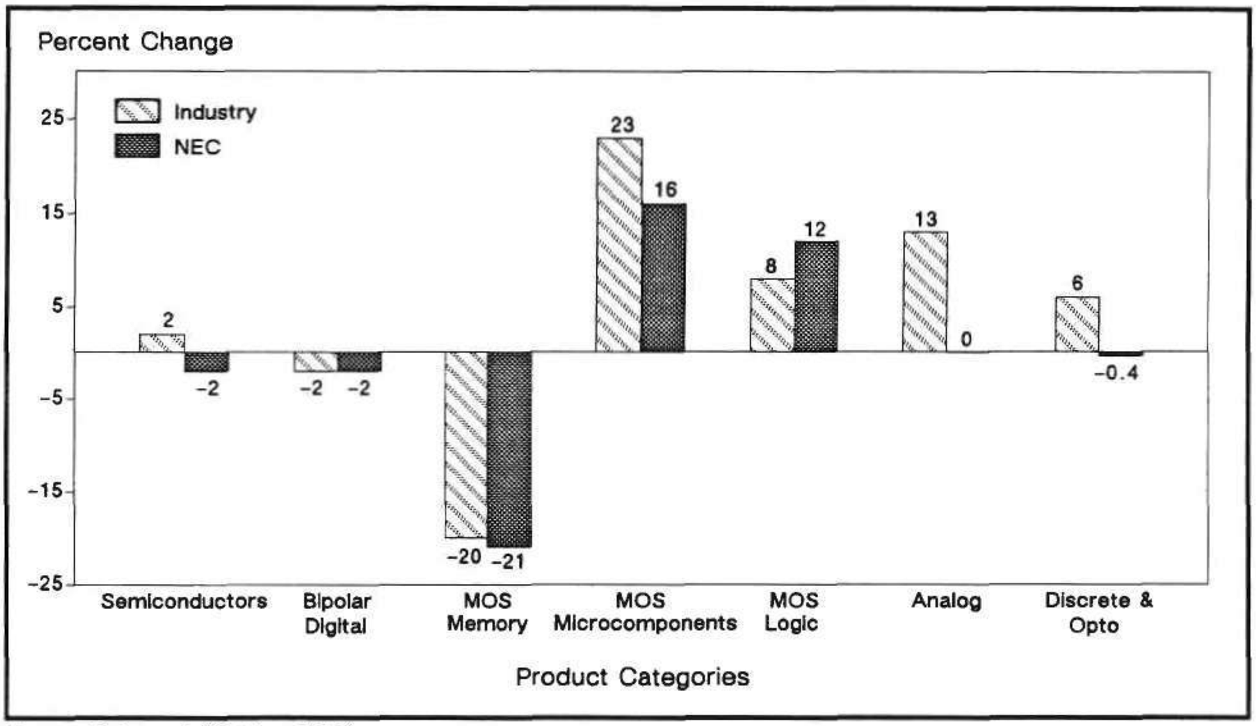
Table 1 provides a listing of the top five players in each of the major semiconductor markets.

Dataquest Perspective

Some key observations that can be summarized from this data are the following:

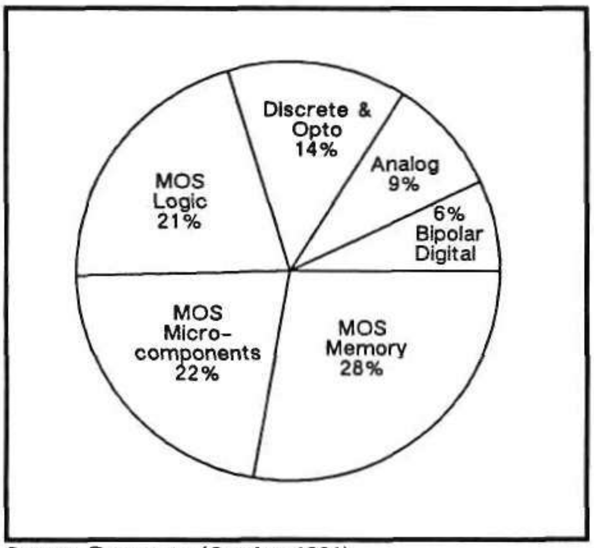
- Steep price declines in the memory market in 1990 significantly impacted the top three vendors—NEC, Toshiba, and Hitachi—for each of whom MOS memory represents the largest single product category.
- The negative impact of memories was much less dramatic for Motorola and Intel, whose shares of this market are in the low teens.
- The dramatic strength of MOS microcomponents caused Intel to shoot up from eighth to fifth place in the rankings.

Figure 1
NEC's 1990 Semiconductor Product Revenue Change versus Corresponding Industry Change



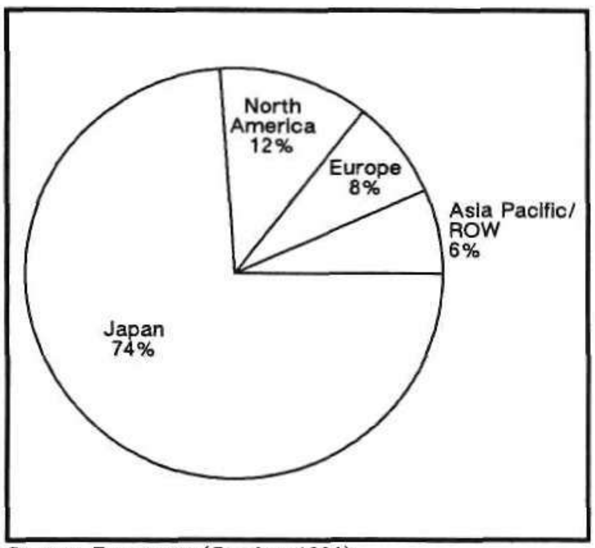
Source: Dataquest (October 1991)

Figure 2
NEC's 1990 Semiconductor Revenue by Product (Percent of Dollars)



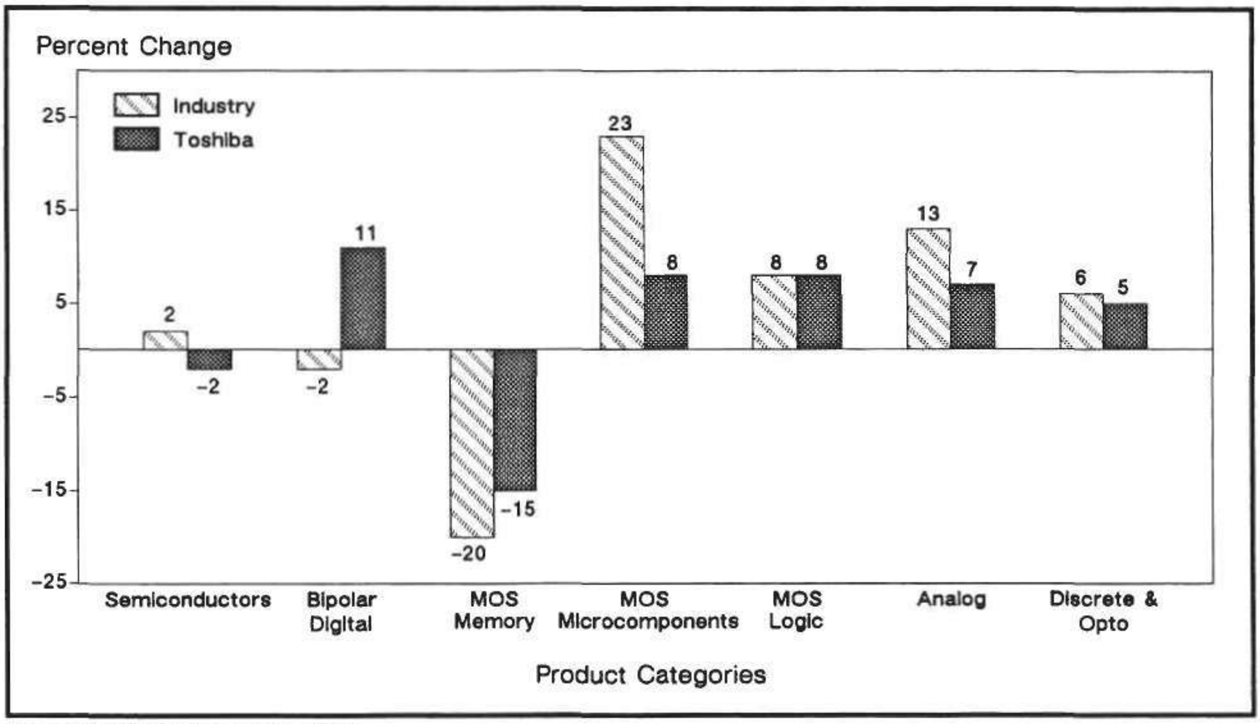
Source: Dataquest (October 1991)

Figure 3
NEC's 1990 Semiconductor Revenue by Region (Percent of Dollars)



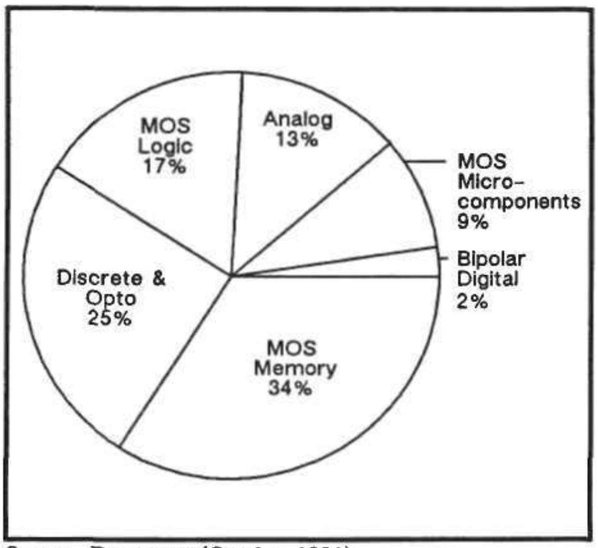
Source: Dataquest (October 1991)

Figure 4
Toshiba's 1990 Semiconductor Product Revenue Change versus Corresponding Industry Change



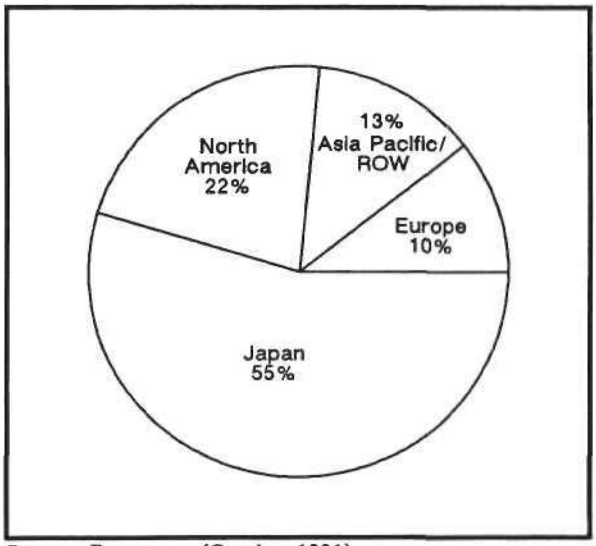
Source: Dataquest (October 1991)

Figure 5
Toshiba's 1990 Semiconductor Revenue by Product (Percent of Dollars)



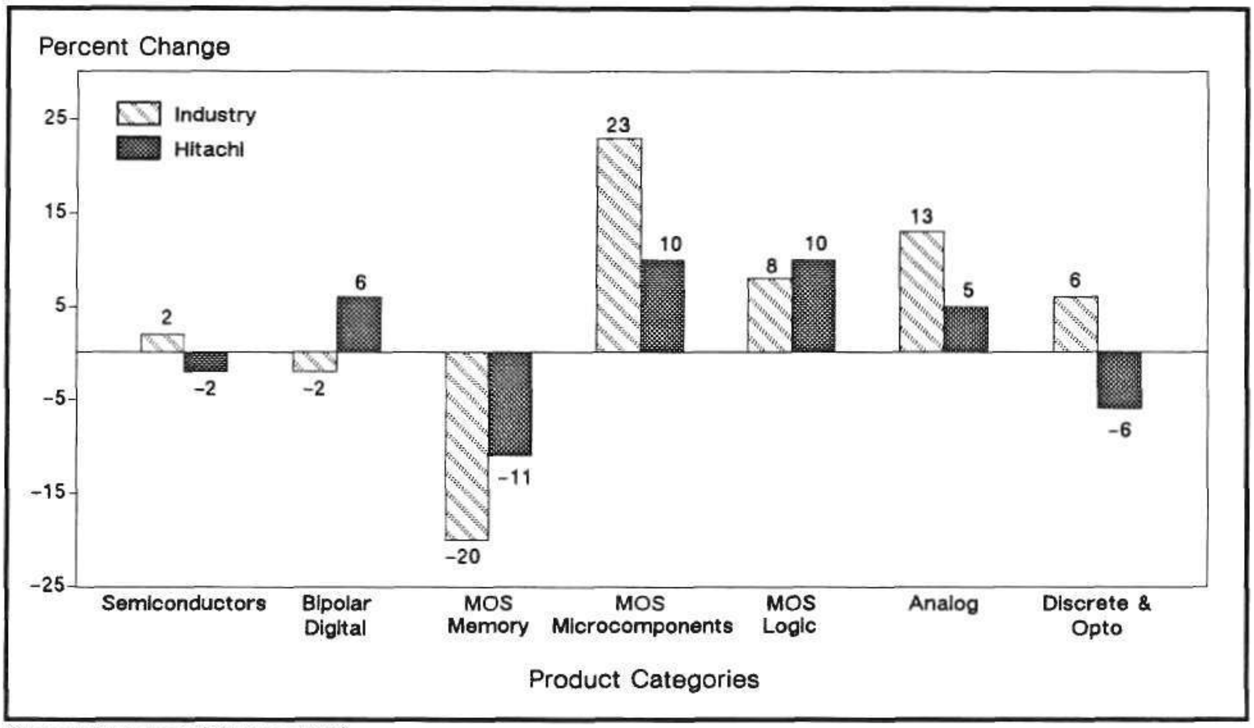
Source: Dataquest (October 1991)

Figure 6
Toshiba's 1990 Semiconductor Revenue by Region (Percent of Dollars)



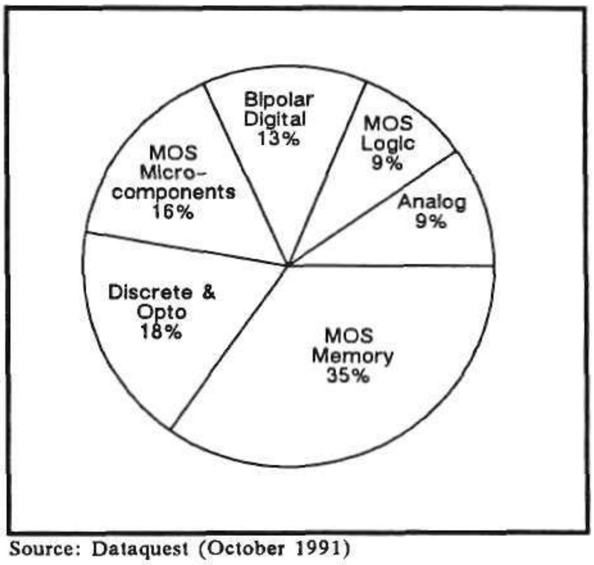
Source: Dataquest (October 1991)

Figure 7
Hitachi's 1990 Semiconductor Product Revenue Change versus Corresponding Industry Change



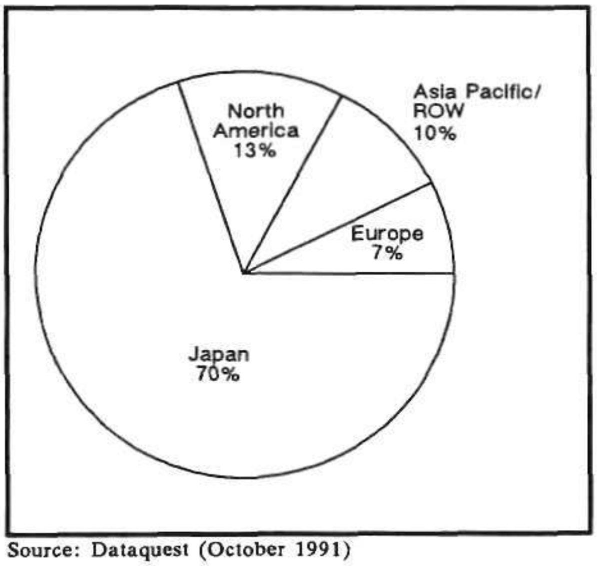
Source: Dataquest (October 1991)

Figure 8
Hitachi's 1990 Semiconductor Revenue by Product (Percent of Dollars)



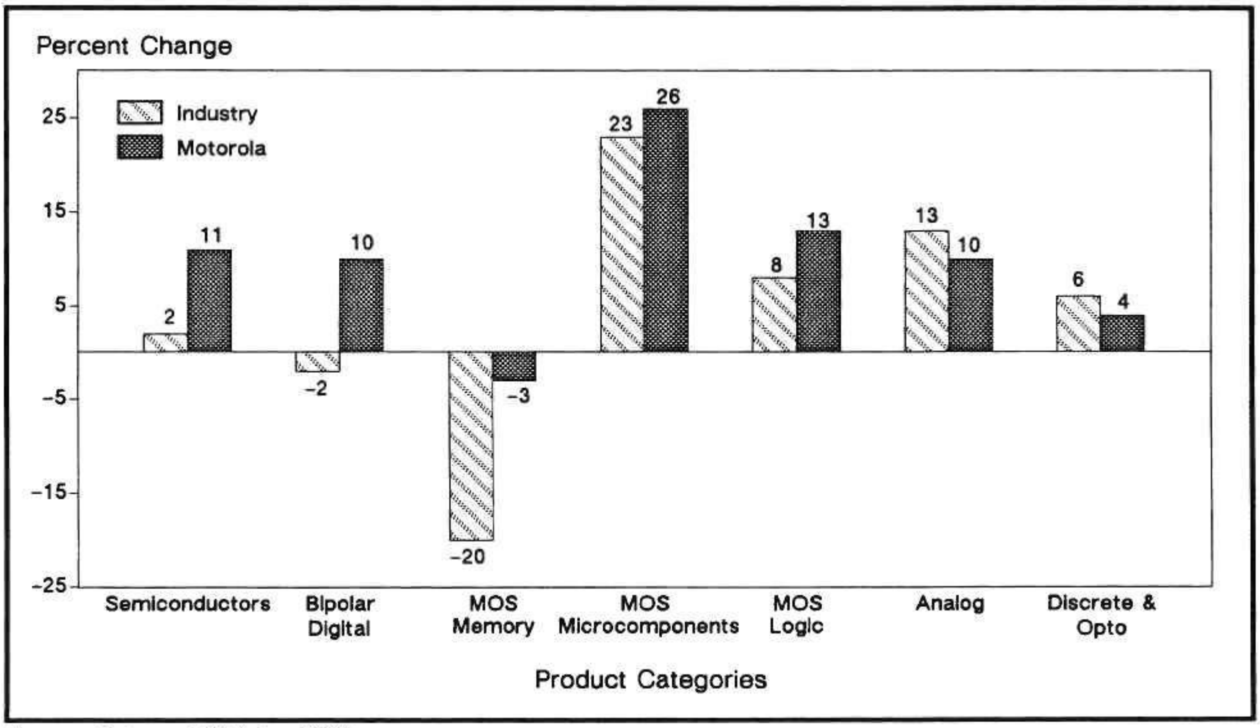
Source: Dataquest (October 1991)

Figure 9
Hitachi's 1990 Semiconductor Revenue by Region (Percent of Dollars)



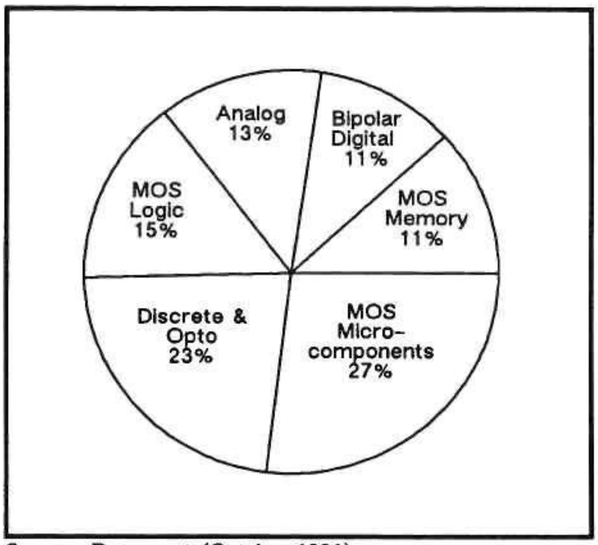
Source: Dataquest (October 1991)

Figure 10
Motorola's 1990 Semiconductor Product Revenue Change versus Corresponding Industry Change



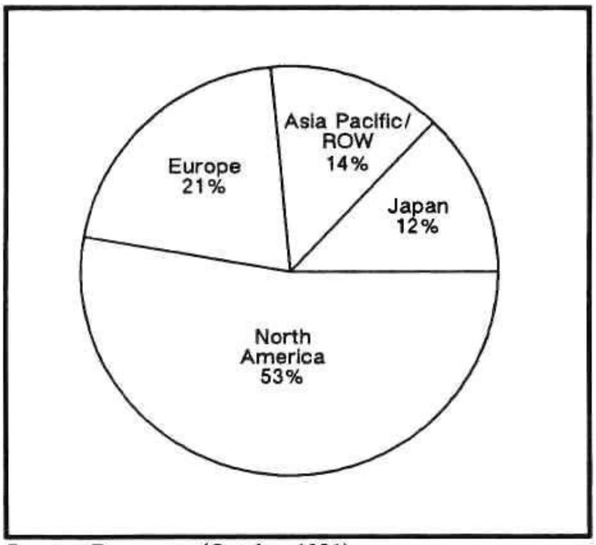
Source: Dataquest (October 1991)

Figure 11
Motorola's 1990 Semiconductor Revenue by Product (Percent of Dollars)



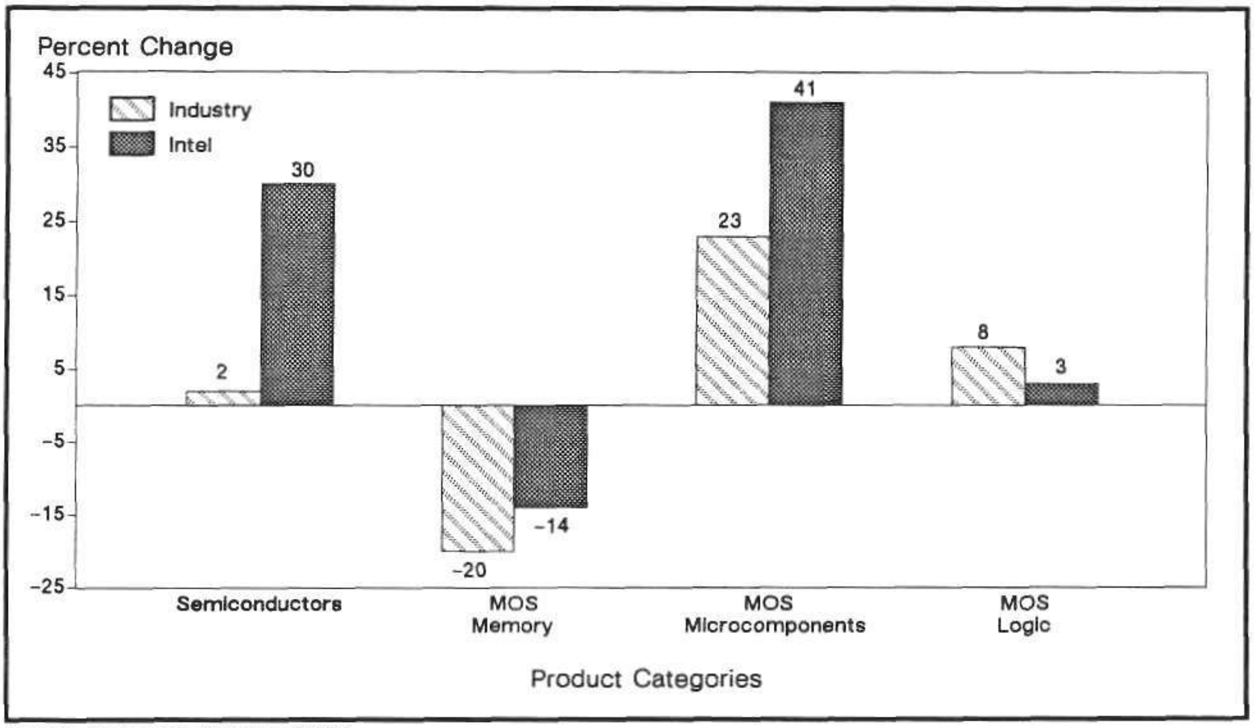
Source: Dataquest (October 1991)

Figure 12
Motorola's 1990 Semiconductor Revenue by Region (Percent of Dollars)



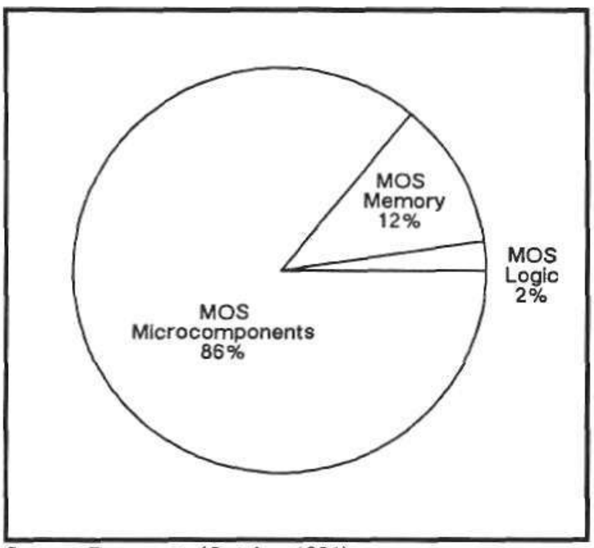
Source: Dataquest (October 1991)

Figure 13
Intel's 1990 Semiconductor Product Revenue Change versus Corresponding Industry Change



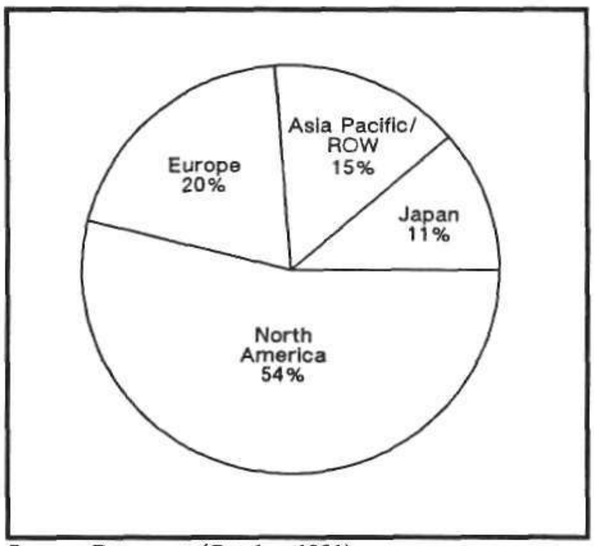
Source: Dataquest (October 1991)

Figure 14
Intel's 1990 Semiconductor Revenue by Product (Percent of Dollars)



Source: Dataquest (October 1991)

Figure 15
Intel's 1990 Semiconductor Revenue by Region (Percent of Dollars)



Source: Dataquest (October 1991)

Table 1
Top Five Worldwide Semiconductor Suppliers by Product—1990
(Millions of Dollars)

Integrated Circuits		Bipolar Digital		MOS Memory		MOS Micro	
Top 5	Revenue	Top 5	Revenue	Top 5	Revenue	Top 5	Revenue
NEC	4,207	Fujitsu	690	Toshiba	1,626	Intel	2,726
Toshiba	3,628	TI	663	NEC	1,376	NEC	1,083
Hitachi	3,182	Hitachi	510	Hitachi	1,366	Motorola	1,009
Intel	3,171	National	423	Fujitsu	1,006	Hitachi	607
Motorola	2,860	AMD	407	Samsung	971	Mitsubishi	464
Market Share (%)	36.0		60.7		48.5		58.5

MOS Logic		Analog		Discrete		Opto	
Top 5	Revenue	Top 5	Revenue	Top 5	Revenue	Top 5	Revenue
NEC	1,036	Philips	653	Toshiba	904	Sharp	339
Toshiba	838	National	619	Motorola	808	Matsushita	325
Motorola	559	Toshiba	610	Hitachi	641	Toshiba	311
Fujitsu	540	SGS	554	NEC	567	Sony	270
LSI Logic	503	Sanyo	541	Philips	507	Hewlett-Packard	223
Market Share (%)	38.1		28.2		41.6		54.6

Source: Dataquest (October 1991)

The Companies

Number One—NEC

NEC was the market leader in 1990. Other important rankings were as follows:

- Number 1 in MOS logic
- Number 1 in MOS microcontrollers
- Number 2 in MOS memory
- Number 2 in MOS microcomponents
- Number 2 in ASICs
- Number 2 in gate arrays
- Number 4 in discretes

Number Two—Toshiba

Toshiba ranked as follows:

- Number 1 in MOS memory
- Number 1 in DRAMs
- Number 1 in discretes
- Number 2 in MOS logic
- Number 3 in optoelectronics
- Number 3 in analog
- Number 4 in ASICs

Number Three—Hitachi

Hitachi ranked as follows:

- Number 3 in bipolar digital
- Number 3 in MOS memory
- Number 3 in discretes
- Number 4 in MOS microcomponents
- Number 4 in gate arrays

Number Four—Motorola

Motorola ranked as follows:

- Number 2 in discretes
- Number 3 in MOS microcomponents
- Number 3 in MOS logic

Number Five—Intel

Intel ranked as follows:

- Number 1 in MOS microcomponents
- Number 1 in MOS microprocessors
- Number 1 in MOS microperipherals
- Number 1 in MOS EPROMs ■

By Patricia Galligan

News and Views

Can Intel Lose the Desktop?

An Institution under Assault

What is happening now in the computer industry is the most exciting development since IBM Corporation entered the personal computer market in 1981. For the first time since its introduction, the viselike grip of the Intel Corporation architecture on the hardware standard for the desktop is seriously challenged. Currently, the hardware platform for the desktop is dominated by DOS-based PCs, which account for 80 percent of the market, followed by Apple-based machines with about a 12 percent share.

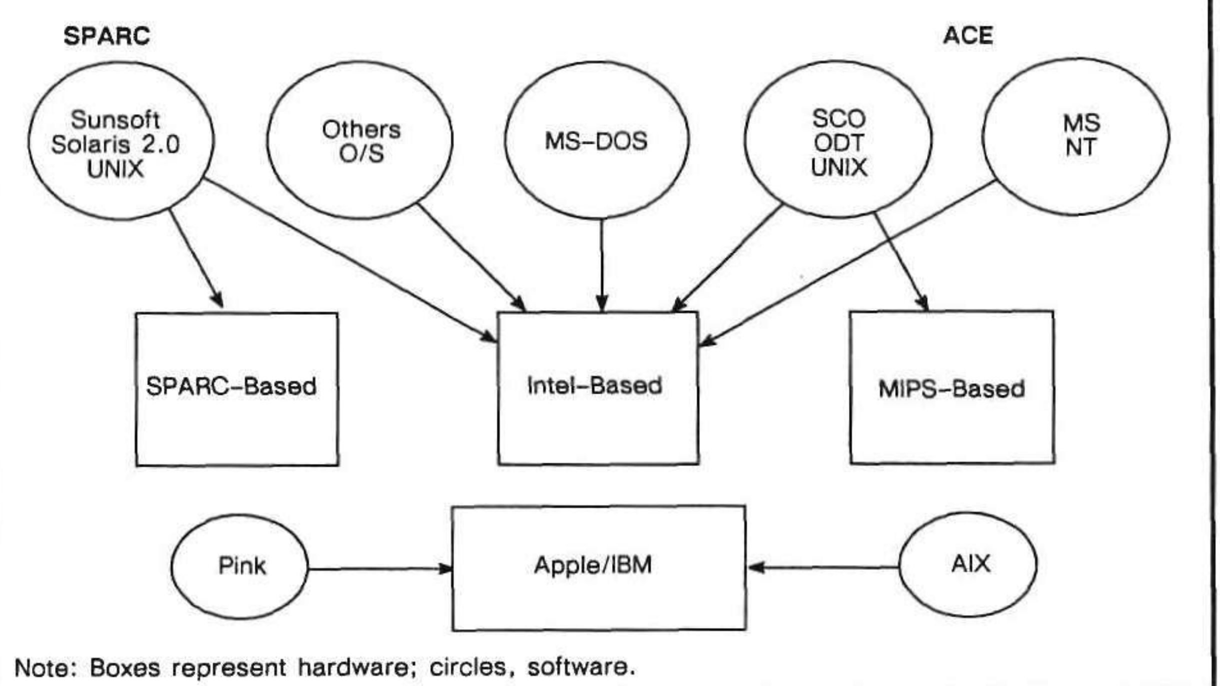
A battle has begun that has the potential to completely recast the leaders in the desktop market. New entrants into the fray have forced the current leaders to form hitherto unlikely alliances in order to defend their leadership positions.

Bid for the Desktop Heats Up

The challenges being made for ownership of the lucrative desktop computing market by Sun Microsystems Inc., through SPARC International, and by the ACE Consortium have caused traditional rivals Apple Computer Inc. and IBM to team up in a formal alliance and begin to establish their counterposition. At the same time that the reduced-instruction-set computing (RISC) camp representated by Sun and MIPS Computer Systems Inc. is gearing up for an assault on the DOS-based PC market, IBM and Apple are together formulating a position that will feature RISC-based processors at the heart of a new generation of PCs and entry-level workstations. In order to make some sense of the various strategies and how they relate to each other, Figure 1 presents a visual depiction of the sights that are being trained on the main target.

It can readily be seen from this chart that Intel-based platforms can or will run all of the operating systems supported by SPARC and ACE. Because the applications written for SPARC and ACE will also run on Intel-based systems, the reason to pick a specific RISC-based hardware platform will break down to price, performance,

Figure 1
Bid for the Desktop



Note: Boxes represent hardware; circles, software.

Source: Dataquest (October 1991)

and availability. From what is readily apparent of the IBM/Apple alliance, their operating systems do not tie in to the prevailing DOS scenario.

"Specmanship" of CISC versus RISC

As many of the new entrants to the desktop market are presently workstation manufacturers, they use Specmark performance benchmarks when comparing their systems with those of the current desktop leaders. In response to the Spec benchmark developed by the workstation vendors for comparing workstation performance, companies including Dell Computer Corporation, IBM, Intel, and NCR Corporation have founded the Business Applications Performance Corporation (BAPC). BAPC's stated charter is to develop and distribute a set of objective performance benchmarks based on popular computer applications and industry-standard operating systems.

Dataquest expects that one of BAPC's major objectives will be to show that the bulk of business applications run fast enough for the majority of users of machines based on complex-instruction-set computing (CISC). Although the new generation of RISC-based computers is better suited for such CPU-intensive tasks as running simulations, place and route, and complex graphics applications, these computers are so much overkill for the average user. Much of today's business software (i.e., word processing, spreadsheets, presentation graphics, and database management) is constrained more by hard disk access time, available RAM/cache, and the typing skills of the user than by pure CPU processing power. When a CPU-intensive application is developed that the mainstream user perceives as a "must have," then it is conceivable that a need will arise for more raw CPU processing power. However, in the time it could take for this to occur, manufacturers will have had time to improve CISC processors' overall performance capabilities and may, perhaps, even match or surpass those of the RISC processors. It is even more likely that CISC-based machines will employ dedicated processors to perform specific applications, leaving the CISC processor free to operate as a host off-loading certain time-critical tasks to the appropriate application-specific processor.

Sales Channels Issues

While PC vendors have the task of improving performance, workstation vendors have the challenge of building a sales network that can handle such massive volumes. In 1990, approximately 24 million desktop PCs shipped worldwide; by contrast, less than 400,000 workstations shipped in the same period. Improving performance can be accomplished in many ways, including faster clock speeds, data and/or instruction cacheing schemes, multiple processors, or any other type of architectual enhancement. Building a distribution network to handle tens of millions of units requires a radically different sales and marketing strategy than that used for a network designed to serve a market of hundreds of thousands. Although the availability of hardware, operating systems, and applications software is a significant component for the success of any venture into the desktop market, developing sales and service networks may be the most daunting challenge of all.

As it is the goal of all of these consortia to dominate the high-volume desktop market, what may be the most important issue of all is the sales and service networks that must be developed to service this market. SPARC International and the key drivers of the ACE Consortium have significant experience in marketing systems in the workstation/server market. Although the ACE Consortium has in excess of 70 members, within the group of key drivers, only Compaq Computer Corporation has extensive experience selling hardware into the desktop market. The nonaligned IBM-clone manufacturers have had their positions strengthened considerably with the recent Sunsoft announcement that Solaris 2.0 will operate on Intel-based platforms. Moreover, if the business user community cannot appreciate the potential performance advantage of a CISC-based system, then the existing CISC-based PC vendors have several factors in their favor: UNIX capability through Sunsoft, name recognition, brand loyalty, known compatibility with existing applications software, and, most importantly, sales and service networks already in place to address the market.

The Wild Card

So far we've said little about the Apple/IBM alliance. It is not yet clear whether these companies' newfound relationship figures in the currently raging onslaught for the DOS-based PC. Rather, this alliance between two key players in the desktop market appears to be looking beyond the immediate horizon. Instead of joining the fray for the DOS-based market, their strategy seems to be to combine Apple's much-lauded user-interface capability with a powerful RISC CPU in an offering that that will run the gamut from entry-level machines on up to mainframes.

The issue of sales, distribution, and service networks for a high-volume market is a nonissue for the Apple/IBM alliance. Perhaps the expectation is that their collaboration will engender the next must-have application, which may either obsolete the winner of the current struggle or else resolve exactly who or what they will have to contend with in the future.

Dataquest Perspective

If these new entrants understand the keys to success in the high-volume PC market—namely, a cost-effective product that can run existing applications software with adequate performance and, more importantly, a distribution/service network that can reach the mainstream user—then the current hardware standard-setters will face a stiff challenge. However, Dataquest believes that the performance of Intel-based machines has advanced to the point that the potential performance improvements of a RISC-based machine are insignificant in a typical business application. Recent market developments tend, in our opinion, to favor manufacturers of Intel-based systems in their continued endeavors to command the lion's share of the desktop computing marketplace. ■

By Gerald Banks
Patricia Galligan

In Future Issues

Among the topics to be featured in our next issue of *Dataquest Perspective* will be an update from this year's Semiconductor Industry Conference (October 14 and 15).

For More Information . . .

On the topics in this issue	Products, Markets, and Technologies (408) 437-8642
About on-line access	On-Line Service (408) 437-8576
About other Dataquest publications	Sales (408) 437-8246
About upcoming Dataquest conferences	Conferences (408) 437-8245
About your subscription	Customer Service (408) 437-8402
Via fax request	Fax (408) 437-0292

0011511

Dataquest
a company of The Dun & Bradstreet Corporation

FILE COPY
Do Not Remove

Dataquest Perspective

Semiconductors
Worldwide

Products, Markets, and Technologies

Vol. 1, No. 4 **November 18, 1991**

Conferences and Exhibitions

Semiconductor Industry Conference: The Focus Is on Applications

In a departure from previous practices, the 17th annual Dataquest Semiconductor Industry Conference broke new ground this year by combining into a single forum representatives from semiconductor equipment companies, semiconductor device manufacturers, and semiconductor users. Our discussion here will not track each presentation in a comprehensive manner, but rather it will highlight some key points that kept recurring throughout the conference proceedings.

A New Way of Looking at Electronics

This year's semiconductor industry conference seemed to be the occasion of much soul-searching on the part of industry participants. Once again, the industry appears to be on the threshold of a new era in microelectronics. As we heard in many of the conference speeches, as the once distinct application areas of data processing, communications, and consumer start to converge, concerns arise that the fundamentals for competing in the semiconductor industry will shift again and that some segments of the industry will find themselves outpaced in the race for the mass markets.

The U.S. electronics industry has been under extreme competitive pressure, having witnessed its once preeminent positions in semiconductor equipment and devices decline as Japanese competitors overtook U.S. companies. Heightened global competition has brought once seemingly invincible systems companies to the forefront as the vanguard for the anticipated next onslaught. Against the current backdrop of soft semiconductor demand, increasing company revenues, but disappointing profitability levels, companies are concerned about what the future can bring to stimulate earnings. In such a capital-intensive business, adequate returns are a prerequisite to enable semiconductor companies to continue to invest. Pressure is mounting as companies strive to position themselves to ensure their participation in the next industry upswing. Today the spotlight is focused on the computer industry. Change is happening at a rapid rate in this industry, where profit levels are currently under pressure. Turmoil and apparent confusion in the industry are causing users to think very carefully about their computer-buying decisions, while U.S.-based and Europe-based computer companies have heightened concerns over their places in the next industry growth phase. There are profits to be derived from delivering the hardware to the customer, but the question is not just what the piece of equipment should be but, increasingly, who will deliver it. Shifting market dynamics raise the question of whether the future will favor those companies with extensive expertise in computers or those that dominate the channels of distribution. Or will it take carefully managed strategic relationships to combine the requisites from each area?

Virtual Integration

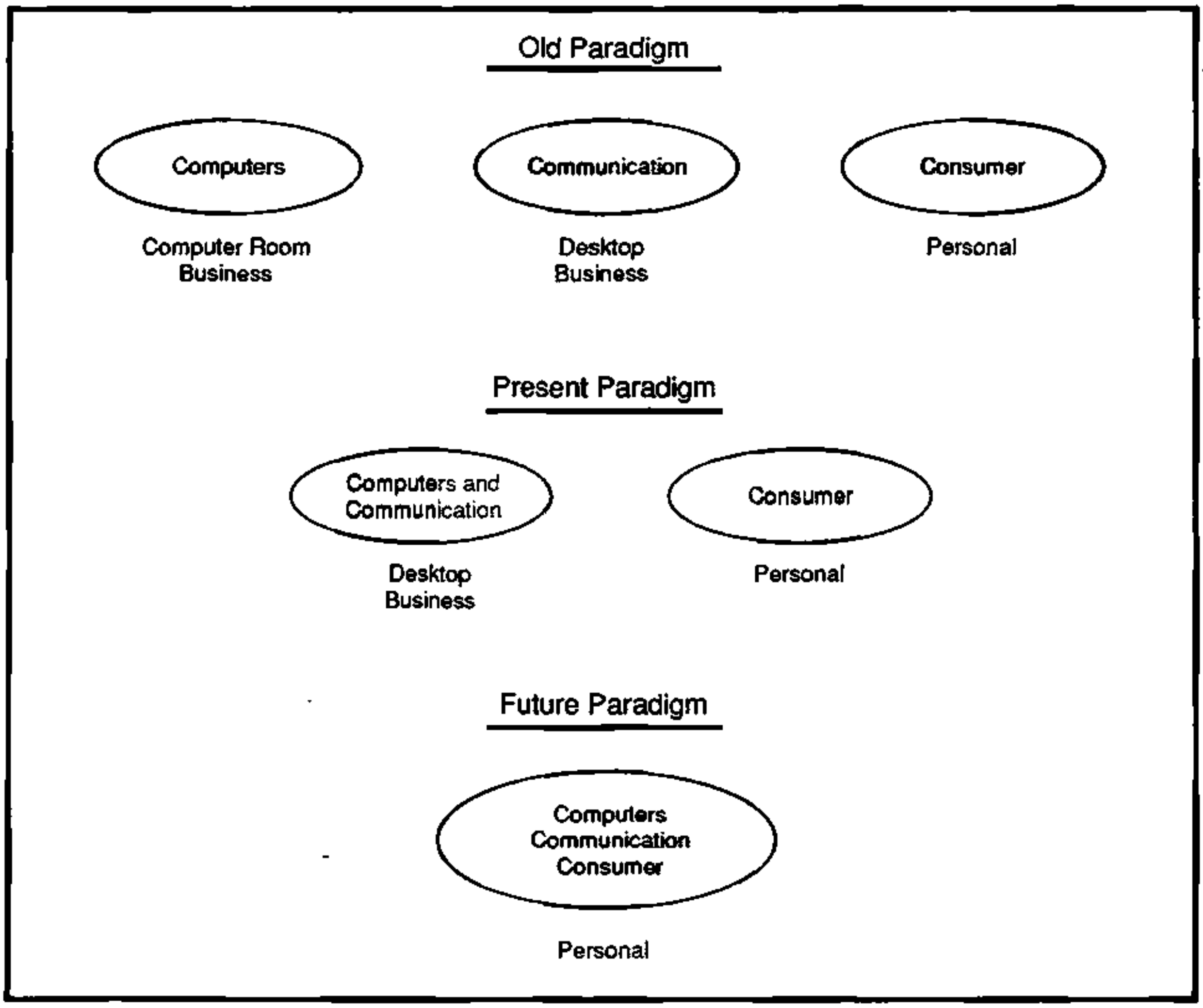
In his speech entitled "Networking for Competitive Advantage," Stan Bruederle of Dataquest attempted to shed some light on the confusion. The rapid pace at which change is occurring in the world of high-technology microelectronics will have profound implications for the way current industry participants do business in the future. On this score, there is consensus; what remains, however, is for individual companies to ensure their places in the new order. To this end, Mr. Bruederle proposed his representation of the changing order as illustrated by Figure 1.

In order to relate this changing model more specifically to interests of semiconductor companies, Mr. Bruederle drew on the following semiconductor megatrends identified at an earlier Dataquest semiconductor conference:

- The system is the chip
- Dawn of application-specific logic products
- Hardware design versus software design
- Commoditization of the computer industry
- Growing importance of strategic alliances

How did those five key trends affect the industry? The years since that enumeration have served to reinforce these trends as indeed being fundamental semiconductor megatrends. To say that the system is the chip may seem trite and overused; nevertheless, this truism has profound implications: Chip manufacturers are driving not only the standards but also the designs. This

Figure 1
Future Electronics—A New Paradigm

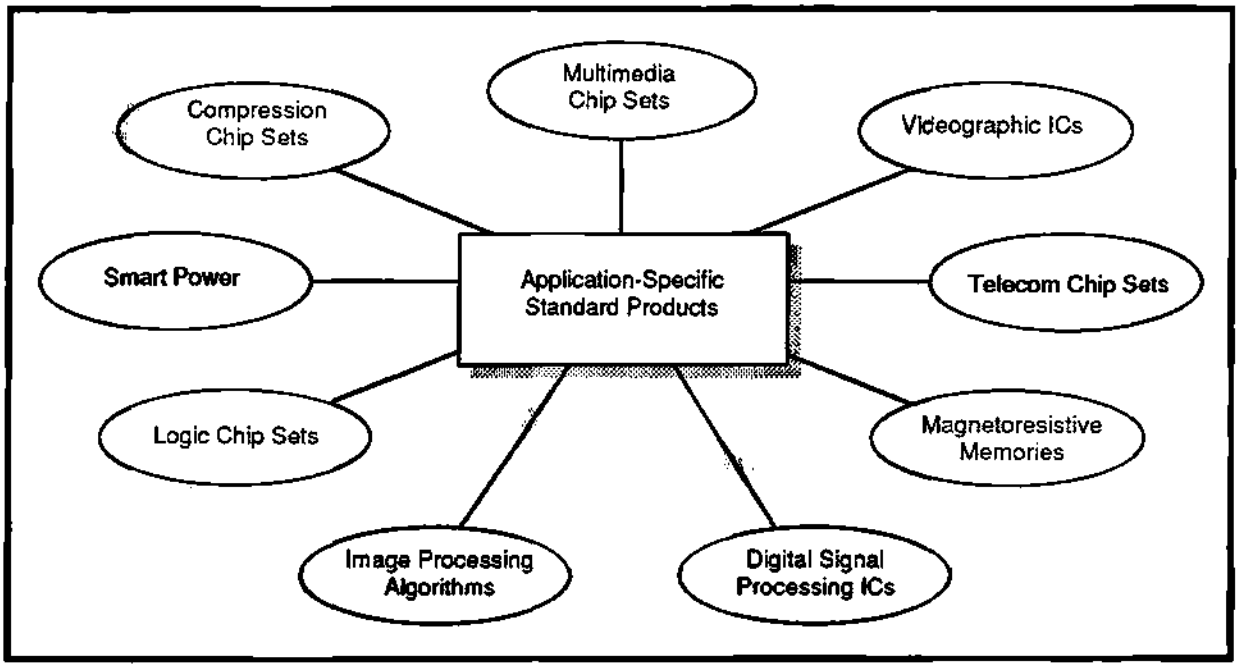


Source: Dataquest (November 1991)

point was taken up later by Wilf Corrigan, chairman and CEO of LSI Logic Corporation, who talked during a panel discussion about how a company such as LSI Logic, a leading application-specific integrated circuit (ASIC) vendor, really has to be tuned in to its customers' customers. In his experience, users have so many transistors at their disposal that they really do not know what to do with them all; definition of their real needs is the problem now. The semiconductor companies' customers are becoming systems integrators that assemble boxes, devise market solutions, and manage partnerships. Never has the phrase "the dawn of application-specific logic products" been more applicable than today. As shown in Figure 2, a whole range of such application-specific device opportunities exists, and more are gathering just over the horizon as companies attempt to implement parallel computing, neural computing, artificial vision, complex speech recognition, and supersemiconductors in hardware.

With the increasing value of a system residing in the software rather than in the hardware, commoditization of the hardware implementation of a computer is a logical outcome. Despite its status as conventional wisdom, the

Figure 2
The Dawn of Application-Specific Standard Products



Source: Dataquest (November 1991)

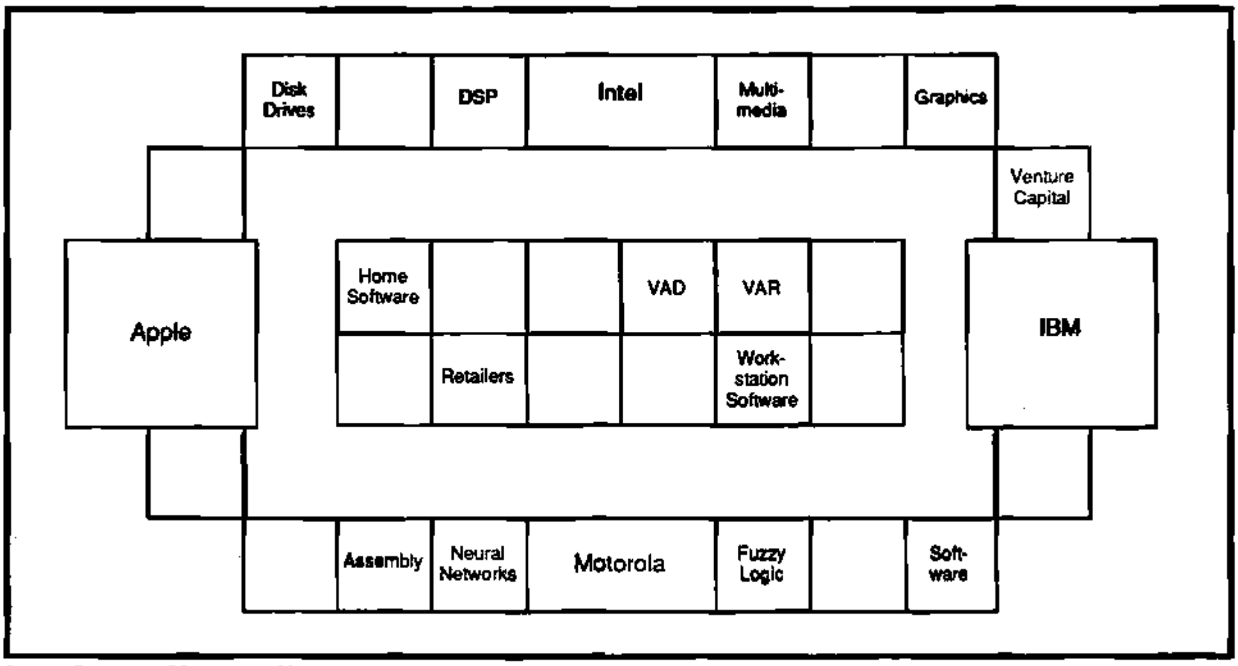
phrase "the growing importance of strategic alliances" continues to hold sway. Dataquest's perspective is certainly that no single company can successfully develop all the technologies needed to produce the sophisticated products of the future. Both the costs and capabilities associated with successfully developing and deploying all technologies needed to produce such products are increasingly not all housed under one roof. Instead, in order to establish market dominance in key technologies, companies will have to focus resources on the development of core technologies and outsource everything else. This fundamental trend is forcing systems companies everywhere to scrutinize their portfolios and evaluate their strategies for the future. Some astonishing associations are emerging as former archivals join forces in new, ground-breaking alliances. Companies will employ networking to achieve greater advantage. Companies with proven track records in their own spheres of expertise will continue to marry themselves to strong partners with complementary expertise in a win-win arrangement.

The notion of a "confederation" of companies, visually represented in Figure 3, permits the flexibility that allows companies to market products through a vast array of marketing channels to serve a vast array of markets. However, effective networking means that a company must be clear on what it needs and where it is going.

True Richness of Life

Mr. Corrigan talked of the user who is "awash in chips" and is in fact faced with an "excess of technological capability." At least one conference attendee voiced strong convictions about the useful exploitation of so much advanced technology. Marc Canter of MacroMind gave an enthusiastic presentation on the subject of multimedia. His speech echoed many of the ideas that were sprinkled throughout the other presentations. He sees multimedia as the third wave of computing—the first two being text and graphical user interface (GUI). Multimedia will incorporate video, animation, and sound; it will be pen-based, portable, networked, and miniature, and it will have fast SCSI. Multimedia represents the promise of technology delivering true richness of life to the consumer. Mr. Canter was extremely bullish on the host of opportunities that multimedia will bring to semiconductor vendors. Indeed, Mr. Canter mentioned that he could have taken a slightly modified version of a slide from Mr. Bruederle's preceding presentation to capture most succinctly what opportunities multimedia held for semiconductor manufacturers (see Figure 2).

Figure 3
The Industrial Shopping Mall



Source: Dataquest (November 1991)

In his presentation, Stagg Newman, assistant vice president of technology at Pacific Telesis Group, reiterated Mr. Canter's view that because people are visual creatures, image communications will add to the richness of life that technology can achieve. Semiconductors are an enabling technology to the 1990s telecommunications trends of personal communications, image communications, and distributed processing. It is also Dataquest's position that communications applications may well be one of the most lucrative opportunities for semiconductor companies in the next several years. Pacific Telesis believes that the enabling technologies of digitization, speech and image processing, fiber optics, and intelligent control will fuel an explosive growth in voice, data, and visual telecommunications during the 1990s, both tethered and tetherless.

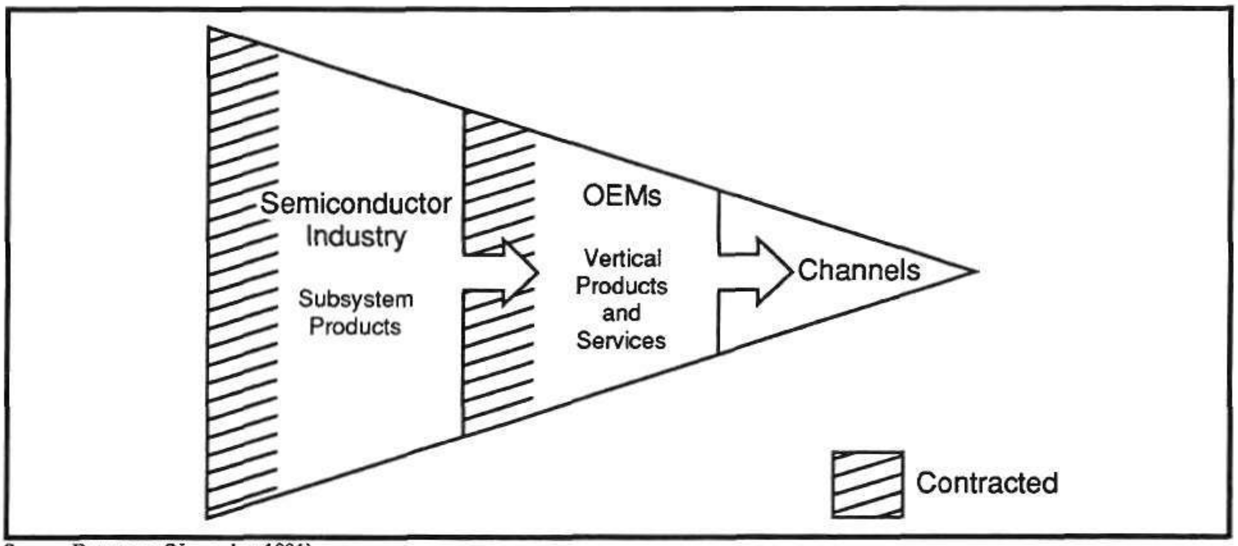
In a world where one size does not fit all, flexible computing calls for distributed computing or—for ultimate flexibility—for wireless distributed computing. In data processing, the PC market has been the traditional driver for a significant amount of the semiconductor devices. Although currently desktop PC growth has been stagnating, the portables and other small-form-factor computing are exhibiting strong growth. Because of the issue of extreme economy of size of portable computing combined with the drive for functionality, this category of equipment will spawn a tremendous need for PC cards to provide such capabilities as data storage, networking connections, application-specific programs, and wireless communications. PC cards will usher in an era of even greater versatility and functionality for the user. Such devices will be used for data storage, LAN connectivity, modems, application-specific extended programs, and wireless communications.

Competitiveness

In order to compete in the mainstream semiconductor business, U.S. companies must participate in the commodity IC arena. To do so means that the United States must possess strong, indigent manufacturing capability. To the extent that SEMATECH can boost productivity and thereby leverage existing expenditures, U.S. semiconductor competitiveness will be enhanced. Dr. William Spencer, SEMATECH president and CEO, characterized SEMATECH's contribution to U.S. manufacturing prowess as facilitating "partnering for total quality."

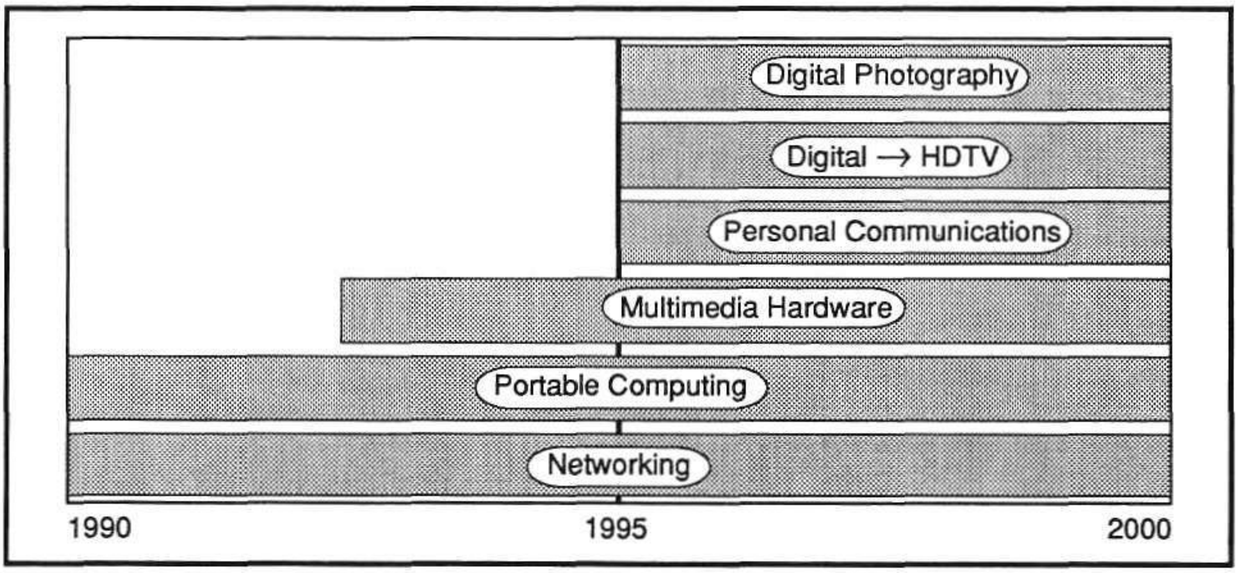
Underlying competitiveness is the issue of quality, which was dealt with from a number of different perspectives. "Quality" is assumed as a given, and the necessity of bearing this distinction in the eyes of the consumer is critical. The case is fairly well documented that once a product is branded as of inferior quality, it can be almost impossible to reverse that perception, even with the later introduction of a superior product. A company's fame and fortune can

Figure 4
Value-Added Shift



Source: Dataquest (November 1991)

Figure 5
Market Drivers



Source: Dataquest (November 1991)

Table 1
Regional Market Drivers

Europe	Japan	North America	Asia/Pacific
ISDN	Video/multimedia	Networking	Consumer
Cellular/PCN	Cellular/PCN	Portable PC	Peripherals
Automotive	ISDN	Workstation/servers	Portable PC
PC/peripherals	Factory controls	Multimedia	Communication
Consumer	PC	ISDN	Automotive
		Cellular/PCN	

Source: Dataquest (November 1991)

evaporate quickly under the eternal vigilance of the consumer. In semiconductors, the Japanese have cultivated an enviable reputation for quality that pervades their other product areas. To remain to be seen as viable, world-class semiconductor suppliers, U.S. semiconductor companies cannot afford to be perceived as any less conscious of quality. According to Geno Ori of Motorola Incorporated, "Quality is what the customer says it is." Mr. Ori believes that although companies claim to understand that product quality really matters, in fact, there are problems in getting companies not only to admit that product quality is a problem, but furthermore to reorient their corporate cultures to embed quality as a way of life. According to Bob Galvin, former chairman of Motorola, this was the kind of problem that could not be addressed by relegating it to a quality-assurance department. Such a commitment to quality necessitated an enormous upheaval in terms of structures and systems at Motorola—and other companies can expect to encounter the same. The point in institutionalizing quality as a mindset is that quality is not a state; it is a process. The end goal is not static; it is a moving target that requires companies to be ever vigilant. Gene Richter of Hewlett-Packard Company made a similar point but did so from the customer's perspective. He said, "We believe it's the buyer's job to help the supplier keep a long-term focus."

Dataquest Perspective

In his presentation reviewing Dataquest's expectations with respect to electronic equipment production trends driving semiconductor consumption, Dataquest's Greg Sheppard reiterated Dataquest's contention that the market dynamics are undergoing a shift in value added and that the driving applications for semiconductor consumption will have as their target the consumer (see Figures 4 and 5).

Despite the fact that the electronics industry is maturing, Dataquest still sees it as an industry offering many application opportunities. Table 1 lists the opportunities that Dataquest predicts will drive semiconductor consumption on a regional basis.

With the boundaries between what constitutes a data processing application and what constitutes a consumer application getting ever more fuzzy, Gene Norrett of Dataquest exhorted U.S. companies to look to the consumer market for future prosperity. Mobility and miniaturization are driving forces in the semiconductor industry. Expertise in marketing and distribution is as important as, if not more important than, the product. ■

By Patricia Galligan

The New MCC: An Attractive Investment

The recent Microelectronics and Computer Technology Corporation (MCC) Packaging/Interconnect Workshop in Austin, Texas, reflected a growing investment being made by North American companies and government agencies in advanced-package and interconnect research. The workshop entitled "Initiatives for High-Value Electronics" provided an in-depth report on MCC's worldwide Packaging/Interconnect (P/I) research project.

As part of its continued coverage of semiconductor packaging and interconnect market research, Dataquest monitors worldwide government and private-industry-supported R&D activity. This article covers MCC's overall R&D funding, technology developments, patent activity, and major announcements, as well as specific MCC packaging program developments and future directions.

History

MCC was formed in 1982 by 10 North American microelectronics and computer companies to compete with Japan in creating a fifth-generation computer. Since then, membership has expanded to 22 shareholders, 36 associate members, 6 government sponsors, and various academia affiliates (see Table 1). With its growth in membership, MCC's research efforts have expanded from four to six long-range advanced technology programs with four new projects in the planning stages (see Table 2). Membership is available to any company with majority ownership and control by U.S. or Canadian citizens. Shareholders pay a one-time entry fee of $250,000.

Shareholders' activities include sharing costs of programs they select to participate in, appointing MCC board representatives, and providing strategic technical direction for MCC. They also receive royalties for MCC technologies licensed to third parties. For a fee of $25,000, an associate member can monitor research programs and receive nonconfidential technical reports and MCC International Liaison Office (ILO) monthly reports. MCC established ILO services to monitor and report on foreign technology efforts. MCC currently has 430 full-time employees and about 50 part-time employees and graduate students. About 300 researchers work cooperatively with research staffs of member companies, major universities, government agencies, and national laboratories. MCC's budget goal is $55 million in 1991.

Table 1
MCC 1991 Membership

	SHAREHOLDERS	
Advanced Micro Devices	General Electric	Motorola
Andersen Consulting	Harris Corp.	National Semiconductor
Bellcore	Hewlett-Packard Co.	NCR
Boeing	Honeywell	Northern Telecom
Cadence Design Systems	Hughes Aircraft Co.	Rockwell International
Control Data Corp.	Lockheed Corp.	Westinghouse Electric Corp.
Digital Equipment Corp.	Martin Marietta	
Eastman Kodak Co.	3M	
	ASSOCIATES	
Advanced Packaging Systems	Itasca Systems Inc.	SAIC
Allied Signal Inc.	Lawrence Livermore National Lab	SEMATECH
Apple Computer Inc.	LTV Missiles & Electronics Group	Software Engineering Inst.
AT&T	MITRE Corp.	Sun Microsystems Inc.
Compaq Computer Corp. Control	NASA JSC	Tandem Computers Inc.
Conner Peripherals	National Security Agency	Teradyne Inc.
Dover Corp.	Northrup Corp.	Texas Instruments Inc.
DSC Communications Corp.	Occidental Chemical Corp.	TRW Inc.
E.I. DuPont deNemours & Co.	Olin Corp.	United Technologies Corp.
E.I.T. Corp.	Projectavision	Valid Logic
ERIM	Promex	W.T. Automation Inc.
E-Systems Inc.	Rogers Corp.	
	GOVERNMENT SPONSORS	
Advanced Technology Program/Department of Commerce		NASA
DARPA		U.S. Air Force
Department of Defense		
	UNIVERSITY RELATIONS	
Carnegie Mellon University	Texas A&M University	University of Houston
Lehigh University	University of California, Berkeley	University of Texas, Austin
Stanford University	University of Cincinnati	

Source: MCC

Table 2
MCC Research Program

Established Programs	New Projects
Advanced Computing Technology	Power Sources Computer Aided Design
Computer Physics Laboratory	Displays
Packaging/Interconnect	First Cities
Software Technology	Enterprise Integration
Experimental Systems Laboratory	

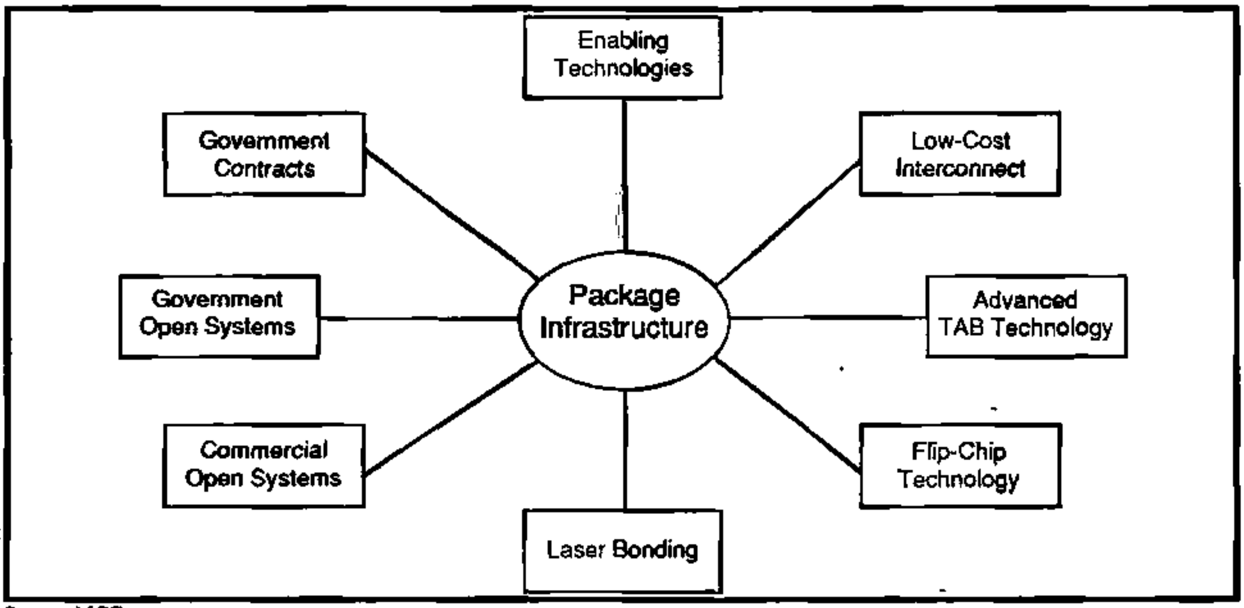
Source: MCC

Packaging Interconnect Program

MCC's P/I program is a continuation of the original six-year, $30 million Semiconductor Packaging and Interconnect Program, initially directed by Dr. Barry Whalen. Currently, 27 companies fund P/I program research. Under direction of Dennis Herrell, the goal of the P/I program is to develop and provide access to a package infrastructure including advanced packaging, assembly, and interconnect technologies consistent with both commercial and military application requirements. As of this publication, MCC's P/I patent activity includes 39 patents under preparation and 37 patents awaiting approval by the U.S. Patent Office. Seventy other patents have already been issued to MCC.

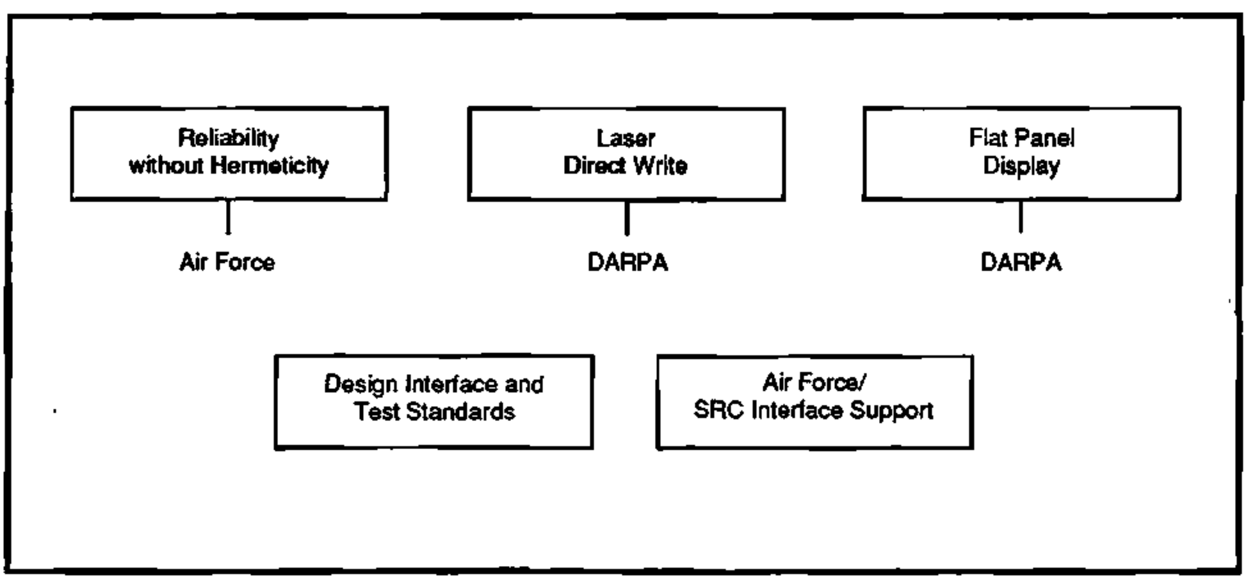
Figure 1 illustrates current MCC P/I research projects funded by both industry and government shareholders. Figure 2 illustrates current

Figure 1
MCC P/I Research Projects



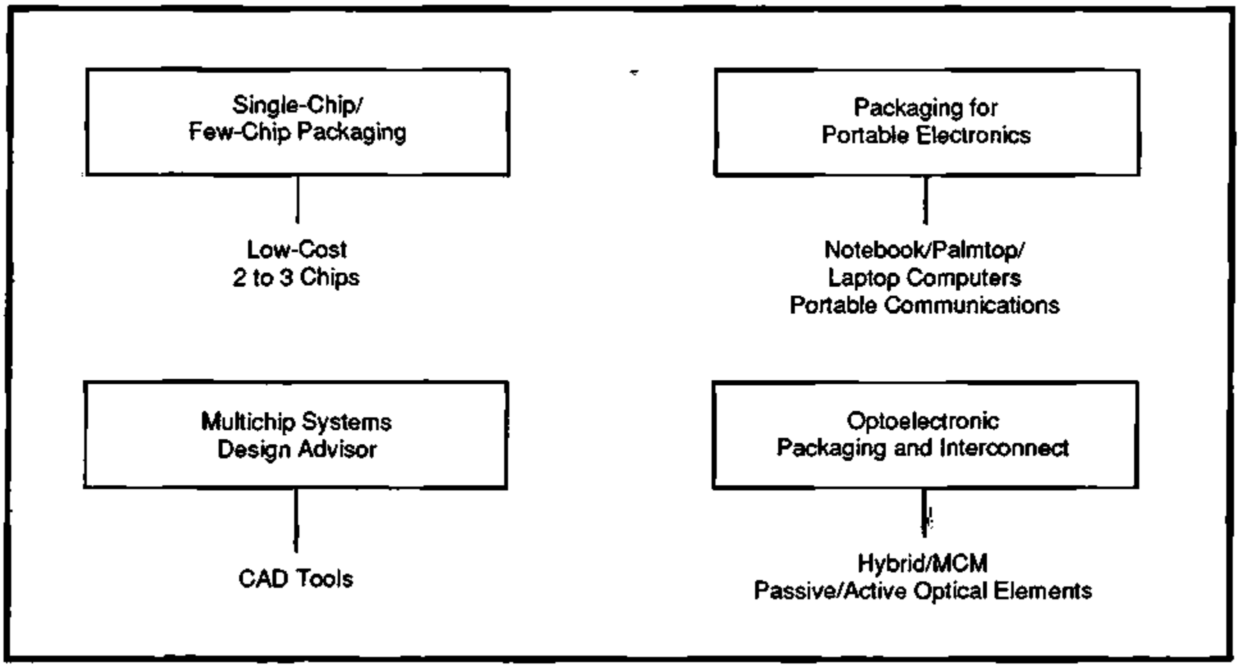
Source: MCC

Figure 2
Government P/I Projects



Source: MCC

Figure 3
Proposed P/I Projects



Source: MCC

government-proposed P/I projects funded by government agencies and private industry. Figure 3 illustrates new P/I projects that are proposed additions to the current P/I program.

Dataquest Perspective

Realistically, the goal of any R&D program is its usefulness to its investors and their ability to capitalize or build a return on their investment. One of the most critical problems that consortia sponsors face is their ability to transfer the consortia-built technology from prototype to commercial product. Companies successful at refining MCC's P/I developments and applying the technology to their real-world problems are:

- Control Data Corporation (CDC) began production on its first order for multichip module interconnect substrates. CDC will also incorporate MCC's quick-turnaround interconnect design, die encapsulation process, and tape-automated bonding (TAB) techniques.
- Electro Scientific Industries is the first third-party licensee of MCC's laser bonding project.
- Digital Equipment Corporation has incorporated the MCC TAB process in the DEC VAX 6000 Model 400 system. ■

By Mary A. Olsson

MCC Promotes Fuzzy Logic

Microelectronics and Computer Technology Corporation (MCC) has caught the fuzzy logic bug and is currently engaged in promoting this technology throughout the United States, where its existence has yet to be acknowledged in any significant measure. In an effort to "defuzzify" this subject somewhat, Dataquest recently attended a fuzzy logic workshop hosted by MCC. Here is what we discovered.

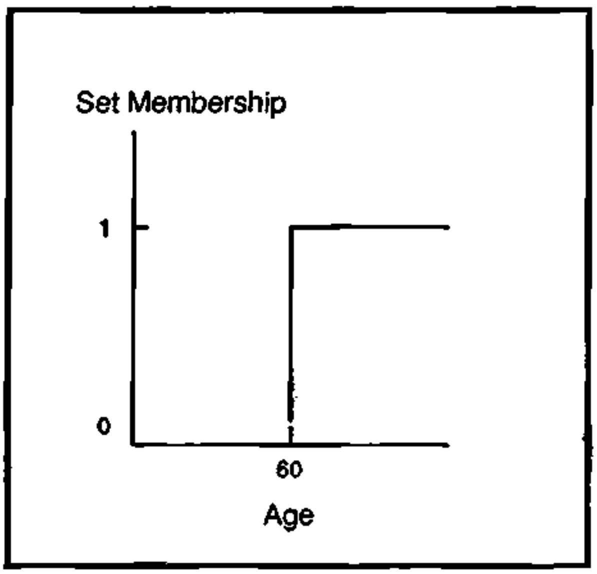
What is Fuzzy Logic?

Apparently MCC has identified a chronic need to raise awareness of the value of fuzzy logic in the U.S. electronics community. MCC wants to work toward setting up standards for fuzzy logic in order to facilitate dissemination of this technology into mainstream computing in the United States. However, before discussing MCC's efforts with respect to fuzzy logic, it may be useful to clarify what is meant by the term "fuzzy logic." An example will illustrate the concept. Suppose that we are designing an exercise program and wish to incorporate special considerations relating to old people. To deal with the set of old people, the characteristic function would be to designate that a "1" is equal to members of the set, whereas "0" is a nonmember (see Figure 1). This concept is represented by the equation A = {x| x > 60} whereby a 60-year-old person is defined as "old."

However, with the threshold point set at 60 years old, a person who is 60 and a day would be in the old set, while someone at sixty minus a day would not. In tailoring an exercise program for these two individuals, their small difference in age should not result in a widely different program. The purpose of a fuzzy logic approach would be to design an exercise program that is applied *in proportion* to the degree that someone is old. This concept is shown by the equation A = {x, f(x)}, so that the degree of set membership is always retained through the function of x as illustrated in Figure 2.

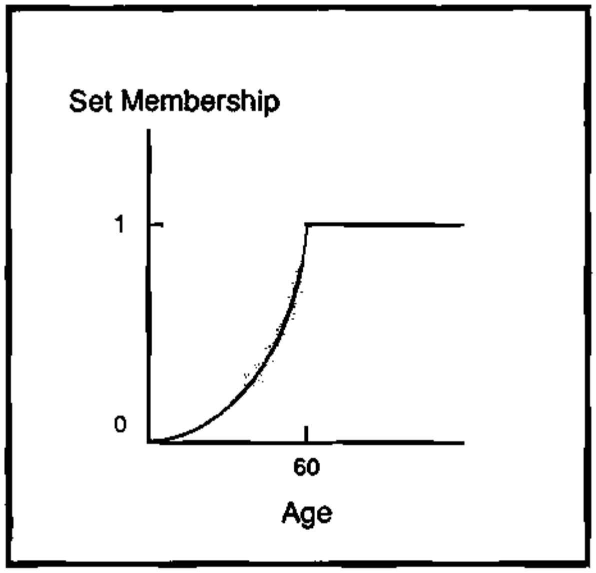
Fuzzy logic is able to deal with what are referred to as linguistic variables (e.g., large-positive, small-negative), thus smoothing out the variability in the continuum. Because each variable does not have to be compartmentalized and represented by a set rule, fuzzy logic results in fewer rules needed to define a system. From empirical data, MCC determined that fuzzy logic is effective in reducing development time and integration time.

Figure 1
Set of Old People—Digital Representation



Source: MCC

Figure 2
Set of Old People—Fuzzy Representation



Source: MCC

Japan Abounds with Fuzzy Projects

Because MCC hopes to borrow from existing standards and experience, participation by the Japanese is viewed as a key ingredient and apparently its proposal in soliciting Japanese participation in its activities was well received. To judge from the scale of their activities in this arena, the Japanese are completely convinced of the merits of this technology. They have major consortia devoted to fuzzy logic development, and many companies are already providing hardware solutions. The Japanese have long been engaged in fuzzy-type activities, holding about 2,000 patents. Their major research activities are represented by three organizations—Laboratory for International Fuzzy Engineering Research (LIFE), Fuzzy Logic Systems Institute (FLSI), and Japan Society of Fuzzy Theory and Systems (SOFT)—that boast widespread industry support. The Japanese view of the applicability of fuzzy logic is very extensive and ambitious. It is referred to as the answer to soft-information processing, and the goal is to embed fuzzy logic throughout all computers so that humans can eventually have an intelligent conversation with a computer. Table 1 provides insight into the extent to which the Japanese can currently implement this technology.

Table 1
A Few Japanese Fuzzy-Based Products

Hitachi Ltd.	**Mitsubishi Heavy Industry**
Light Rail System	Air Conditioning System
Appliances	**Nissan Motor**
Investment Advisory System	Automobile Transmission
Keihin, Nippon, and Toshiba	Anti-Lock Braking System
Scheduling for Bus Transportation	**Omron**
Komatsu Ltd.	Universal Fuzzy Controller
Diagnostic System for Machine Tools	Data Analysis for Physicians
Maruman Golf	**Sanyo Electric**
Analysis of Player and Golf Stroke	8mm Video Camera
Matsushita Electric	**Sony Corporation**
Washing Machine	Palmtop Computer
Vacuum Cleaner	TV Enhancement System
Shower Head	**Yamaichi Securities**
Camcorder	Portfolio Management System
Mitsubishi Electric	
Elevator Control System	
Air Conditioner	

Source: MCC

Table 2
Comparison of Machine Intelligence Technologies

	NN	FS	ES
Adaptive	Y		
Data Intensive	Y		
Good for Nonlinear Problems	Y	X	
Good for Large Dimensional Problems	Y	X	
Can Learn from Existing Data	Y	X	
Generalizes	Y	X	
Good for Noisy/Inaccurate Data	Y	Y	
Works Well in Clearly Defined Domains	X	Y	Y
Transparent (not a black box)		Y	Y
Knowledge Intensive		X	Y
Can Generate Explanations		X	Y

Y = Yes, X = In Certain Cases
Source: MCC

MCC To Spearhead Fuzzy Logic Project

Project Background

MCC's work in neural networks and artificial intelligence (AI) has led it to embrace fuzzy logic as "the missing link." MCC's perception of fuzzy logic is that it occurs somewhere between neural nets and expert systems with knowledge-intensive applications best done by expert systems and adaptive/learning/generalized applications being performed by neural nets. The real advantage of fuzzy logic is that it is considered "transparent," that is, the internal workings of the system are accessible and understandable, a major problem with neural networks. Table 2 gives a comparative assessment of the relative applicability of neural networks, fuzzy systems, and expert systems, respectively.

Table 2 compares these three machine intelligence technologies on the basis of general intelligence criteria, but it does not give a clear view of application areas where each of these technologies represents the optimum choice. Fuzzy logic has strong advantages in simplifying traditional control systems, the proportional-integral-derivative controls that are traditionally used in mechanical systems.

MCC wants to be involved in advancing the cause of fuzzy logic from an early stage before it gains widespread acceptance in the United States to encourage greater convergence toward a single, de facto standard. MCC believes that, initially, products should map to existing hardware, but it does not want to force a convergence to a standard until the best model is known. A de facto standard implies a symbiotic relationship with a standard that would emerge from the empirical development work. A convergence at some later time would start to impact hardware considerations also.

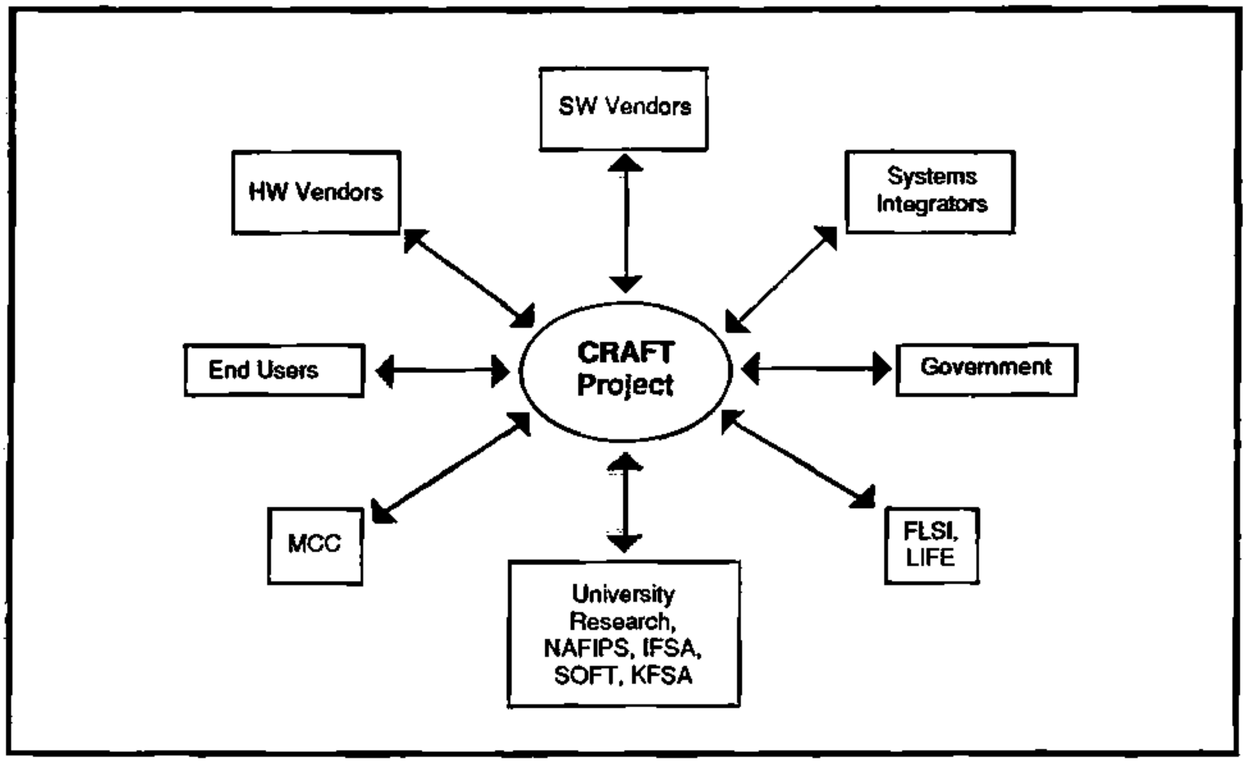
Project Administration

The fuzzy logic project would be administered under the auspices of ATLAS, a separate company from MCC. The impetus for forming a separate company is the need to be able to address its objectives from a worldwide perspective (in contrast to MCC's traditional charter with membership activities restricted to North American majority-owned companies). Designated CRAFT for Common Runtime Architecture for Fuzzy Technology, this project will be soliciting membership from organizations worldwide. Figure 3 provides a visual representation of how MCC views participation in the CRAFT project.

Among MCC's credentials, which support its role as a driver for this undertaking, are its strong technical expertise in the areas of distributed systems, heterogeneous systems interoperability, neural networks, and AI.

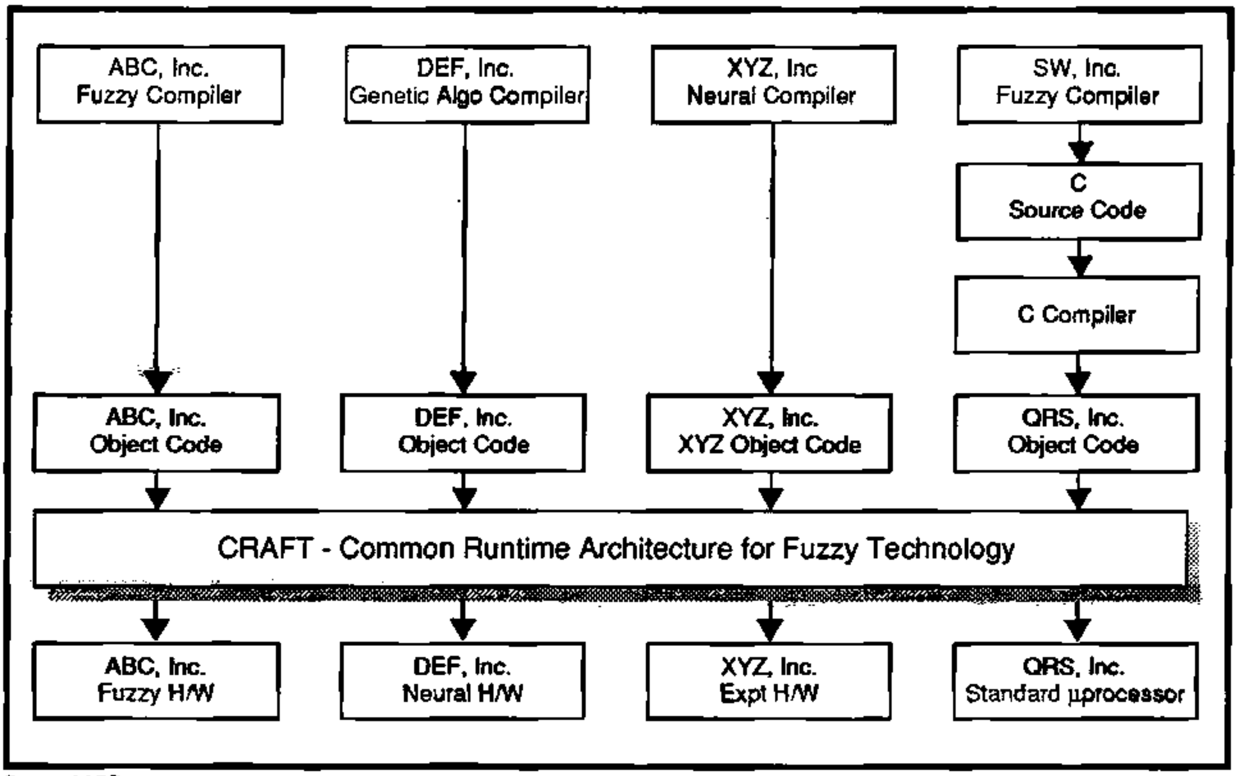
These are in addition to considerable administrative experience in establishing multicompany collaborative research projects. CRAFT is envisioned as a three-year project with a first release of software scheduled for mid-1993 and a second software release scheduled for the latter part of 1994. MCC is hoping to staff the project in time

Figure 3
A Distributed Cooperative Project



Source: MCC

Figure 4
CRAFT—Needed for Expanded Fuzzy Use



Source: MCC

for an April 1992 launch. Figure 4 illustrates CRAFT's place in expanding the role of fuzzy logic.

Dataquest Perspective

This venture is beyond the scope of MCC's charter as originally conceived (please refer to "The New MCC: An Attractive Investment" in this issue) in that it solicits membership on a worldwide basis, which may raise questions among MCC's current membership/sponsorship community. If MCC is successful in its venture, its efforts will serve to educate a potentially large U.S. user base as to the merits of fuzzy logic, an audience to whom the Japanese companies are anxiously awaiting the opportunity to sell their hardware products. At this point Dataquest recommends that interested companies invest some resources in evaluating this potentially lucrative market in order to formulate such strategies as may be needed should the market materialize. ■

By Patricia Galligan

News and Views

The "Branding" of Intel

Intel Corporation's announcement at its recent financial analyst meeting of plans to spend some $125 million on consumer advertising over the next 18 months has struck a responsive chord with industry watchers, who are attempting to digest its implications. Intel will be spending large sums on "brand" recognition. What are such large expenditures likely to buy?

The Issues

In consumer marketing it is a well-documented phenomenon that brand recognition is important and generates greater market share. This premise presumably underlies any program targeting the consumer. Intel's presumed objective is that everyone in the market for that product—high-end PCs—will specify its brand name. One question we would ask is whether the X86 family of processors is a product that will respond to direct consumer advertising.

Another question concerns issues of potential conflict with Intel's OEM customers. The OEM is interested in differentiating its products and wants to promote brand recognition for its own name and not necessarily for anyone else's. After all, powering one's DOS-based product family on the Intel architecture is not a differentiator within the DOS-based environment; rather, it is a requirement for competing in that market segment. Hence, DOS compatibility is a given and OEM product differentiation is achieved through other system features.

Promoting brand name recognition for a sometimes sole-sourced product for which so much impetus already exists seems inefficient (and possibly dangerous for OEMs). Does Intel expect such an influx into its territory by other manufacturers of X86 chips as to necessitate differentiating its IC from the competition? In fact, the near-sole-source conditions for the latest generations of X86 devices mean that the majority of OEMs depend on Intel for their supply of DOS-compatible CPUs. Does Intel anticipate that brand name recognition could allow it to lure away buyers from other non-Intel architectures? This would seem to be a more remote proposition. Because the OEMs have long been engaged in such efforts, it would seem improbable that Intel could best their efforts.

Intel has stated that, because it commands a dominant share of the DOS-based market, in order to grow, the company will have to expand the market at the same time as it increases its share. Advanced Micro Devices Inc.'s (AMD's) second-source license with Intel will expire in about 1995. That means that AMD will have to produce a clean-room version of X86 devices developed after that date and the necessary microcode in order to offer future generations of the architecture. We believe that, contrary to Intel's apparent displeasure at having AMD as a second source for its family, a second producer serves to diminish the need for other (non-Intel) architectures. At a recent Dataquest conference, in fact, Wilf Corrigan, chairman and CEO of LSI Logic Corporation, alluded to Intel's aggressive sole-source posture as having resulted in increased impetus for the development of RISC-based microprocessors in response to market frustration about Intel policies. From Intel's point of view, competition of course forces a decline in margins because its pricing strategy has to take account of a competitor's products. But from the OEM's point of view, some competition contributes to a more aggressive pricing curve than might otherwise exist (and promotes incorporation).

Intel's strategy may also make life difficult for the OEM when it introduces its next processor version (say the 586) and then advertises it to the end consumer. Intel thus will be undercutting its OEM's 486-based product advertising. It is possible that this could generate some ill will among its OEM customers, for although Intel may be targeting the end consumer, its customer will still be the OEMs. OEMs are resigned to having other OEMs undercut their product advertising, but they may not look too kindly on such advertising emanating from their supplier!

Dataquest Perspective

No doubt Intel has launched this strategy under advisement. However, from our vantage point, there doesn't seem to be any particularly compelling reason for undertaking such an expensive advertising campaign. Targeting the end consumer is always a risky proposition; the end consumer can be very fickle. It is probably safe to say that nothing is too good or too inexpensive for the average consumer. Because Intel is not known as the low-cost leader of the Intel architecture, the company runs the risk of being viewed as either the high-priced or overpriced option; moreover, if there are product shortages or any kind of quality problems, the ire of the consumer is easily aroused and slow to be assuaged. We consider it fair to characterize the consumer as a high-risk proposition and a creature with which Intel has limited (if any) experience.

Nevertheless, it must also be said that Intel's management has demonstrated superior canniness over the past 20-plus years in building the company into its current impressive status as a $4 billion-plus corporation. Unless we have missed the point entirely, it therefore begs the question that management's intentions in this stratagem are not at this juncture totally transparent. So what might they be?

It is possible that this tactic is a precursor to some more grandiose future plans. For example, it is conceivable that this experience may feed into future product unveilings such as the company's multimedia products or possible aspirations to launch a computer product line of its own. Intel may envision such product offerings as a realization of its Digital Video Interactive technology as a future Nintendo-type consumer product or as a vehicle to increase consumption of its chip production. Acquiring consumer expertise may be part of a long-term plan to position Intel as a main contender in the race for the consumer's attention. As stated in this issue, the consumer will increasingly be the target of the largest of the worldwide vertically integrated semiconductor companies as the application markets of computing, communication, and consumer merge. Intel obviously aspires to number among these companies. As it launches this new strategy, we suggest that Intel be very careful about whether its mass market advertising is intended to be product-specific or to promote Intel as a corporate entity. ■

By Patricia Galligan

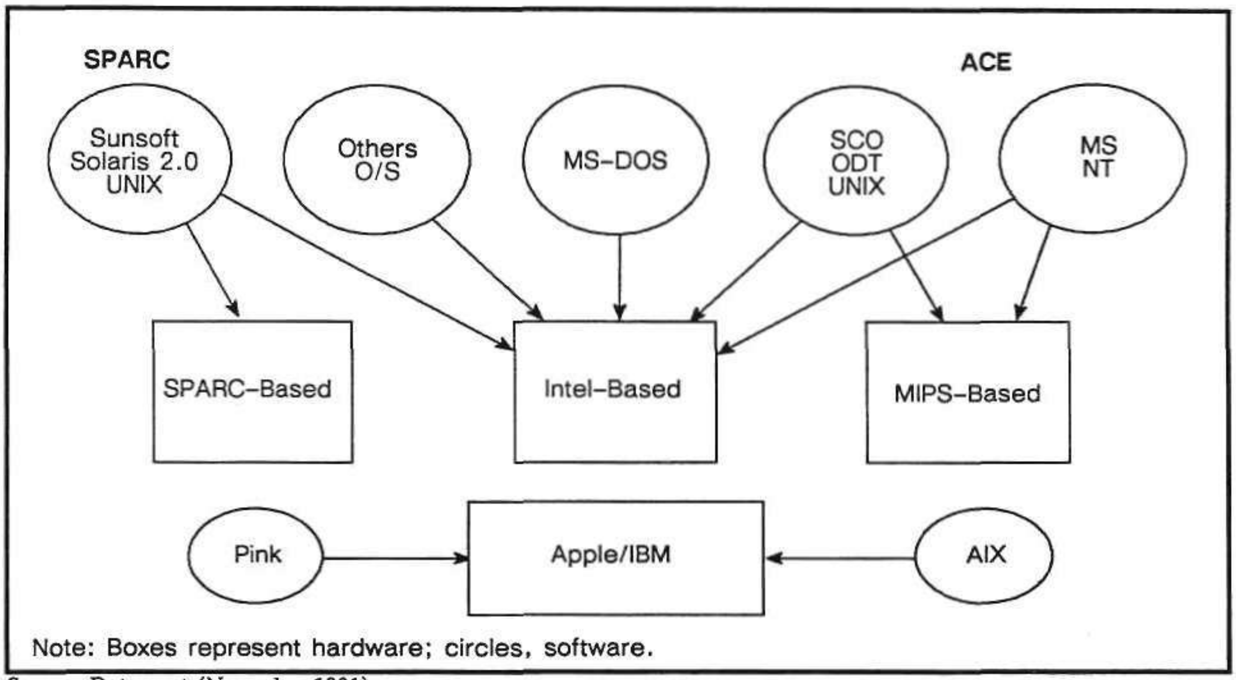
Errata

In the article entitled "Can Intel Lose the Desktop?" in the Products, Markets, and Technologies *Dataquest Perspective,* Vol. 1, No. 3, Figure 1 inadvertently omitted a connecting line pointing from the MS NT circle to the MIPS-Based box. We reprint the correct figure here and apologize for any confusion this may have caused.

In Future Issues

Among the topics to be featured in a future issue of *Dataquest Perspective* is a discussion of the issues relating to the transition of ICs from the 5-volt standard to a low-voltage standard.

Figure 1
Bid for the Desktop



Source: Dataquest (November 1991)

For More Information . . .

On the topics in this issue	Products, Markets, and Technologies (408) 437-8642
About on-line access	On-Line Service (408) 437-8576
About other Dataquest publications	Sales (408) 437-8246
About upcoming Dataquest conferences	Conferences (408) 437-8245
About your subscription	Customer Service (408) 437-8402
Via fax request	Fax (408) 437-0292

Dataquest
a company of The Dun & Bradstreet Corporation

Dataquest Perspective

Semiconductors
Worldwide

Products, Markets, and Technologies

Vol. 1, No. 5 **December 23, 1991**

Technology Analysis

On the Verge of 3 Volts

A host of battery-powered, hand-held systems has heralded the advent of low-voltage ICs. The 5-volt standard has reigned for more than two decades, and the transition to a new standard will not be a trivial task. Companies will have to contend with many complex issues as they formulate their strategies to migrate products to the new standard. This article attempts to put the various issues relating to this topic in perspective by addressing the following elements:

- Technical considerations regarding migration to 3 volts
- Standards
- Issues
- Driving applications
- Dataquest's perspective

Technical Considerations

Components of Power Consumption

The question of what is driving low voltage raises two main technical considerations. These considerations relate to lithography and to power consumption. Companies say that the driving force to low voltage is customer requirements that specify battery operation of portable equipment. Some of the major benefits incurred from a lower operating voltage include the following:

- Systems will have a longer battery life.
- ICs can still be packaged in inexpensive plastic packages.
- Small hand-held devices do not need fans or other expensive thermal management schemes.

Nevertheless, although power consumption is mostly referenced as the driving force toward lower-voltage operation, an equally compelling reason relates to device physics. It just so happens that the applications are emerging at a time when lithography would soon have forced the issue.

Options for Reducing Power Consumption

The power consumption of a CMOS transistor is primarily a function of capacitance, frequency, and voltage. Over the past several years, capacitance and voltage have been held relatively constant while frequency (driven by system clock rates) has steadily increased. Concurrently, ever-increasing transistor count means that with each new product generation there are more transistors, each of which consumes more power. Thus each new generation of products consumes more power than the last. Consequently, system power consumption has increased dramatically. This increasing power consumption places a greater load on the power source and requires more efficient thermal management, in terms of both an IC package's ability to conduct heat away from the die and the heat being removed from within the system.

In a battery-operated system, increased load shortens battery life and increased heat adversely affects system reliability. As frequency and performance are interdependent, reducing operating frequency is not usually considered a viable option to power reduction. Capacitance is inherent in the manufacturing process; therefore, it is difficult to reduce. Reducing the number of transistors decreases the functionality of the system, which is also an impractical solution. While capacitance and frequency contribute linearly to power consumption (see Figure 1), voltage is a square relationship (see Figure 2). Because of the square relationship of voltage, a small reduction in voltage significantly reduces the power consumed. This fact is the primary motivation behind the move to a lower-voltage standard.

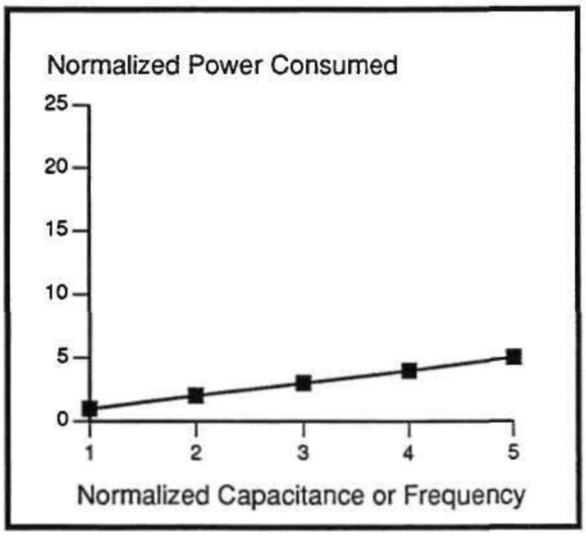
Other Forces Driving Low Voltage

As lithographies continue to shrink, the channel width of the transistors also continues to shrink. As these channel widths approach 0.5 micron, the voltage placed across the channel must be reduced. Placing 5 volts across a 0.5-micron transistor causes a permanent drain turn-on, which is effectively a short circuit rendering the transistor useless. To eliminate this drain turn-on condition the voltage applied across the transistor must be reduced. Although voltage reduction can be performed on-chip with a simple voltage divider without requiring an external low-voltage power source, such an approach not only increases the size (and hence the cost) of the die, but also it does not address the applications needs of portable systems.

Conservation

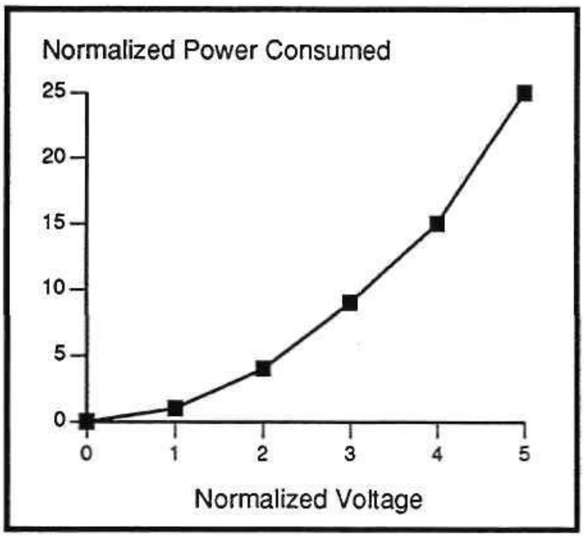
Figure 3 shows where power is consumed in a full-featured laptop computer. Mechanical peripheral devices consume most of the power—especially the display subsystem, hard disk, and floppy-disk drives. Main memory is the next major power consumer, while other electronic components account for the rest.

Figure 1
Linear Relationship



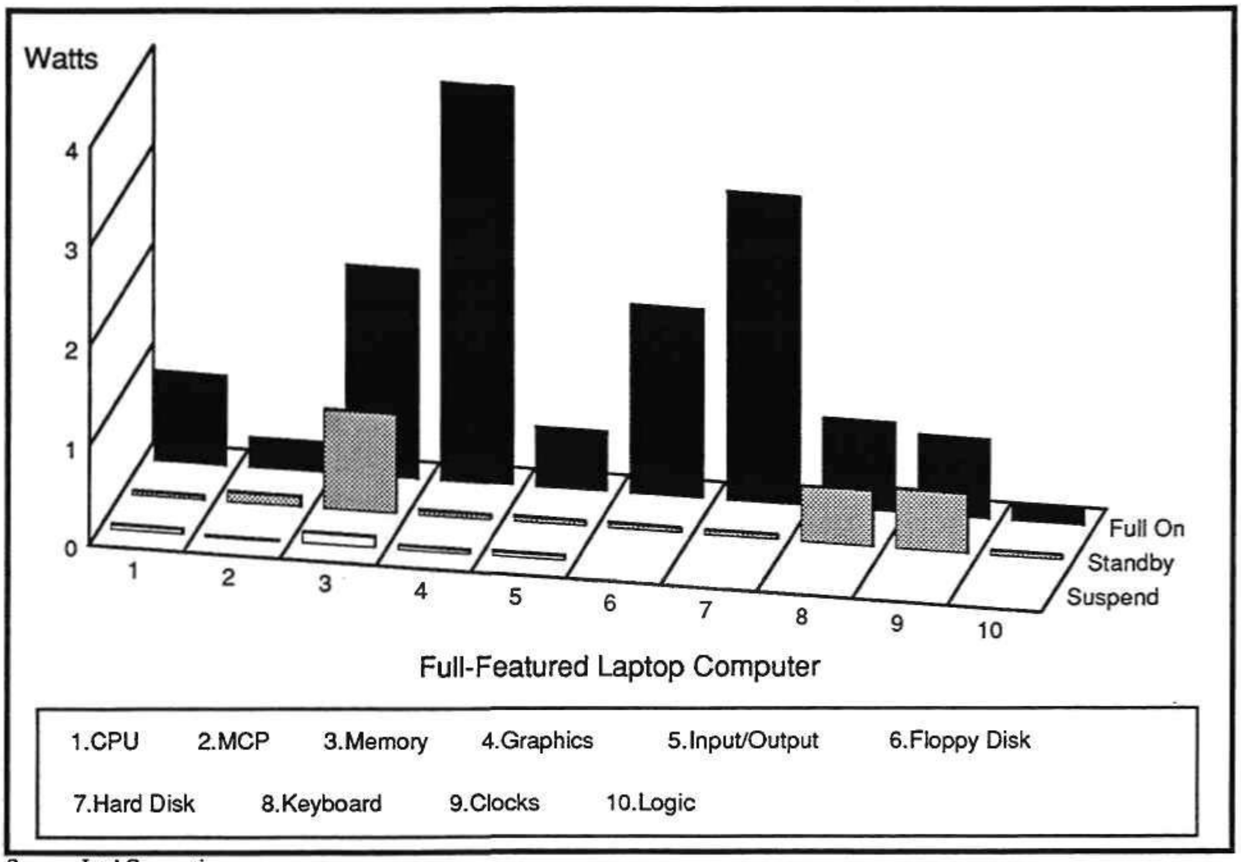
Source: Dataquest (December 1991)

Figure 2
Square Relationship



Source: Dataquest (December 1991)

Figure 3
Estimated System Power Consumption



Source: Intel Corporation

Unfortunately, most of the power consumed by a fully energized PC under typical operating conditions is wasted. Idle PCs may do no useful work for an extended period of time, yet power continues to be consumed. In battery-operated equipment, such a power drain is intolerable. Low-voltage operation as a means of extending battery life goes hand in hand with power management or conservation, which is a critical ingredient in maximizing battery life. Power management techniques focus on minimizing the active operating power in particular when a system is not in full use.

To illustrate how significant the improvement in battery life time can be through effective power-management schemes, we present here data sourced from Intel based on the Intel386 SL SuperSet (see Figure 4). This device currently operates on the 5-volt standard, although all ongoing SL product development is being undertaken in the context of 3.3-volt operation.

In addressing the problems of power optimization, Intel defined its approach as threefold: System components must be designed to reduce power demands or let power be removed entirely; control logic must monitor peripheral usage to determine when to disable or re-enable power to the peripheral subsystems; and power-management facilities must preserve full compatibility with all existing software. Intel's objective in introducing its Intel386 SL product was to provide systems integrators with transparent power management for the CPU as well as other system elements.

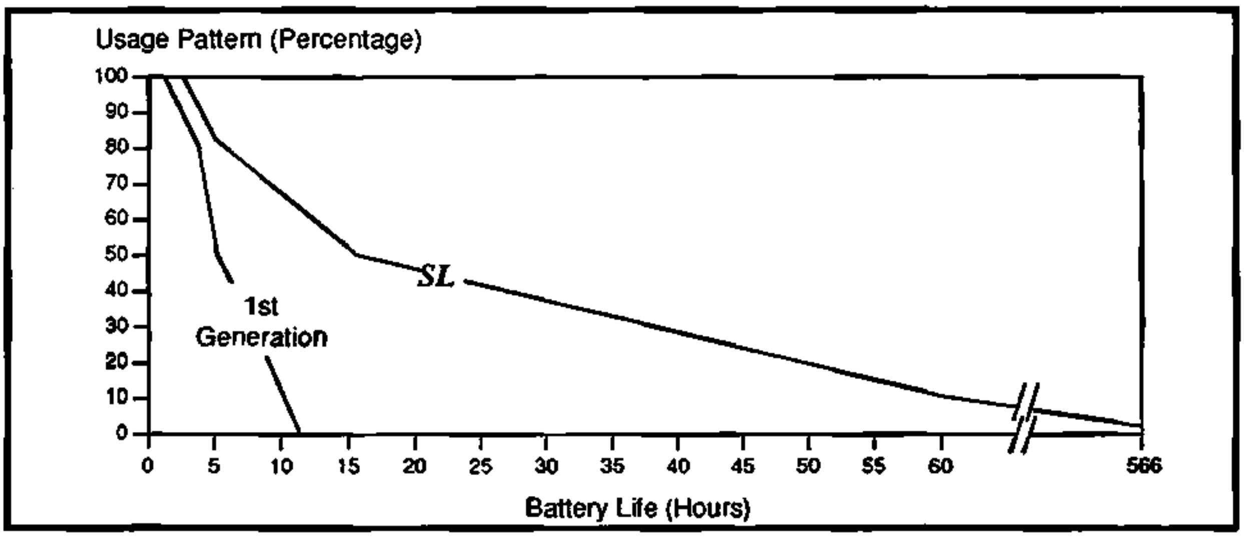
Standards

Standards represent an area of prime importance and, currently, something of a dilemma. Standards involving supply voltage, supply voltage tolerances, input/output (I/O) voltage thresholds, and issues such as regulated versus unregulated power are a source of confusion and debate.

The original JEDEC standards that most companies claim as their references—JESD8.1 and JESD8.0—date from 1984. The former targets higher performance applications, with a regulated power supply and transistor-transistor logic (TTL) interface. The latter was intended to address battery users' needs for low power to enable unregulated 2.0- to 3.6-volt operation as well as regulated 3.0- to 3.6-volt operation.

All the companies interviewed claimed adherence to the JEDEC standard for 3.3 volts; nevertheless, it became increasingly obvious that companies seemed to be implementing I/O voltage thresholds differently. Although agreement existed with regard to the supply voltage being specified as 3.3 volts ±0.3 volts, direct current specifications between individual suppliers seem to be inconsistent with those specified in Table 1.

Figure 4
Power Management Aids Battery Life



Source: Entry Level Products Group

Table 1
JESD8.1 DC Characteristics

Description	Parameter	Limits Min.	Limits Max.	Conditions
Output Low Voltage	V_{OL}		0.4V	I_{OL} = 4.0 mA
Output High Voltage	V_{OH}	2.15V		I_{OH} = -200 μA
Input Low Voltage	V_{IL}	-1.2V	0.8V	$V_{OUT} \geq V_{OH}$ (min.) *or*
Input High Voltage	V_{IH}	2.0V	4.8V	$V_{OUT} \leq V_{OL}$ (max.)

Notes: V_{CC} = 3.3 ± 0.3V, across operating temperature range
Source: JEDEC

Research into the JEDEC standard revealed that its low-voltage and electrical-interface standards committee, JC16, is feverishly working on updating the existing standards. Ballots have been distributed to its members and will affect JESD8.1, referred to as the LVTTL (low-voltage TTL) standard. The intention is to bring the standards in line with the limitations of technology as well as supporting practical systems requirements. Although JESD8.0—otherwise referred to as the low-voltage CMOS standard—is currently under review, it is not certain that a revision will be required. However, as most systems are still designed to TTL interface specifications, JESD8.1 is the most critical standard to be addressed at this time.

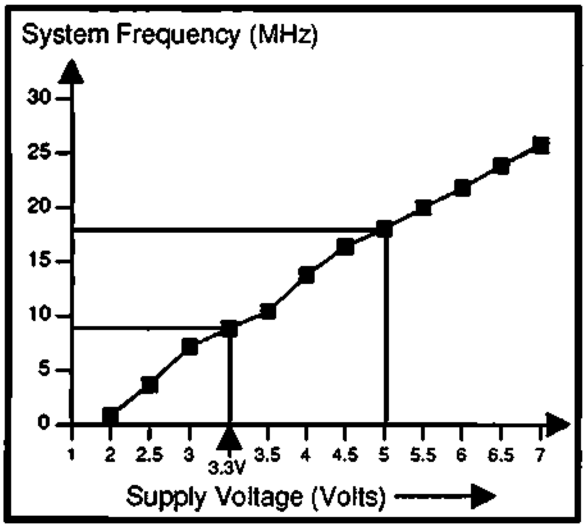
The LVTTL standard proposal is expected to be completed early in 1992 with a companion proposal for battery-operated systems expected to be completed a few months later. However, until standards are solidified and adhered to, the onus rests with the system designer to ensure that the various components of the system can interface together under worst-case operating conditions. Given the differences in existing data sheet specifications, it may be necessary for systems manufacturers to require special testing to ensure compatibility. Once JESD8.1 has been updated, we may begin to see consistency between the various IC suppliers.

Issues

Performance

The move toward lower operating voltages is not without its trade-offs. A fundamental problem is performance. Although lowering voltage dramatically reduces power consumption, it also reduces the field across the transistor; this in turn reduces the transistor's performance. As supply voltage decreases, the frequency of operation goes down (see Figure 5). To illustrate how significantly a decrease in voltage can impact performance, the performance of a 5-volt device would be roughly halved if operated at 3.3 volts.

Figure 5
Supply Voltage versus Frequency



Source: Hitachi

Conversion

Power savings would be considerable for systems fully converted to the new low-voltage standard. However, systems based on mixed-level voltages would equate to only moderate savings. The issue from the systems integrator's point of view is that, in order to take full advantage of the switch to 3.3 volts, all components need to be available. Many component specs are not at 3.3 volts yet; for a large-scale conversion to occur, a critical mass of needed components will have to exist. The conversion is no simple task. No boilerplate plan exists; there will have to be a transition phase. It seems that many suppliers are preparing to introduce their products initially to operate over the range of 3.3 to 5 volts. Companies delivering portable solutions will not wish to involve themselves in more levels of voltage than are absolutely essential. Applications that need the benefits of low voltage will be re-engineered.

Component Availability

Meanwhile, access to adequate supplies of devices is spotty, and specification compatibility is an issue. For instance, although it is not widely known, many Japanese suppliers offer 3.3-volt products. Although current 16Mb memory devices operate internally at 3.3 volts through a step-down feature, their interface is still at the 5-volt level. Another issue is whether suppliers of memory devices will redesign the current volume shipper, the 1Mb, to the new standard. Certain product areas may present significant difficulties when it comes to the transitions to low voltage. Such products include disk drives, analog-to-digital (A/D), EPROMs, liquid crystal displays (LCDs), and RF (radio frequency). The recently introduced 1.8-inch small form factor disk drives operate at the 5-volt level. Dataquest believes that the 1.2-inch version could be introduced next year to operate at the 3.3-volt level. We believe that some of the drives—for example, the 1.8-inch and 2.5-inch drives—may be reworked to operate at the lower-voltage levels. It is unlikely that this rework would go beyond the 2.5-inch form factor, however. A few suppliers have announced EPROMs/OTPs that can be read at 3.3 volts, but programming at that level would pose a major challenge. Low voltage is more of a concern for FLASH memory devices because of their in-circuit programming requirement. Suppliers are currently struggling to reach a 5-volt program voltage. Of course no one is even talking about bringing LCD operation into the realm of 3.3 volts. Systems already currently incorporate a separate power supply for the LCD, however, and it is expected that the current levels of ±15 volts will also be reduced to help improve battery life.

Reliability and Noise

Lower operating voltage also means less heat generation, helping both circuit manufacturers and system designers improve packaging and reliability. Also, the fact that low-voltage operation may enable certain devices to be housed in lighter packaging can be a bonus as the lighter packaging tends to be more resistant to certain kinds of damage. For example, heavy ceramic packaging is susceptible to cracking when dropped because of the sheer weight involved.

Another advantage inherent in lower operating voltages pertains to a reduction in system "noise" generation of electromagnetic interference and radio frequency interference. Moving to a 3.3-volt system, however, entails no advantages with respect to ground bounce. Ground bounce—a function of inductance, the switching speed of the transistor, and the amount of current that is put through the transistor—may in fact be adversely impacted. If the same loading and transistor switching times are used in a 3.3-volt system as in a 5-volt system, migrating to the lower voltage level will only exacerbate the problems associated with ground bounce (that is, performance degradation and reliability). To alleviate this problem, the JEDEC specification for LVTTL has limited the current that can be switched to 4.0mA. However, it does not set any limits on switching speed (edge rates). Optimizing output switching speeds for system performance will be a major challenge for semiconductor manufacturers and will require systems-level expertise.

Although questions have been raised about how the switch to lower voltage would affect electro-static discharge (ESD), it appears that because ESD dissipation occurs at the pad area and because the peripheral transistors on a 3.3-volt device will not shrink, susceptibility to ESD should pose no additional problems.

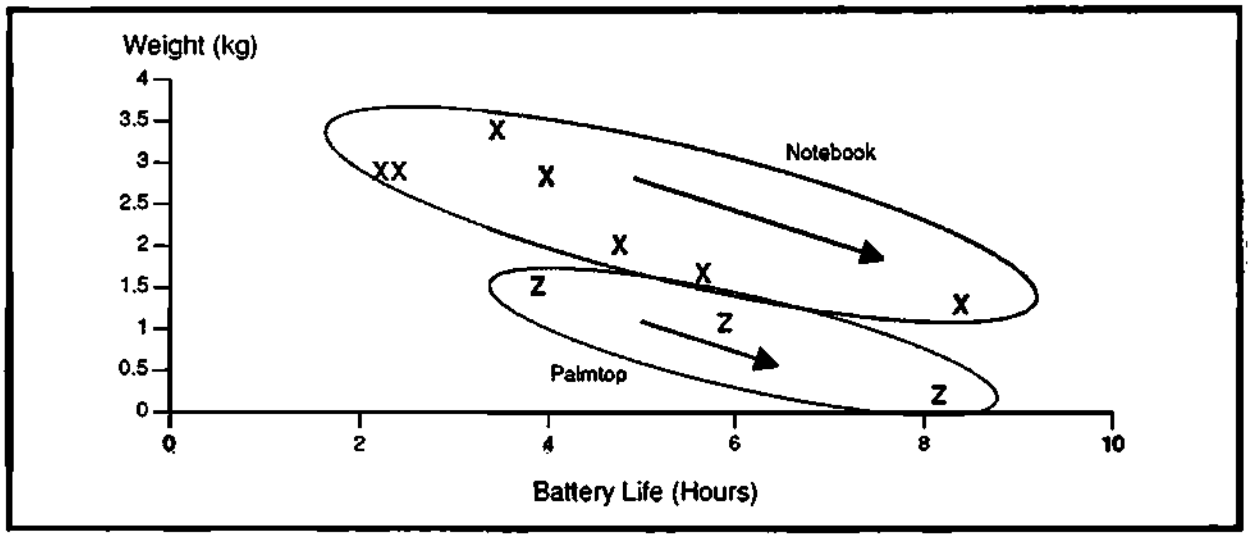
Battery Technology

Extending the useful battery life of a portable system is a major objective. In estimating how long a battery should last in order to meet the most common requirement, companies appear to be assuming a rule of thumb that batteries should last at least the duration of an airplane trip across the United States or about an eight-hour work day. A pair of AA batteries, the preferred power source for hand-held designs, can supply only 2.7 volts toward the end of their operating life. Therefore, unregulated two-battery systems cannot support the requirements of 3.3-volt devices; they require a more aggressive design such as 3 volts ±10 percent. The pervasive nicad battery produces a nominal 1.1 volts during recharge but can get up to 1.3 volts. In a standard 3-cell arrangement, this could result in 3.9 volts being supplied to the system if a regulator is not employed. Until battery technologies can provide a flatter voltage over time, regulated systems will be the norm for high-performance, battery-operated systems. However, advances are occurring in battery technology to lead companies to believe that improvements will be forthcoming.

Driving Applications

The rapid migration to a low-voltage standard is being driven by the need to extend the battery life of hand-held or portable systems as shown in Figure 6. Popular applications are likely to include laptop, notebook, and palmtop computers; cellular phones; and memory cards. Dataquest expects the smaller form factor

Figure 6
Battery Life Trend



Source: Hitachi

portable PCs, by virtue of their high volume and high visibility nature, to play a leadership role in driving the migration to low-voltage systems (see Figure 7). Dataquest believes that the high growth portion of the PC market (as represented in Figure 7 by the second bar) may see some 3.3-volt-based systems in the 1993 time frame. For this reason we indicate here a potential 15 percent adder to the market segment that incorporates our forecast of notebook, pen-based, hand-held, and companion PC shipments.

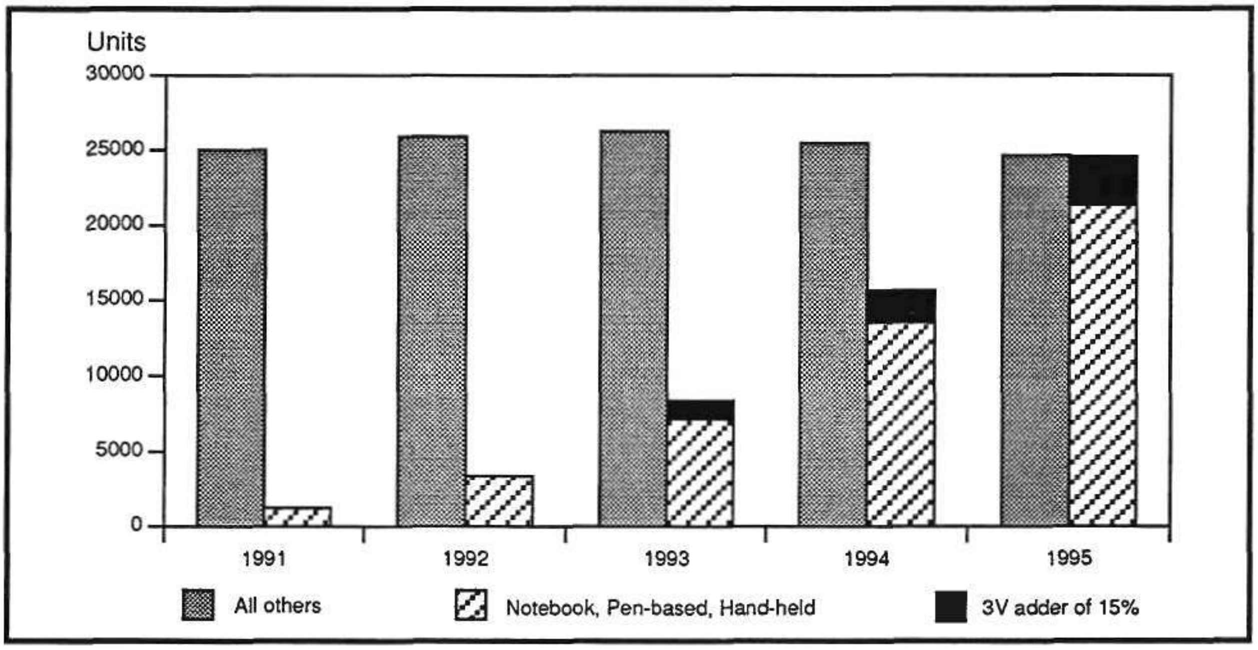
When operating voltage is reduced from 5 volts to 3.3 volts, theoretical component power consumption declines by more than 50 percent. Figure 8 shows how power dissipation is affected by reducing the supply voltage.

The motherboard of a typical notebook PC consumes approximately 35 percent of the system power; therefore, that reduction translates directly to significant battery life enhancement. However, converting the CPU alone to 3.3-volt operation is not sufficient to provide the significant battery life enhancement needed in order to achieve the range of 8 to 10 hours of battery life. The conversion to lower-voltage operating systems will occur in stages. The first notebook PCs taking advantage of lower-voltage technology will be mixed-voltage systems because only the motherboard will operate at 3.3 volts. However, if today's typical notebook consumes 10 watts, for a 1992 hybrid product with the CPU, logic, and main memory converted to 3.3 volts, wattage would be in the order of 7 watts. Such a system will have an operational battery life of seven or more hours. When the PC's peripheral subsystems (such as hard drive, floppy drive, modem) are converted to 3.3-volt operation, additional power savings are achievable; such savings would equate to a notebook of today's size and weight offering battery life of nine hours or more. Dataquest does not expect full 3.3-volt systems to be available until 1993.

Dataquest Perspective

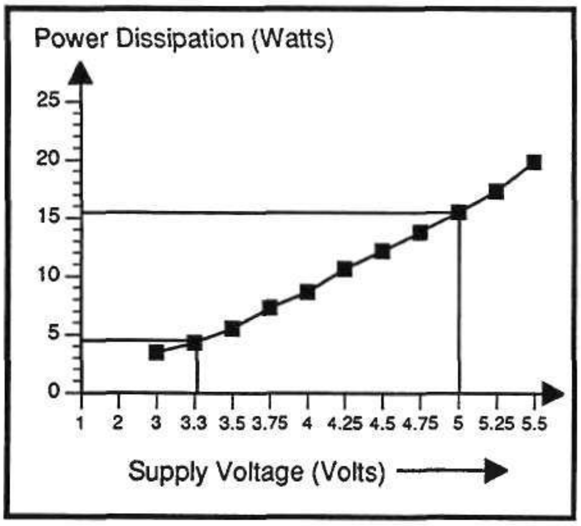
This new technology will take time to develop, and many issues remain to be resolved. Dataquest believes that blanket conversion will not progress quite as rapidly as many industry spokespeople are predicting. Clearly, the PC arena is experiencing a great deal of design activity centered on the very small form factor PCs. Some of the key players in the PC arena are working together to ensure that an adequate supply of critical components will be available according to the new low-voltage specifications. Most of the component suppliers are simply recharacterizing existing 5-volt products to the new standard, however, and interface problems may arise owing to the apparently variable interpretation of JEDEC's 3.3-volt standard of the I/O threshold levels. Moreover, certain clone manufacturers have been known to push an IC beyond its data sheet specification or to base their designs on "typical" rather than "worst-case" specifications.

Figure 7
Worldwide PC Shipments Forecast



Source: Dataquest (December 1991)

Figure 8
Supply Voltages versus Power Dissipation (40-MHz 386 PCMB with 64KB Cache)



Source: Hitachi

While this practice may work in "typical" applications, there is no guarantee that the system will consistently function as expected. In fact, inconsistent or "soft" errors may be a direct result of a manufacturer not designing for worst-case conditions. Current confusion in relation to the low-voltage standards may exacerbate this problem. To further compound the confusion, those attempting to optimize designs for a 3.3-volt environment will find their efforts stymied because the existing standards are in flux.

Despite all the talk that multivoltage systems will be announced in the spring of 1992, followed by fully converted systems in the fall, we believe that this aggressive transition schedule will get pushed out anywhere from 6 to 18 months. With increasing IC integration, chip designers would be ill-advised to simply take existing components wholesale and respecify them for the lower voltage. Extensive redesign may be necessary and, for the broad range of components, will take some time. Despite the fact that product design cycles are ever-decreasing, an average system design cycle will still take between 12 and 18 months, and many of these designs will not be under way until a larger selection of the requisite low-voltage parts is available. Other significant concerns that will still require extensive attention relate to test, design, and device modeling. It may be advisable for IC manufacturers to proceed with such experimentation by recharacterizing existing devices to the new low-voltage standard. ■

By Gerald J. Banks
Patricia Galligan

Product Analysis

Mixed-Signal ICs: North American Domination Masks a Worldwide Opportunity

Summary

Although North American suppliers of analog ICs have been losing worldwide market share during the past decade, mixed-signal IC dominance still belongs strongly to North American vendors. Mixed-signal IC manufacturing requires a combination of analog design, process, and test expertise and specialty processing capabilities such as linear-compatible CMOS and BiCMOS. These particular skills have traditionally been the strength of North American suppliers. This article looks at the mixed-signal IC market, examining the strength of regional suppliers to penetrate this growing worldwide market.

Mixed-Signal versus Linear ICs

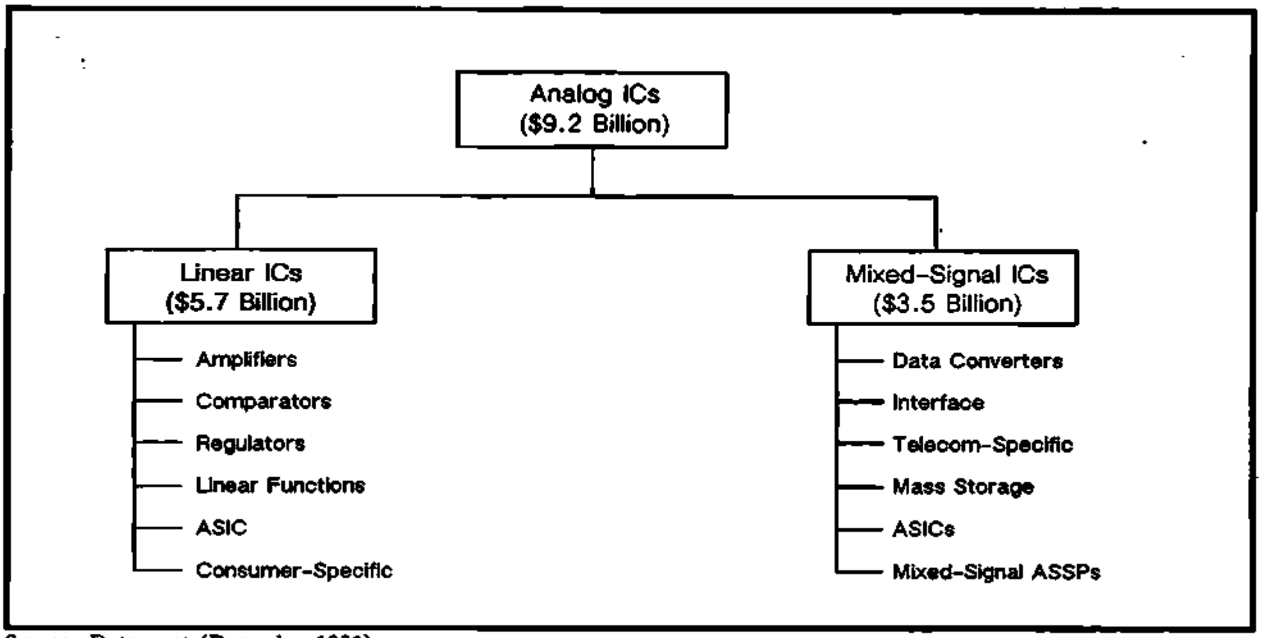
Both mixed-analog/digital and linear ICs are included in the analog IC category. Figure 1 shows these two major divisions of the analog IC market. Although not always completely clear-cut, general categories can be assigned to the mixed-signal or linear IC divisions. Mixed-signal IC categories include data converters, interface ICs, mass-storage ICs, telecommunications-specific ICs, and mixed-signal ASICs. Linear ICs, which are completely analog in nature, include the standard linear functions such as amplifiers, comparators, regulators, and special-function ICs as well as the very large consumer-specific IC category.

Competition

The 1990 mixed-signal IC market share listing in Table 1 shows the strong presence of North American suppliers, which hold 8 of the top 10 positions. It is significant that not one of the top 10 suppliers is a Japanese company.

North America's mixed-signal IC market share, as shown in Table 1, contrasts dramatically with the linear IC segment market shares shown in Table 2. Note that only two North American companies made the top 10 in the linear supplier listing. Six Japanese suppliers and two European suppliers also were in the top 10. The linear listing is dominated by vertically integrated manufacturers that supply ICs for their own internal use as well as to the merchant market. The linear listing also shows a

Figure 1
Analog Product Family



Source: Dataquest (December 1991)

Table 1
1990 Market Shares for Mixed-Signal ICs

Rank	Company	Percent Share	Revenue (Millions of Dollars)
1	SGS-Thomson	8.1	282.3
2	National Semiconductor	7.5	263.5
3	Analog Devices	6.8	236.0
4	Texas Instruments	6.3	219.8
5	Silicon Systems	4.6	162.0
6	Rockwell	4.6	160.0
7	Harris Semiconductor	3.9	136.9
8	AT&T	3.9	135.7
9	Motorola	3.6	124.2
10	GEC Plessey	2.5	89.0
	Others	48.0	1,660.6
	Total	100.0	3,470.0

Source: Dataquest (December 1991)

Table 2
1990 Market Shares for Linear ICs

Rank	Company	Percent Share	Revenue (Millions of Dollars)
1	Philips	9.1	521.7
2	Toshiba	8.5	483.0
3	Sanyo	6.7	380.8
4	Matsushita	6.2	353.4
5	National Semiconductor	5.7	326.6
6	NEC	5.1	289.0
7	Sony	5.0	284.0
8	SGS-Thomson	4.8	271.7
9	Motorola	4.7	268.8
10	Mitsubishi	4.6	262.0
	Others	40.0	2,297.0
	Total	100.0	5,738.0

Source: Dataquest (December 1991)

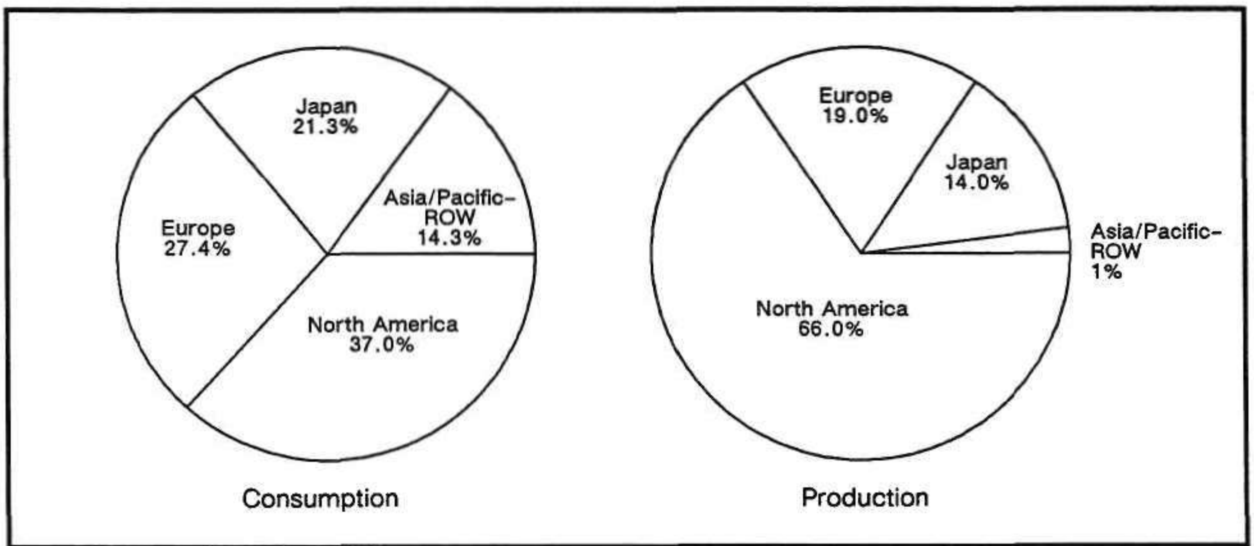
stronger share of the total market by the top 10 suppliers than does the mixed-signal market (60 versus 52 percent), a common characteristic of a more mature product line.

Regional Markets

The market share tables show North America's strength in supplying to the mixed-signal market, which is due, in part, to the size of the North American market for mixed-signal ICs. Mixed-signal IC consumption by region is compared with production by region in Figure 2. This figure shows North America to be both the dominant consumer and producer of mixed-signal ICs, which contrasts with the comparable regional consumption/production graphs for linear ICs (see Figure 3). It is interesting to note that Japan and North America have reversed mixed-signal and linear IC consumption profiles (21 and 39 percent, respectively, for Japan, and 37 and 20 percent, respectively, for North America).

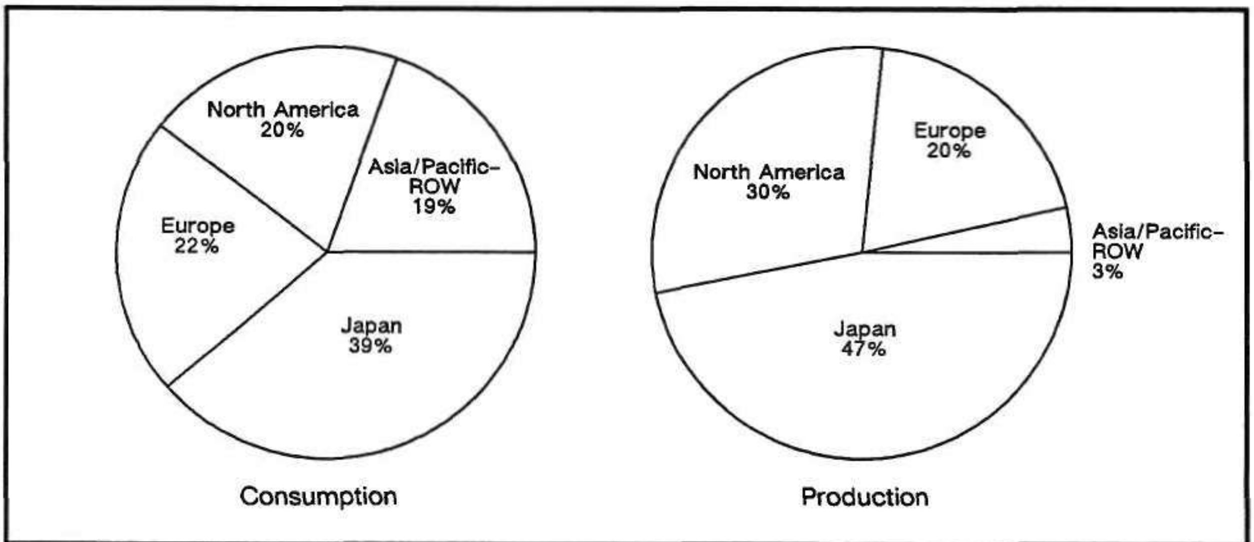
Europe is notably consistent in both mixed-signal and linear IC consumption and

Figure 2
Mixed-Signal ICs—Regional Consumption/Production



Source: Dataquest (December 1991)

Figure 3
Linear ICs—Regional Consumption/Production



Source: Dataquest (December 1991)

production, a position that is less likely to be jarred by dynamic changes in the local market. Although it is apparent that Japan is not likely to be displaced from its dominance in the relatively mature consumer-specific linear IC market, it is less apparent (and far less likely) that North American dominance in mixed-signal ICs will continue at this magnitude. Purely linear solutions in all markets, including the consumer market, are being displaced by mixed-analog/digital solutions involving microprocessor control and/or digital signal processing (DSP). The emergence of large mixed-signal IC markets such as communication, improvement in mixed-signal design tools, and the growing presence of mixed-signal ICs in consumer and automotive products suggests that the mixed-signal arena will become more hotly contested in the future. Despite all of these competitive pressures, the mixed-signal product area offers the greatest potential for growth, for penetration into relatively closed markets, and for high-margin products with average selling prices.

Regional Market Penetration

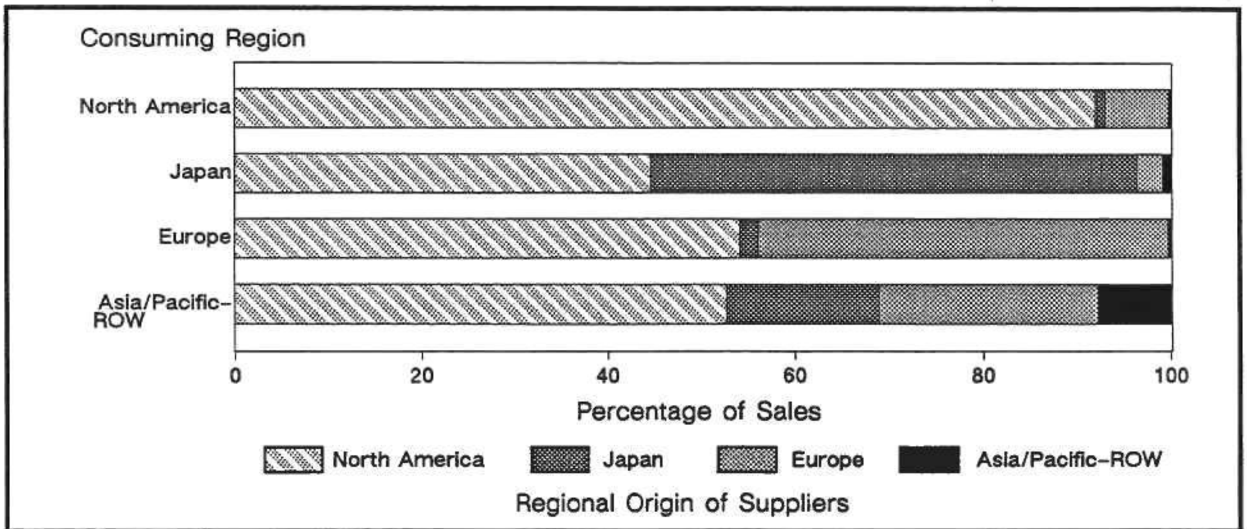
Figures 2 and 3 show the relative size of the regional IC consumption and production but do not indicate where the ICs consumed in any given region originate. Figures 4 and 5 provide a means of understanding the mix of regional suppliers to each consuming region. Each horizontal bar represents 100 percent of a region's IC consumption. The percentage supplied by the regional vendors is shown as a proportional part of the stacked bar. Figure 4 shows that the North American mixed-signal IC market is largely supplied by North American vendors. In addition, North American vendors have a more than 40 percent share of the Japanese, European, and Asia/Pacific-Rest of World (ROW) markets. Figure 5 shows that the regional pattern of consumption for linear ICs is less dominated by supply from a single region. These mature linear products are relatively well supplied by vendors within each geographic region and represent a less attractive growth market for companies outside of each region.

Figures 4 and 5 emphasize the significant North American dominance in mixed-signal ICs as well as highlighting the relative worldwide opportunity offered by mixed-signal ICs compared with linear ICs. Mixed-signal application-specific ICs represent the easiest way to penetrate foreign markets. Mixed-signal IC consumption in Japan and the Far East, although currently relatively small compared with the North American market, will experience equal, if not greater, growth in coming years.

The fact that Japanese mixed-signal IC production lags their mixed-signal IC consumption has provided an opportunity for non-Japanese suppliers to gain some share of the Japanese market. Digital-audio, computer graphics, and disk-drive support ICs have allowed North American mixed-signal suppliers to enter this marketplace. The mixing of analog/digital functions and analog/digital processing technologies has long been a technical strength of North American companies. This strength will be important for minimizing any further decline of North American suppliers in the worldwide market.

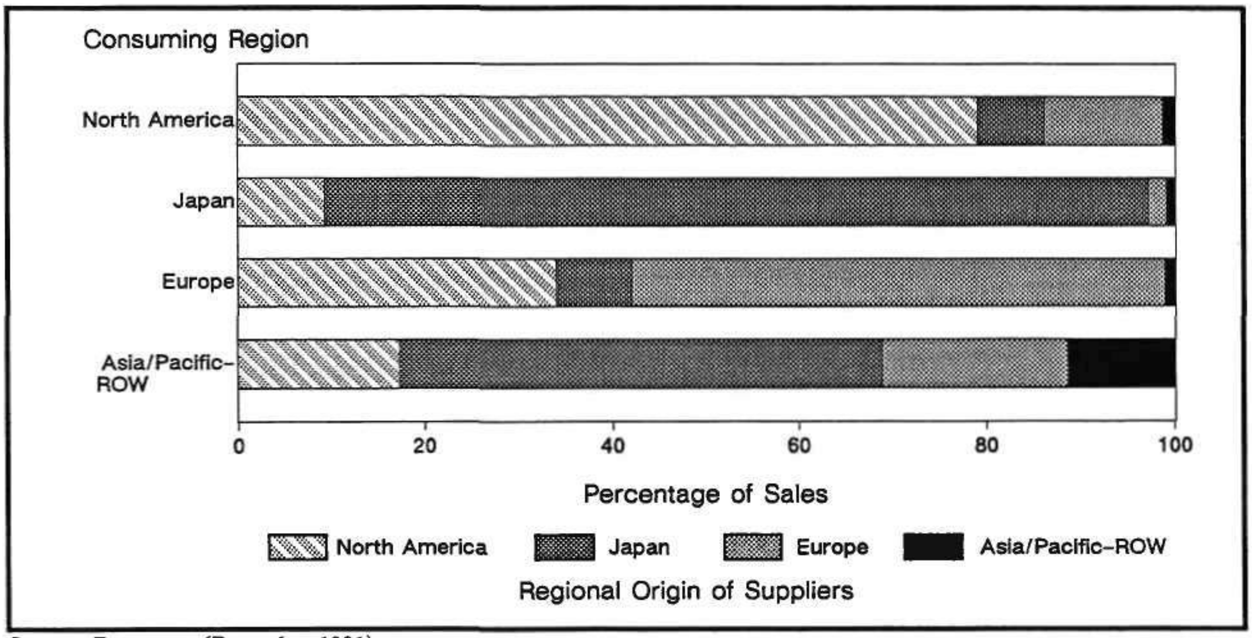
The major mixed-signal IC suppliers and top linear IC suppliers to each consuming region are listed in Tables 3 and 4.

Figure 4
Mixed-Signal ICs—Regional Share by Supplier Origin



Source: Dataquest (December 1991)

Figure 5
Linear ICs—Regional Share by Supplier Origin



Source: Dataquest (December 1991)

Table 3
Mixed-Signal ICs—Top Five Suppliers to Each Geographic Region

	Geographic Region			
Rank	North America	Japan	Europe	Asia/Pacific-ROW
1	Analog Devices	Rockwell	SGS-Thomson	Silicon Systems
2	National Semiconductor	Texas Instruments	National Semiconductor	SGS-Thomson
3	AT&T	Sony	Mietec	National Semiconductor
4	Texas Instruments	Fujitsu	Analog Devices	Motorola
5	Harris Semiconductor	Matsushita	Texas Instruments	GEC Plessey

Source: Dataquest (December 1991)

Table 4
Linear ICs—Top Five Suppliers to Each Geographic Region

	Geographic Region			
Rank	North America	Japan	Europe	Asia/Pacific-ROW
1	National Semiconductor	Matsushita	Philips	Toshiba
2	Motorola	Toshiba	SGS-Thomson	Sanyo
3	Texas Instruments	Sanyo	Siemens	Philips
4	Harris Semiconductor	NEC	National Semiconductor	Samsung
5	Philips	Mitsubishi	Motorola	Matsushita

Source: Dataquest (December 1991)

Dataquest Perspective

North American suppliers currently have the edge in one of the fastest-growing pieces of the semiconductor marketplace. Dataquest has forecast mixed-signal ICs to have a 16.7 percent compound annual growth rate (CAGR) from 1990 through 1995, which is considerably higher than the 9.6 percent CAGR expected for linear ICs. Mixed-signal ICs are moving into consumer and automotive products, displacing the traditional linear bipolar blocks that have characterized these markets for so long. Innovative mixed-signal ICs such as those originated by Burr-Brown (audio DACs), Brooktree (palette DACs), and PMI/Analog Devices (Pro-logic Sensurround IC) have been able to penetrate the difficult Japanese market. The movement to mixed-signal IC solutions has been difficult because of the problems of analog design capability, the availability of CAD/CAE tools, product definition, testing, and performance tradeoffs. Although offering a considerable barrier to the mixed-signal market, these problems represent an avenue for engineering-oriented niche suppliers to tap into a rapidly growing IC market with international opportunities. ■

By Gary Grandbois

Conferences and Exhibitions

Semiconductor Opportunities in Telecommunications

Semiconductors for Personal Communications Networks

Dataquest held its 1991 U.S. Telecommunications Industry Conference in August. The theme of the conference (Personal and Wireless Communications: The Next Frontier) aptly describes the focus of the conference speeches and panel sessions. This article provides an analysis and summary of key semiconductor trends for telecommunications applications as presented at the conference.

The ultimate goal of a personal communications network (PCN) system is to provide every person with a low-cost pocket telephone (less than $100) that is connected to a ubiquitous digital network using low-cost microcell-based base stations. Such a pervasive digital PCN system will be compatible with existing and planned future long distance digital telecommunications networks. The aim is to provide a seamless, user-friendly network that will enable "anytime, anywhere, any person" communication.

Table 1 shows a comparison of cost/functionality for the various personal communications system types, ranging from low-cost cordless telephone systems to digital PCN systems.

PCN in the United States

The FCC has granted experimental licenses to BellSouth Corporation, Graphic Scanning, Motorola Incorporated, NYNEX Corporation, and PCN American (Millicom subsidiary). Experimental licenses are pending for American Personal Communications, Ameritech, GTE Corporation, McCaw, and several others. The goal of these FCC trails is to test the technology, cost, and user-friendliness feasibility of PCN systems based on microcell-based, spread-spectrum (2-GHz) transmission using code-division multiple access algorithms. Regulatory and licensing standards, frequency allocation, and industry structure issues are expected to be resolved for the U.S. market in the 1992 to 1993 time frame.

Meanwhile, the U.S. cellular telephone market is entering the analog-to-digital (A/D) market transition period. Dataquest estimates that the U.S. cellular telephone equipment market will grow at a healthy compound annual growth rate (CAGR) of 19.4 percent, from $1.8 billion in 1991 to $3.6 billion by 1995. Dataquest expects a gradual transition from a high analog content to a high digital content in the cellular telephone equipment market by 1995. The actual digital PCN telephone market is not expected to blossom into a large, mainstream market until 1995. Beyond 1995, the digital PCN equipment market is forecast to grow rapidly to $5.4 billion by the year 2000. In Europe, the Pan-European GSM digital cellular phone standard is the best documented of Europe's new wireless standards.

PCN Developments

Many telecommunications IC companies are using ASICs (gate arrays and standard cells) in combination with programmable logic array building blocks in order to hasten time to market for the first-generation digital cellular telephone design. Dataquest anticipates that future PCN chip sets will be optimized as ASSPs using core telecommunications standard cells and digital signal processing (DSP) building blocks. Submicron high-performance CMOS and

Table 1
Functional Comparison of Personal Communications Devices

	CT2	Paging	Cellular	PCN
Function	originate	receive	send/receive	send/receive
Range	200m	Metro area	>2 miles	200m
Mobility	limited	high	automobile	pedestrian
Terminal cost	low ($100)	low ($100)	high ($500)	low ($100)
Terminal size	small	small	medium/large	small
Battery life	high	high	low	high
Base station cost	low	medium	very high	low

Source: Dataquest (December 1991)

BiCMOS technology will enable shrinking chip counts, smaller sizes, lower power dissipation, and better performance in future-generation digital PCN systems.

The semiconductor industry believes that it can offer single-chip 0.5-micron technology CMOS/BiCMOS PCN solutions using 500K-type embedded gate arrays with optimized embedded telecommunications macro cells such as DSP cores, microcontrollers, analog-to-digital converters, digital-to-analog converters, filters, cache RAMs, and coder/decoder circuits (CODECs).

Semiconductors for Premise Telecommunications PBX Application

Dataquest expects wireless PBX technology to inject some life into the mature office premise PBX equipment market. Wireless PBX equipment revenue is projected to grow at an astounding CAGR of 75 percent, from $36 million in 1991 to $340 million by 1995. The semiconductor market for wireless PBX pocket phones, base terminals, and network access interface cards should grow rapidly in response to wireless PBX system growth projections.

Semiconductors for Data Communication

Data communication appears to be going wireless—analogous to voice communication. Much attention is focused on wireless LANs using radio frequency (RF) and infrared transmission technologies. Wireless LANs need to provide high flexibility in office configuration, low change costs, and compatibility with hard-wired backbone-wired LANs and long distance wide area networks (WANs). The U.S. wireless LAN market, in particular, is expected to grow explosively at a CAGR of 124 percent, from $10 million in 1991 to $250 million by 1995. Numerous proprietary standards and protocols are emerging for wireless LAN applications using 920-MHz spread spectrum transmission/conventional bipolar technology ICs and infrared point-to-point transmission using conventional RF technology ICs.

Choice of Semiconductor Technology for Telecommunications Applications

Historically, telecommunications applications have lagged behind data processing applications in their use of increasing very large scale integration system-on-chip architectures. The mixed-signal nature of telecommunications applications—RF, microwave, analog input/output (I/O) and amplification, and digital switching—has traditionally implied relatively low levels of integration and performance. However, with the recent trend toward digital cellular networks, high-speed digital data networks, and wireless transmission, a gradual segmentation of telecommunications semiconductor applications is occurring. High-performance CMOS technology is being universally embraced for the data compression, digital signal processing, and switching applications. Mixed-signal ASICs and ASSPs incorporating telecommunications core cells are being implemented in CMOS as well as BiCMOS technology, which combines the high gain-frequency sensitivity of bipolar process technologies with the integration and low-power properties of CMOS technology. The adoption of microwave transmission standards in direct broadcast satellite communication, global positioning systems, and satellite-based global cellular telephone networks has spurred the acceptance of gallium arsenide (GaAs) technology.

Dataquest Perspective

Telecommunications is shaping up to be a key semiconductor applications driver for the 1990s. The emergence of cost-effective ultralarge-scale integration-level submicron chip technologies, open network systems architecture, digital cellular networks, and advanced networking software is revolutionizing the telecommunications industry. Dataquest predicts the rapid emergence of a high-volume, cost-driven, highly competitive telecommunications chip set industry that will cater to a competitive open-standards-based voice, data, still-image, and interactive full-motion video communications market. Semiconductor companies that develop strong applications expertise in conjunction with influential telecommunications hardware/service companies can exploit the near-term emergence of comprehensive open standards for digital voice, data, and video communications. ■

By *Krishna Shankar*
Patricia Galligan

In Future Issues

Among the topics to be discussed in future issues of Products, Markets, and Technologies *Dataquest Perspective* will be semiconductor manufacturing.

For More Information . . .

On the topics in this issue .... Products, Markets, and Technologies (408) 437-8642
About on-line access .... On-Line Service (408) 437-8576
About other Dataquest publications .... Sales (408) 437-8246
About upcoming Dataquest conferences .... Conferences (408) 437-8245
About your subscription .... Customer Service (408) 437-8402
Via fax request .... Fax (408) 437-0292

0012444

Dataquest
a company of The Dun & Bradstreet Corporation

Research *Newsletter*

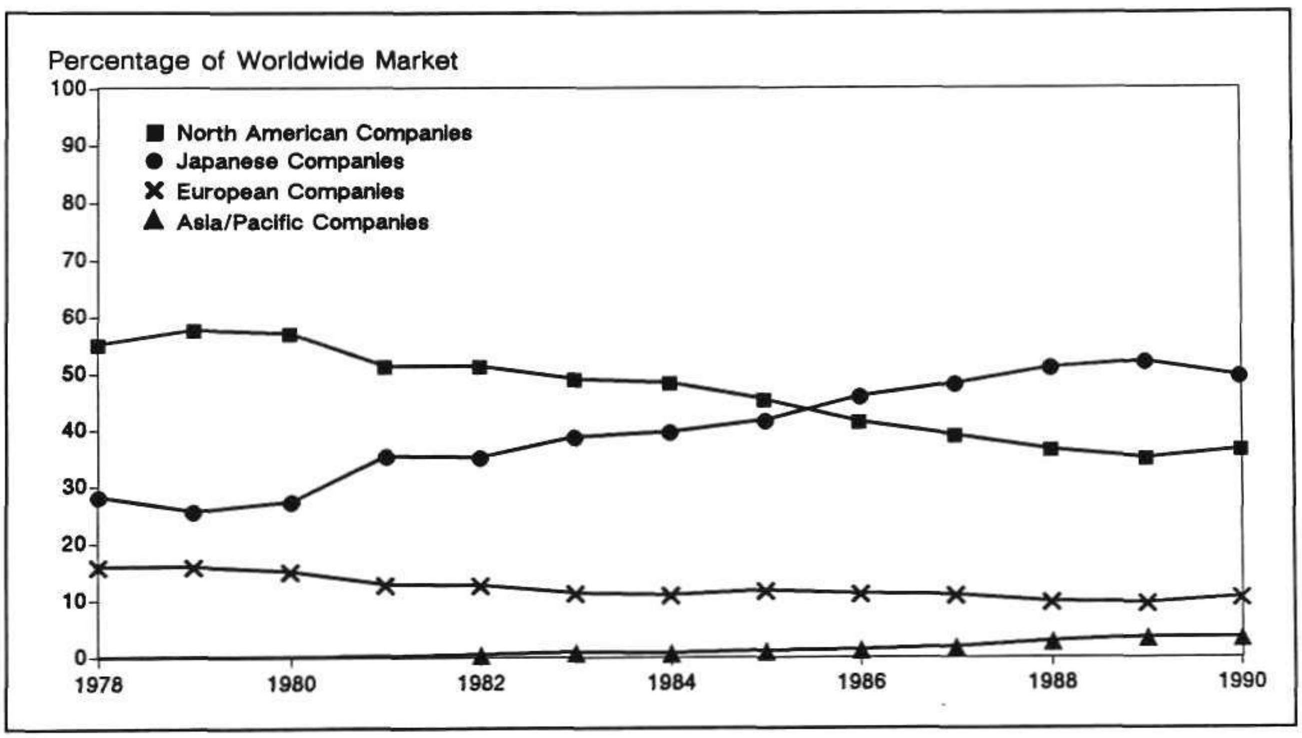
PRELIMINARY 1990 WORLDWIDE SEMICONDUCTOR MARKET SHARE ESTIMATES: THE MICROPROCESSOR REIGNS

INTRODUCTION

Dataquest has completed its preliminary analysis of 1990 semiconductor market shares for more than 150 semiconductor vendors worldwide. We have reached the following conclusions based on surveys of these vendors and our analysis of the market:

- In a worldwide semiconductor market that grew only 2 percent, MOS microcomponents grew a whopping 23 percent, paying off in a big way for Intel, Motorola, Texas Instruments, National Semiconductor, and Philips.
- MOS memory revenue dropped by 17 percent worldwide, resulting in market share losses for the companies that participate in this market.
- For the first time since 1982, Japanese companies lost share of the worldwide market, dropping from a 52.1 percent market share in 1989 to 49.5 percent in 1990.

FIGURE 1
Regional Shares of Worldwide Semiconductor Market (Percentage of Dollars)



Source: Dataquest (January 1991)

 0009146
SG Market Share Newsletters 1991-1

- For the first time since 1979, North American companies gained market share, growing from 34.9 percent of the worldwide market in 1989 to 36.5 percent in 1990.
- While Asian companies held steady at 3.5 percent market share, European companies reversed a downward slide and gained a percentage point of worldwide market share at 10.5 percent. We expect this upward trend to continue in the future.
- Japanese companies now control 22 percent of the North American semiconductor market, down from 24 percent in 1990; at the same time, North American companies have increased their Japanese market share to 10.4 percent, up from less than 10 percent in 1989.

Figure 1 shows the worldwide market share held by each regional company base.

RANKINGS

Table 1 lists the top 20 semiconductor suppliers worldwide. Although the semiconductor market grew only 2 percent in 1990 (in line with our forecast of a flat year), the growth rates of individual players varied widely, depending on product portfolio. Among the top 20, Intel's 29 percent growth because of its strength in microcomponents was by far the highest, catapulting Intel to the number five position worldwide, up from number eight in 1989.

By the same token, although the top four players remained the same as in 1989 (NEC, Toshiba, Hitachi, and Motorola), the first three each experienced revenue declines of 1 percent because of the heavy proportion of MOS memory in their product portfolios. Motorola, on the other hand, was able to grow 11 percent because of its strong microcomponent growth.

The bipolar digital IC market is still shrinking; it declined 1 percent in 1990. Although most players in this market are suffering because of a shift to CMOS, Fujitsu was able to buck this trend with its super ECL gate arrays, which are used in its new mainframe computer (among other products), which had very strong growth this year. This high-ASP product enabled Fujitsu to surpass Texas Instruments to become the top-ranked bipolar digital supplier in 1990.

MOS memory, the largest semiconductor product category, suffered from free-falling DRAM prices and a slowdown in nonvolatile memory demand, with revenue declining 17 percent from 1989. The Japanese companies clearly were the most severely hit because of their dominance in this market. Samsung's DRAM revenue actually grew in 1990, however, because of its shift to 1Mb production. In 1989, most of its production had been 256K. Sharp was able to grow its MOS memory revenue on the strength of its swift entry into the SRAM market and strong demand from the game market for its 8Mb ROMs.

As mentioned previously, MOS microcomponents was the fastest-growing product category, increasing 23 percent from 1989. Intel retained its position as the number one supplier, growing 41 percent; in fact, it strengthened its lead over the number two supplier, NEC, quite significantly. North American and European companies succeeded in taking market share in microcomponents from Japanese companies.

MOS logic grew by 5 percent in 1990. The top 5 players remained the same—NEC, Toshiba, Motorola, Fujitsu, and LSI Logic. Among the top 20, VLSI Technology showed strong growth at 25 percent and moved from number 18 in 1989 to number 14 in 1990. Siemens also showed strong growth at 24 percent and moved from number 20 to number 17.

In the analog market, European companies showed extremely strong growth over 1989, because of the strength of the telecommunications market in Europe. European telecom companies did very well in 1990, winning projects not only in Europe but in third-world countries as well as Eastern Europe. Philips, the analog revenue of which grew by 17 percent and which jumped to the number one spot in the rankings, also profited from its own very strong consumer electronics business. The analog growth rate in 1990 also is influenced by a change in our definition of mixed-signal IC revenue, some of which was reported previously in the MOS logic category.

The discrete and optoelectronic markets both showed growth in 1990. Particularly strong growth was shown by International Rectifier, which grew 30 percent in discrete and went from the number 14 position to number 12.

Tables 2 through 9 list the top 20 suppliers in the product segments of total integrated circuit,

TABLE 1
Preliminary Estimated Worldwide Market Share Ranking
Total Semiconductor
(Millions of Dollars)

1990 Rank	1989 Rank		1989 Revenue	1990 Revenue	Percent Change	1990 Market Share (%)
1	1	NEC	5,015	4,952	(1)	8.5
2	2	Toshiba	4,930	4,905	(1)	8.4
3	3	Hitachi	3,974	3,927	(1)	6.7
4	4	Motorola	3,319	3,692	11	6.3
5	8	Intel	2,430	3,135	29	5.4
6	5	Fujitsu	2,963	3,019	2	5.2
7	6	Texas Instruments	2,787	2,574	(8)	4.4
8	7	Mitsubishi	2,579	2,476	(4)	4.2
9	9	Matsushita	1,882	1,945	3	3.3
10	10	Philips	1,716	1,932	13	3.3
11	11	National Semiconductor	1,618	1,718	6	2.9
12	13	SGS-Thomson	1,301	1,463	12	2.5
13	12	Sanyo	1,365	1,381	1	2.4
14	15	Sharp	1,230	1,360	11	2.3
15	14	Samsung	1,260	1,315	4	2.3
16	16	Siemens	1,194	1,221	2	2.1
17	19	Sony	1,077	1,172	9	2.0
18	17	Oki	1,154	1,074	(7)	1.8
19	18	Advanced Micro Devices	1,100	1,067	(3)	1.8
20	20	AT&T	873	830	(5)	1.4
Total Market			57,213	58,414	2	100.0

Source: Dataquest (January 1991)

bipolar digital, MOS memory, MOS microcomponent, MOS logic, analog, discrete, and opto.

The following notes apply to the tables in this newsletter:

- Our company base has grown from approximately 125 in 1989 to 155 in 1990.
- Some revenue reported in 1989 as MOS logic was reported in 1990 as analog (mixed signal), because of a change in our definitions.
- NM = Not meaningful
- NA = Not available

Table 2
Preliminary Estimated Worldwide Market Share Ranking
Total Integrated Circuit
(Millions of Dollars)

1990 Rank	1989 Rank		1989 Revenue	1990 Revenue	Percent Change	1990 Market Share (%)
1	1	NEC	4,321	4,263	(1)	9.0
2	2	Toshiba	3,774	3,684	(2)	7.8
3	3	Hitachi	3,218	3,195	(1)	6.7
4	7	Intel	2,430	3,135	29	6.6
5	6	Motorola	2,519	2,851	13	6.0
6	4	Fujitsu	2,738	2,777	1	5.9
7	5	Texas Instruments	2,691	2,488	(8)	5.2
8	8	Mitsubishi	2,185	2,092	(4)	4.4
9	9	National Semiconductor	1,548	1,645	6	3.5
10	10	Philips	1,250	1,416	13	3.0
11	11	Matsushita	1,244	1,285	3	2.7
12	12	Samsung	1,182	1,238	5	2.6
13	15	SGS-Thomson	1,019	1,148	13	2.4
14	14	Advanced Micro Devices	1,100	1,067	(3)	2.2
15	13	Oki	1,111	1,031	(7)	2.2
16	17	Sharp	902	1,021	13	2.2
17	16	Sanyo	975	979	0	2.1
18	18	Siemens	847	833	(2)	1.8
19	19	Sony	732	817	12	1.7
20	20	AT&T	716	681	(5)	1.4
Total Market			46,924	47,426	1	100.0

Source: Dataquest (January 1991)

Table 3
Preliminary Estimated Worldwide Market Share Ranking
Bipolar Digital
(Millions of Dollars)

1990 Rank	1989 Rank		1989 Revenue	1990 Revenue	Percent Change	1990 Market Share (%)
1	2	Fujitsu	617	710	15	15.9
2	1	Texas Instruments	671	663	(1)	14.8
3	3	Hitachi	479	510	6	11.4
4	5	National Semiconductor	458	440	(4)	9.8
5	6	Motorola	369	408	11	9.1
6	4	Advanced Micro Devices	474	380	(20)	8.5
7	7	Philips	306	299	(2)	6.7
8	8	NEC	302	292	(3)	6.5
9	9	Mitsubishi	125	121	(3)	2.7
10	11	Toshiba	102	113	11	2.5
11	12	Sanyo	67	67	0	1.5
12	16	Harris	50	60	20	1.3
13	13	AT&T	56	59	5	1.3
14	14	Raytheon	55	54	(2)	1.2
15	15	Siemens	54	53	(2)	1.2
16	17	Oki	48	47	(2)	1.1
17	NM	GEC Plessey	0	40	NM	0.9
18	18	Goldstar	32	32	0	0.7
19	19	Chips & Technologies	24	25	4	0.6
20	20	Applied Micro Circuits Corp.	20	24	20	0.5
Total Market			4,510	4,472	(1)	100.0

Source: Dataquest (January 1991)

TABLE 4
Preliminary Estimated Worldwide Market Share Ranking
MOS Memory
(Millions of Dollars)

1990 Rank	1989 Rank		1989 Revenue	1990 Revenue	Percent Change	1990 Market Share (%)
1	1	Toshiba	1,918	1,681	(12)	12.3
2	2	NEC	1,739	1,453	(16)	10.7
3	3	Hitachi	1,534	1,346	(12)	9.9
4	4	Fujitsu	1,265	1,114	(12)	8.2
5	5	Mitsubishi	1,161	997	(14)	7.3
6	7	Samsung	935	971	4	7.1
7	6	Texas Instruments	1,095	741	(32)	5.4
8	8	Sharp	476	547	15	4.0
9	12	Motorola	407	409	0	3.0
10	9	Oki	473	392	(17)	2.9
11	10	Intel	433	344	(21)	2.5
12	11	Siemens	416	344	(17)	2.5
13	14	Matsushita	370	319	(14)	2.3
14	15	SGS-Thomson	269	299	11	2.2
15	13	Micron Technology	395	286	(28)	2.1
16	16	Advanced Micro Devices	258	280	9	2.1
17	18	Sony	228	252	11	1.9
18	17	NMB Semiconductor	247	201	(19)	1.5
19	21	Cypress Semiconductor	149	159	7	1.2
20	23	National Semiconductor	138	147	7	1.1
Total Market			16,361	13,612	(17)	100.0

Source: Dataquest (January 1991)

TABLE 5
Preliminary Estimated Worldwide Market Share Ranking
MOS Microcomponent
(Millions of Dollars)

1990 Rank	1989 Rank		1989 Revenue	1990 Revenue	Percent Change	1990 Market Share (%)
1	1	Intel	1,929	2,718	41	27.0
2	2	NEC	937	1,083	16	10.7
3	3	Motorola	803	1,002	25	9.9
4	4	Hitachi	554	648	17	6.4
5	5	Mitsubishi	435	462	6	4.6
6	6	Toshiba	407	449	10	4.5
7	7	Texas Instruments	252	320	27	3.2
8	8	Matsushita	217	240	11	2.4
9	10	Fujitsu	211	239	13	2.4
10	11	National Semiconductor	172	237	38	2.4
11	9	Chips & Technologies	216	230	6	2.3
12	12	Advanced Micro Devices	172	200	16	2.0
13	17	Philips	131	189	44	1.9
14	13	SGS-Thomson	161	175	9	1.7
15	16	Western Digital	135	148	10	1.5
16	14	Oki	149	147	(1)	1.5
17	15	AT&T	141	145	3	1.4
18	19	Sharp	112	134	20	1.3
19	31	Cirrus Logic	29	129	345	1.3
20	18	Harris	115	110	(4)	1.1
Total Market			8,202	10,076	23	100.0

Source: Dataquest (January 1991)

Table 6
Preliminary Estimated Worldwide Market Share Ranking
MOS Logic
(Millions of Dollars)

1990 Rank	1989 Rank		1989 Revenue	1990 Revenue	Percent Change	1990 Market Share (%)
1	1	NEC	928	1,036	12	11.7
2	2	Toshiba	775	832	7	9.4
3	3	Motorola	495	553	12	6.2
4	4	Fujitsu	482	550	14	6.2
5	5	LSI Logic	445	504	13	5.7
6	6	Oki	406	410	1	4.6
7	7	Hitachi	319	354	11	4.0
8	8	Matsushita	267	309	16	3.5
9	10	Texas Instruments	256	306	20	3.4
10	11	Sharp	249	271	9	3.1
11	9	AT&T	257	267	4	3.0
12	12	Philips	231	235	2	2.6
13	13	National Semiconductor	222	219	(1)	2.5
14	18	VLSI Technology	169	211	25	2.4
15	14	Harris	210	201	(4)	2.3
16	17	Sanyo	178	194	9	2.2
17	20	Siemens	133	154	16	1.7
18	22	Samsung	123	153	24	1.7
19	21	Yamaha	130	145	12	1.6
20	15	Seiko Epson	201	128	(36)	1.4
Total Market			8,461	8,884	5	100.0

Source: Dataquest (January 1991)

TABLE 7
Preliminary Estimated Worldwide Market Share Ranking
Analog
(Millions of Dollars)

1990 Rank	1989 Rank		1989 Revenue	1990 Revenue	Percent Change	1990 Market Share (%)
1	4	Philips	522	613	17	5.9
2	1	Toshiba	572	609	6	5.9
3	2	National Semiconductor	558	602	8	5.8
4	8	SGS-Thomson	393	554	41	5.3
5	3	Sanyo	530	541	2	5.2
6	5	Motorola	445	479	8	4.6
7	6	Texas Instruments	417	458	10	4.4
8	9	Mitsubishi	384	434	13	4.2
9	10	Matsushita	376	403	7	3.9
10	11	Sony	361	401	11	3.9
11	7	NEC	415	399	(4)	3.8
12	12	Analog Devices	337	360	7	3.5
13	13	Hitachi	332	337	2	3.2
14	15	Rohm	277	282	2	2.7
15	14	Harris	280	260	(7)	2.5
16	16	AT&T	249	197	(21)	1.9
17	151	GEC Plessey	0	195	NA	1.9
18	24	Silicon Systems	112	180	61	1.7
19	19	Siemens	152	175	15	1.7
20	17	Fujitsu	163	164	1	1.6
Total Market			9,390	10,382	11	100.0

Source: Dataquest (January 1991)

TABLE 8
Preliminary Estimated Worldwide Market Share Ranking
Total Discrete
(Millions of Dollars)

1990 Rank	1989 Rank		1989 Revenue	1990 Revenue	Percent Change	1990 Market Share (%)
1	1	Toshiba	848	910	7	11.0
2	2	Motorola	775	814	5	9.9
3	3	Hitachi	690	662	(4)	8.0
4	4	NEC	574	565	(2)	6.8
5	5	Philips	442	494	12	6.0
6	6	Mitsubishi	364	352	(3)	4.3
7	7	Matsushita	332	351	6	4.2
8	8	Rohm	301	320	6	3.9
9	10	SGS-Thomson	282	315	12	3.8
10	9	Fuji Electric	287	312	9	3.8
11	11	Siemens	232	260	12	3.1
12	14	International Rectifier	187	243	30	2.9
13	12	Sanyo	230	232	1	2.8
14	13	Sanken	213	224	5	2.7
15	NA	Shindengen Electric	NA	177	NA	2.1
16	15	General Instrument	170	173	2	2.1
17	16	ITT	155	161	4	1.9
18	17	AT&T	147	135	(8)	1.6
19	18	Harris	120	130	8	1.6
20	19	Fujitsu	109	117	7	1.4
Total Market			7,662	8,262	8	100.0

Source: Dataquest (January 1991)

TABLE 9
Preliminary Estimated Worldwide Market Share Ranking
Total Optoelectronic
(Millions of Dollars)

1990 Rank	1989 Rank		1989 Revenue	1990 Revenue	Percent Change	1990 Market Share (%)
1	1	Sharp	328	339	3	12.7
2	2	Toshiba	308	311	1	11.6
3	3	Matsushita	306	309	1	11.5
4	4	Sony	249	270	8	10.1
5	5	Hewlett-Packard	213	223	5	8.3
6	6	Sanyo	160	170	6	6.4
7	9	Siemens	115	128	11	4.8
8	8	Fujitsu	116	125	8	4.7
9	7	NEC	120	124	3	4.6
10	10	Rohm	96	105	9	3.9
11	11	Telefunken Electronic	78	90	15	3.4
12	13	Hitachi	66	70	6	2.6
13	12	Optek	77	66	(14)	2.5
14	14	Quality Technologies	38	35	(8)	1.3
15	15	Texas Instruments	36	33	(8)	1.2
16	16	Oki	33	33	0	1.2
17	18	Mitsubishi	30	32	7	1.2
18	19	Motorola	25	27	8	1.0
19	17	Honeywell	31	25	(19)	0.9
20	20	Philips	24	22	(8)	0.8
Total Market			2,627	2,676	2	100.0

Source: Dataquest (January 1991)

DATAQUEST ANALYSIS

The year 1990 was a flat one for the worldwide semiconductor industry. Although the first half of the year showed some surprising strength in end markets, particularly personal computers, this demand slacked off as the year progressed. This slackening, combined with severe downward pricing pressure on memories (in spite of unit demand growth), an uncertain economy, industry layoffs, and the unrest in the Middle East, caused a depressed state of mind in the semiconductor industry.

The bright spots in 1990 were high microcomponent demand and the moderately positive growth in the stable analog, discrete, opto, and MOS logic markets.

The Asia/Pacific companies, while unable to increase market share, were at least able to hold steady. North American and European companies should be happy with their gained market share. Japanese companies' revenue declined, but they still control more of the semiconductor market than any other company base. The uncharted waters of 1991 may demonstrate if the strategy of relying heavily on DRAMs is still the way to maintenance or growth of market share in the semiconductor market of the 1990s.

Patricia S. Cox

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

U.S. COMPANIES TOP LIST FOR STRATEGIC ALLIANCES

INTRODUCTION

Strategic alliances among companies have become commonplace in the semiconductor industry around the world. But the United States tops the list for the number of strategic semiconductor alliances with 63.3 percent of the 1,875 strategic alliances instituted worldwide since 1961 (see Table 1). This should not be a surprise because the majority of individual semiconductor companies are in the United States. What is significant are the types of agreements instituted in the different regions.

THE STRATEGIC ALLIANCE STUDY

Because alliances have a direct effect on the direction of the industry, Dataquest sponsored a study and analysis of the alliances by Whorton School of Business, University of Pennsylvania. Data on semiconductor company alliances, going back 29 years, were compiled and analyzed by Professor Bruce Kogut and Doctoral Candidate Dong-Jae Kim of the Department of Management at Whorton. The following seven types of alliances were identified:

- Acquisition (includes merger) (ACQ)
- Joint venture (JV)
- Equity investment (EQT)
- Licensing (LIC)
- Second sourcing (SCND)
- Cooperative agreement (COAG)
- Technology transfer (TECH)

The recorded agreements cover 20 countries and have been grouped into four regions: the United States, Japan, Europe, and Asia/Pacific-Rest of World (ROW). These data come from Dataquest and from unpublished studies conducted by the Electronic Industries Association of Japan (EIAJ, 1987) and New York University (NYU, 1986). The study covered the period from 1961 to 1989. In a few cases, the agreements include more than two companies.

TABLE 1
Total Number of Alliances (1961-1989)*

	United States	Japan	Europe	Asia/Pacific-ROW	Total*
United States	1,538	506	214	120	2,378
Japan	506	242	61	31	840
Europe	214	61	49	25	349
Asia/Pacific-ROW	120	31	25	13	189
Total	2,378	840	349	189	3,756

*Double counted: each participant in an alliance is counted as one.
Source: EIAJ, NYU, Dataquest (February 1991)

Semiconductor Group Newsletters 1991-02

0009385

Since the early 1980s, the most accepted form of alliance worldwide is the cooperative agreement (53.3 percent) followed by technology transfers at 10.9 percent (see Table 2). Licensing accounted for only 8.4 percent, second-sourcing for 8 percent, acquisition for 7.8 percent, and joint ventures for 6.3 percent. Equity investment was the least-used form of alliance. Although the acquisition form of alliance is considered "noncooperative," it is still popular, growing from 3 percent of the alliances in 1986 to 15.1 percent in 1989 (see Table 3).

Alliances increased dramatically in the 1980s, with an average annual growth rate of 33.3 percent, but reached the peak in 1987. It is likely that the decline since 1987 indicates the increasing density of relationships within the industry because of the limited number of companies in the industry.

United States

In the United States, 49.6 percent of the alliances are cooperative agreements (see Table 4). This is fairly close to the worldwide industry average of 53.3 percent. But the second-highest type of strategic alliances in the United States is acquisition at 13.1 percent of the total—nearly twice the

TABLE 2
Worldwide Alliance Type Trends

Year	ACQ	JV	EQT	LIC	SCND	COAG	TECH	Total
1980	10	1	4	2	0	3	1	21
1981	7	0	4	5	2	13	4	35
1982	8	1	4	6	4	17	12	52
1983	2	2	7	16	10	34	17	88
1984	4	12	6	11	24	67	29	153
1985	9	18	7	23	26	117	32	232
1986	10	18	11	18	35	169	39	300
1987	33	39	21	30	27	240	30	420
1988	33	15	13	16	9	220	19	325
1989	22	6	14	22	4	62	9	139
Total	138	112	91	149	141	942	192	1,765
Percentage	7.8	6.3	5.1	8.4	7.9	53.3	10.8	

Source: BIAJ, NYU, Dataquest (February 1991)

TABLE 3
Alliance Shares by Region
(Cumulative Percentages)

Year	United States	Japan	Europe	Asia/Pacific-ROW
1980	75.4	4.9	13.4	6.3
1981	76.3	4.7	12.2	6.8
1982	75.3	7.9	11.6	5.2
1983	73.1	10.2	10.7	6.0
1984	71.2	13.3	10.5	5.0
1985	66.1	18.2	10.2	5.5
1986	62.1	22.4	9.8	5.7
1987	62.0	23.4	9.4	5.2
1988	62.7	23.1	9.4	4.8
1989	63.3	22.4	9.3	5.0

Source: BIAJ, NYU, Dataquest (February 1991) industry average. The other forms of alliances participated in by U.S. companies are technology transfer (9.8 percent), second-sourcing (8.3 percent), licensing (8.2 percent), equity investment (6.3 percent), and joint venture (4.3 percent).

Japan

Japan pursued strategic alliances more actively in the latter half of the 1980s, gathering 20 percent of the total number of agreements by 1989 (Table 5). The cooperative agreement appears to be the preferred form of alliance for Japanese companies (60 percent as opposed to 49.6 percent for the United States). Japanese companies use acquisition (2 percent) far less than do U.S. companies (13 percent). Joint venture is the second-most popular type of alliance in Japan (11.2 percent), followed by technology transfers (9.5 percent), licensing (6.9 percent), second-sourcing (6.3 percent), and equity investment (3.9 percent).

It is not coincidental that the Japanese have chosen U.S. partners most frequently (60 percent) for strategic alliances, because the majority of technology developments and innovations have occurred from U.S. research. Alliances between Japanese companies account for 29 percent of Japanese alliances, while these companies partner with European companies 11 percent of the time.

Asia/Pacific-ROW

One interesting phenomenon of industry dynamics is the emerging role of companies from the Asia/Pacific Rim, specifically those from South Korea and Taiwan (see Figure 1). Taiwanese companies have demonstrated a use of strategic

Table 4
U.S. Alliances by Type

Regional Partner	ACQ	JV	EQT	LIC	SCND	COAG	TECH	Total*
United States	258	39	106	132	130	740	126	1,538
Japan	11	49	23	36	32	293	60	506
Europe	25	3	16	8	28	101	31	214
Asia/Pacific-ROW	16	11	4	19	8	46	16	120
Total	310	102	149	195	198	1,180	233	2,378
Percentage	13.1	4.3	6.3	8.2	8.3	49.6	9.8	

*Double counted: each participant in the alliance is counted as one. Totals include 11 unidentified nationalities.
Source: EIAJ, NYU, Dataquest (February 1991)

Table 5
Japanese Alliances by Type

Regional Partner	ACQ	JV	EQT	LIC	SCND	COAG	TECH	Total*
Japan	2	32	8	10	10	170	10	242
United States	11	49	23	36	32	293	60	506
Europe	2	9	0	6	10	27	7	61
Asia/Pacific-ROW	1	4	2	6	1	14	3	31
Total	16	94	33	58	53	504	80	840
Percentage	1.9	11.2	3.9	6.9	6.3	60.0	9.5	

*Double counted: each participant in the alliance is counted as one. Totals include two unidentified nationalities.
Source: EIAJ, NYU, Dataquest (February 1991)

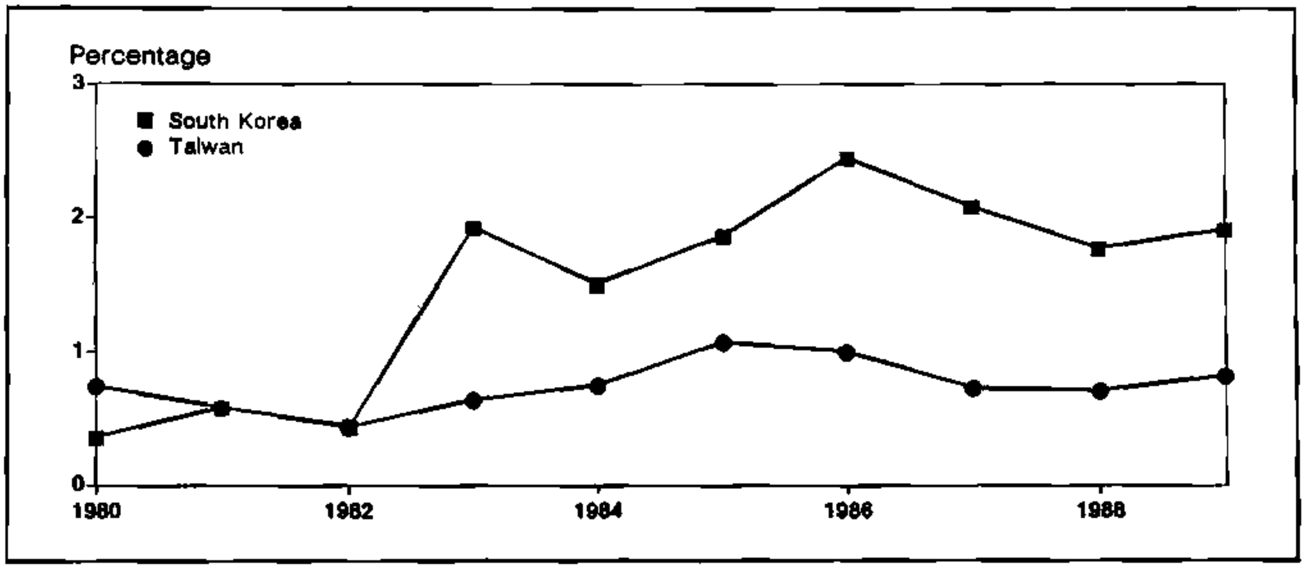
alliances since the first two licensing agreements in 1979. South Korean companies have actively participated in strategic alliances since 1980. South Korean companies reached their peak in alliances in 1986, with 2.5 percent of total worldwide alliances. Taiwan companies peaked in 1985 with about 1.1 percent of total alliances.

South Korea

More than 41 percent of South Korea's 36 alliances are cooperative agreements (see Table 6). Technology transfer (20.8 percent) and licensing (18 percent) were the second and third most frequently used types of alliances. Second sourcing (9.7 percent) has also been actively pursued. Their heavy reliance on technology transfers, licensing, and second sourcing indicates that South Korean companies have, so far, been technology innovation followers. However, this may be gradually changing as they sink more money into R&D.

More than 76 percent of South Korean companies' alliances are with U.S. companies. But it is interesting to note that few (only seven) of the alliances have been with Japanese companies. This small portion of Japanese partners might indicate the basis of an old argument against Japanese companies' policies toward developing countries: they are unwilling to share or transfer technological know-how.

Figure 1
Alliance Shares—South Korea and Taiwan



Source: EIAS, NYU, Dataquest (February 1991)

Table 6
South Korean Alliances by Type

Regional Partner	ACQ	JV	EQT	LIC	SCND	COAG	TECH	Total*
South Korea	0	0	0	0	0	6	0	6
United States	1	2	3	11	7	20	11	55
Japan	0	0	0	1	0	4	2	7
Europe	1	0	0	0	0	0	2	3
Asia/Pacific-ROW	0	0	0	1	0	0	0	1
Total	2	2	3	13	7	30	15	72
Percentage	2.8	2.8	4.2	18.0	9.7	41.7	20.8	

*Double counted: each participant in the agreement is counted as one.
Source: EIAJ, NYU, Dataquest (February 1991)

TABLE 7
Taiwanese Alliances by Type

Regional Partner	ACQ	JV	EQT	LIC	SCND	COAG	TECH	Total*
Taiwan	0	0	0	4	0	0	0	4
United States	1	1	0	4	1	10	2	19
Japan	0	0	0	0	1	2	0	3
Europe	0	0	2	0	0	1	0	3
Asia/Pacific-ROW	0	0	1	1	0	0	0	2
Total	1	1	3	9	2	13	2	31
Percentage	3.2	3.2	9.7	29.0	6.5	41.9	6.5	100.0

*Double counted: each participant in an alliances is counted as one.
Source: EIAJ, NYU, Dataquest (February 1991)

Taiwan

Licensing and technology transfers explain 35 percent of the 15 Taiwanese strategic alliances (see Table 7). The Taiwanese companies are technology followers, similar to South Korean companies. However, unlike the South Korean companies, the Taiwanese are more diversified in partner nationality. About 13 percent of the agreements are with domestic companies. The rest of the agreements are with offshore companies as follows: 61 percent, United States; 10 percent, Europe; 10 percent, Japan; 6 percent, other countries.

DATAQUEST PERSPECTIVE

A View of the Giants

A quick look at the tables shows that the United States and Japan dominate the number of strategic alliances. However, differences exist in the type of agreements used. Japanese companies generally use cooperative forms of alliances, and U.S. companies typically take a more aggressive posture. More than 60 percent of the alliances in Japan are cooperative agreements, compared with 49.6 percent in the United States. However, acquisition is used 13 percent of the time in U.S. agreements, compared with 1.9 percent in Japan.

Actually, U.S. companies use mergers and acquisitions more frequently than do companies from all the other countries in the world combined. This is a fundamental difference between U.S. business practices and those of companies in other countries.

A second basic difference is that Japanese companies have formed alliances with foreign partners more frequently than have U.S. companies. U.S. companies tend to rely on domestic partners for alliances. Japanese companies select domestic partners 29 percent of the time, whereas U.S. companies select domestic partners 65 percent of the time. This trend might be explained by a higher proportion of technology leadership in the United States; however, the leadership in several technologies has shifted to Japan.

Emerging Influences

Although South Korean and Taiwanese companies lagged behind their counterparts in technology, they do exhibit strong competitive qualities. They have been acquiring technology through their strategic alliances. With growing domestic economies and increasing domestic and worldwide semiconductor demand, Dataquest believes that the companies of these two countries will place an increasingly stronger emphasis on technology development. As a result, we expect to see more important roles played by these two emerging countries in the future.

Marc Elliot

Dataquest
a company of
The Dun & Bradstreet Corporation

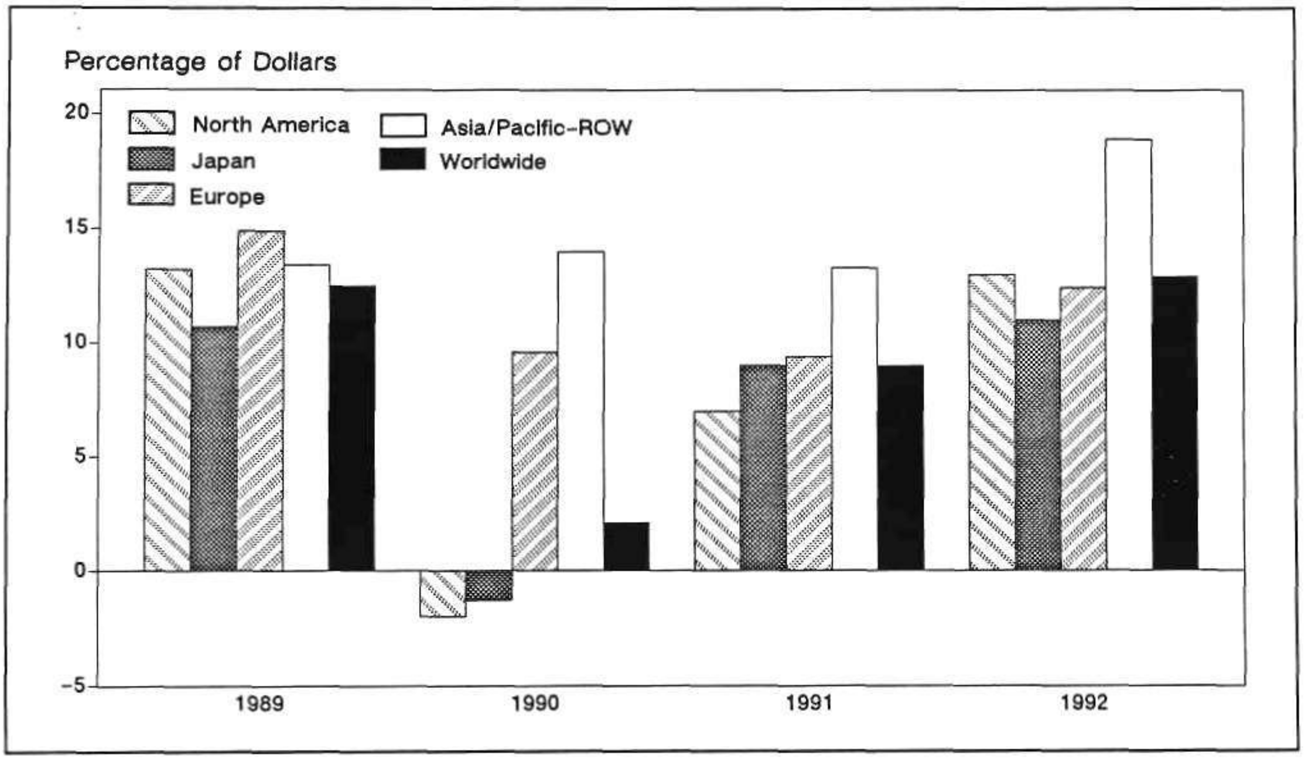
Research Newsletter

FIRST QUARTER 1991 WORLDWIDE SEMICONDUCTOR INDUSTRY OUTLOOK: EMBATTLED, BUT NOT BOMBED OUT

INTRODUCTION

In spite of a U.S. recession and the threat of war, the worldwide semiconductor industry grew in the fourth quarter of 1990 in both bookings and billings. The Persian Gulf war, which began on January 16, 1991, when the allied forces started bombing Baghdad, might be expected to cast a pall over the entire world economy to the detriment of the semiconductor industry. However, Dataquest believes that the industry will continue to grow, albeit modestly, through 1991. We expect quarterly growth to be stronger in 1992. Our annual growth forecast by region is shown in Figure 1. Overall, we expect 9 percent growth in 1991 and 13 percent growth in 1992.

FIGURE 1
Annual Semiconductor Industry Growth Rates by Regional Market (Percentage of Dollars)



Source: Dataquest (January 1991)

Semiconductor Group Newsletters 1991-04

0009372

The reasons for our relative optimism are as follows:

- Our monthly survey of major OEM semiconductor procurement managers continues to support improvement in the systems market outlook.
- Semiconductor inventories at OEMs are less than 20 days and within 8 days of target.
- Many semiconductor manufacturers are reporting strong bookings for the month of January.
- WSTS statistics show both bookings and billings on an upward trend through November, the last worldwide actuals available.
- Increasing pervasiveness of semiconductors in electronics and consumer goods and increasing functionality per chip will continue to raise chip average selling prices and allow the semiconductor industry to grow faster than the electronic equipment industries.
- Telecommunications equipment production continues to do well, due in part to demand from eastern Europe. This will continue to drive semiconductor consumption in Europe.
- There is evidence—in the huge approval rating of U.S. President George Bush, the large U.S. stock market rallies, and signs of improvement in the index of leading indicators—that U.S. consumer confidence has increased dramatically since the bombing of Baghdad began.
- U.S. allies have pledged $45 billion toward the cost of the war thus far, thereby alleviating a potentially onerous financial burden on one nation.

To be sure, there are also possible hazards on the horizon:

- Protraction and/or major expansion of the war in the Persian Gulf could sabotage world economies.
- Increased political and economic instability in the Soviet Union could become a very explosive situation with worldwide repercussions.
- Lack of soundness of the U.S. financial system could damage the U.S. economy if massive bank failures were to occur. This possibility can be averted by effective action on the part of the Federal Reserve Board, Congress, and the Bush administration.
- A trade war, brought on by patriotic fervor in the United States, could disrupt world economies enough to adversely affect the semiconductor industry. This possibility is avoidable if the U.S. government and its allies actively control events that might result in protectionist U.S. policies.

OUTLOOK FOR 1991 AND 1992

We have looked at several different scenarios for semiconductor industry growth this year and next. They range from highly optimistic to highly pessimistic. We believe that the most likely scenario is somewhere in between, with worldwide growth of 9 percent in 1991 and 13 percent in 1992.

In the final months of 1990, both bookings and billings were well ahead of the same period in 1989, at 13 and 14 percent, respectively. The same trend holds when looking at the three months ended November 1990 versus the three months ended November 1989. Because of this trend and because of renewed confidence levels since fighting began in the Gulf, we believe that the first and second quarters of 1991 are going to show growth, with most of it in the second quarter. We are forecasting modest growth in the third and fourth quarters of 1991. We think quarterly growth will be considerably higher in 1992 for the following reasons:

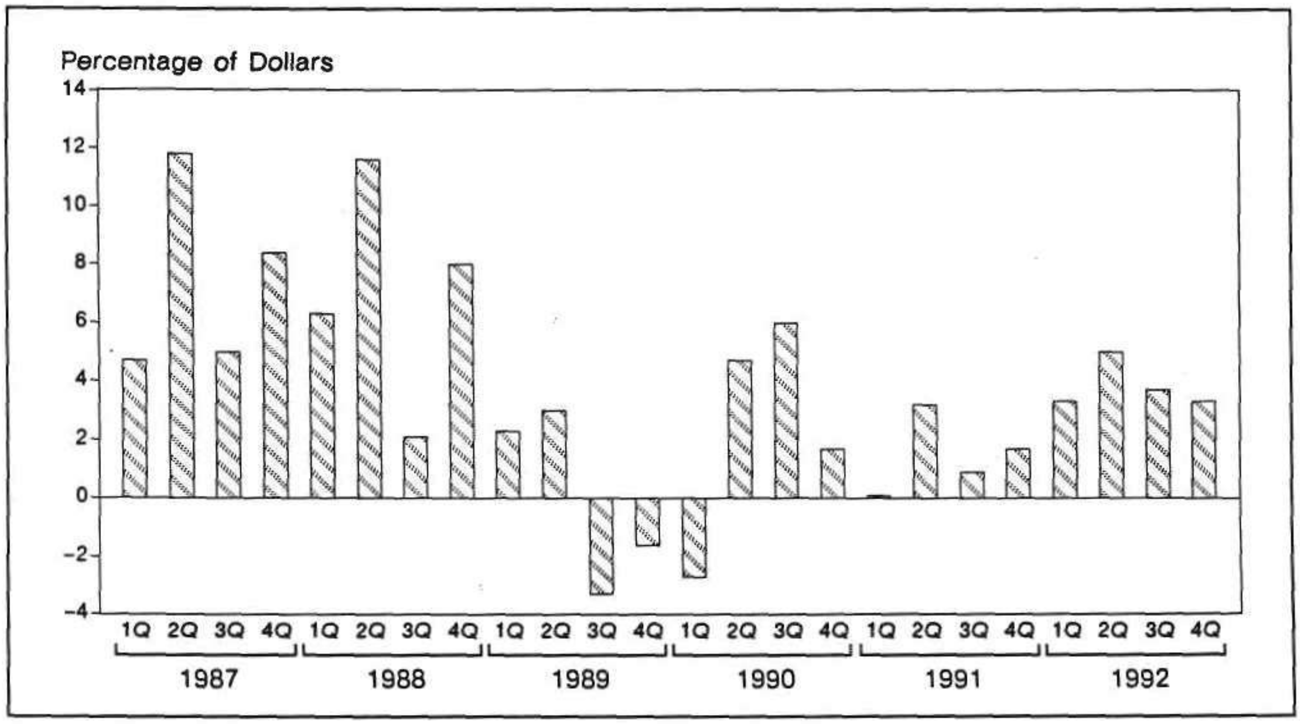
- We believe that the war will have been resolved.
- We believe that the U.S. savings and loan and banking crisis will be in the solution phase.
- We believe that psychology will play a strong role: Just as low consumer confidence contributed strongly to the U.S. recession in the fourth quarter of 1990, a positive mind frame in the electronics industry can buoy up the semiconductor industry.

Figure 2 shows our sequential quarterly growth history and forecast worldwide. Figure 3 shows worldwide growth by quarter versus the same quarter a year ago.

Regionally, we expect to see the following trends in 1991:

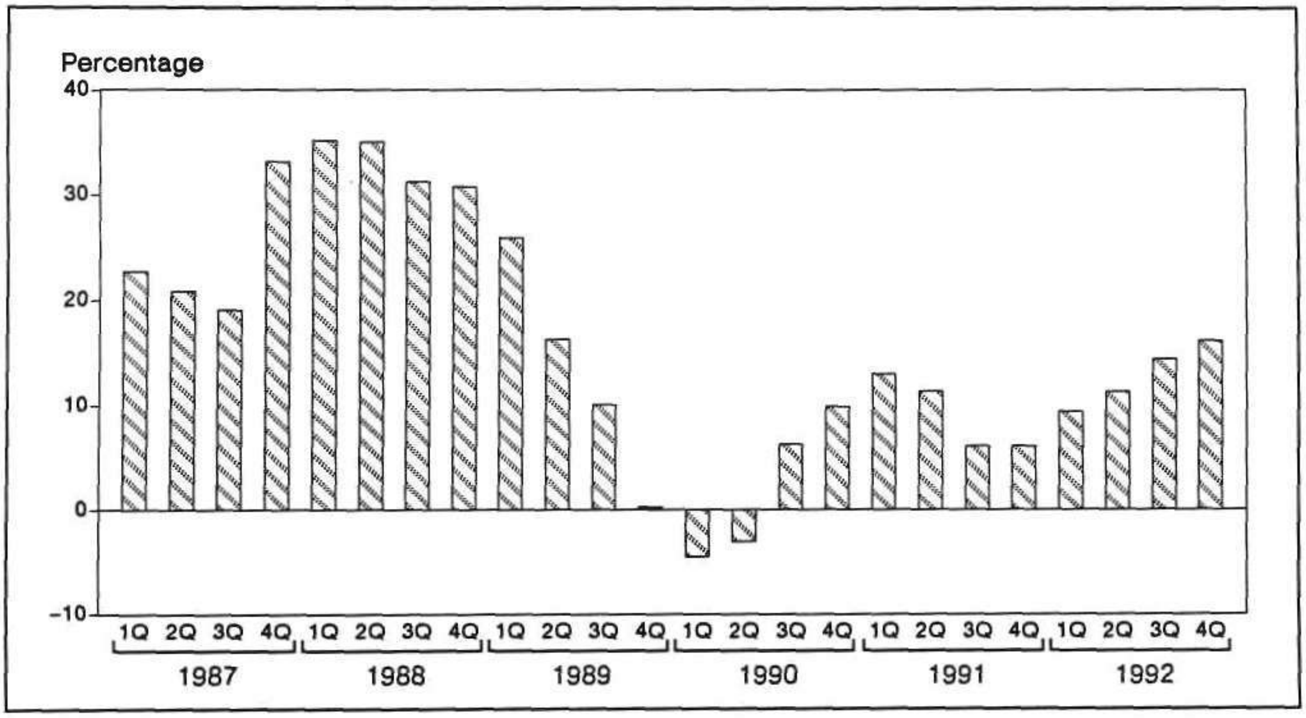
- North American market growth will be strongest in the second quarter.
- European market growth will be strongest in the first quarter. European semiconductor consumption benefited in 1990 from a boom in TV and VCR production, which we do not believe will be repeated this year.

FIGURE 2
Worldwide Semiconductor Industry Growth by Sequential Quarters



Source: Dataquest (January 1991)

FIGURE 3
Worldwide Semiconductor Industry Growth versus the Same Quarter One Year Ago



Source: Dataquest (January 1991)

- Japan will show the weakest quarterly growth of any region this year, largly due to the unprecedented economic challenges it is facing in its stock market and real estate market and the slowdown in consumer spending in the United States, upon which a large part of Japan's semiconductor consumption depends.
- The Asia/Pacific-Rest of World (ROW) market, which slowed in the fourth quarter of 1990 due to a falloff in clone demand, will resume growth in the second quarter of 1991.

In general, the outlook for the Asia/Pacific markets continues to be brighter than that for other regions for the following reasons:

- The Asia/Pacific countries' GDPs in general continue to grow at high single-digit rates.
- Much of the Asia/Pacific semiconductor demand will come from products to be sold within the country of manufacture. In fact, Japanese companies are now producing goods in Asian countries for sale there rather than for export to other regions.
- This market is still the smallest, least mature regional market; therefore, it can support a higher percentage growth than can other regions.

Our 1992 outlook calls for Asia/Pacific-ROW to remain the fastest-growing regional market, followed, in order of growth, by North America, Europe, and Japan.

DATAQUEST ANALYSIS

Never before has Dataquest forecast semiconductor industry growth during a global conflict that could affect worldwide economic powers. We believe that enough positive factors exist to result in modest industry growth both this year and next. The war could have either a significantly positive effect or, conversely, a significantly depressing effect on the semiconductor industry. We have chosen a scenario in which most volatile effects are counterbalanced by other influences, and life continues on, though perhaps not at the frenetic pace of the 1980s.

Patricia S. Cox

Dataquest
a company of
The Dun & Bradstreet Corporation

Research *Newsletter*

ALLIANCES: LARGE COMPANY RIVALRIES SPAWN START-UPS

Small start-up semiconductor companies, conceived in response to exogenous technological changes, are born of the competitive rivalry among large incumbent companies. This view is contrary to the popularly held belief that large companies stifle the emergence of start-ups. However, according to Dr. Bruce Kogut, professor in the Department of Management of Wharton School, University of Pennsylvania, it is exactly the acceptance of strategic technological alliances by large companies that fosters the emergence of start-ups.

Dr. Kogut further believes that major companies strategically encourage start-up companies as a way to promote proprietary technologies into industry standards. In this manner, they may even consciously extend their competition with their major rivals.

Under Dataquest's sponsorship, Dr. Kogut and doctoral candidate Dong-Jae Kim, also of the Wharton School, have been analyzing data that have been collected from as long ago as 29 years on semiconductor company alliances. Between 1961 and 1989, there were about 1,975 alliances involving semiconductor companies, with 1,765 occurring after 1979 (see Figure 1). About 63 percent involved U.S. companies. Data for the study were compiled from Dataquest databases and unpublished studies by the Electronic Industries Association of Japan (EIAJ, 1987) and New York University (NYU, 1986).

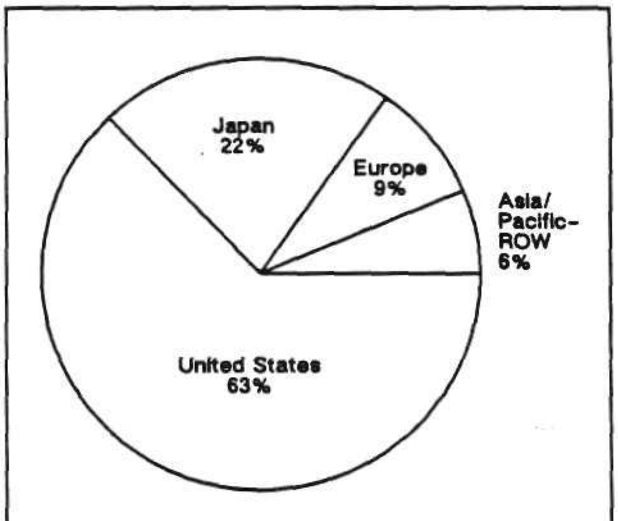
Dr. Kogut initially noted that the relationships implied some sort of network structure in the global semiconductor industry. But upon further examination he found that the companies tended to pursue strategic, hence long-term, relations. This tendency made the structure of the industry look more like an interrelated web. "A typical structure consists of one or more central players and affiliated satellite partners," he said.

He found that the central roles were most commonly played by the large, incumbent companies, while satellite roles were taken by the small, and often new, companies. Guided by this discovery, Dr. Kogut began exploring the role of large incumbent semiconductor companies in regard to the entry process of start-ups and the relationship between large and small semiconductor companies.

The traditional belief about the relationship among large and small companies competing in the same industry is characterized as antithetical. Many analysts believe that competition for market share between companies inhibits start-up activities.

The assumption of implicit hostility between large and small companies is reflected in policy debates on the very factors that sustain the health of the American economy. As per their debate in the *Harvard Business Review*, George Gilder, who supports small companies, and Charles Ferguson,

FIGURE 1
Alliances by Region (1961-1989)



Source: EIAJ, NYU, Dataquest (February 1991)

SG Newsletters 1991-03

0009451

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

who believes that large organizations are needed to sustain heavy capital and R&D requirements, represent the typical positions.

Mr. Gilder affirms that the American strength comes not from the law of complexity, but from the law of microcosm; the case in point being the down-scaling and technological development in the computing industry. He believes that the entrepreneur remains the driving force of economic growth in all vibrant economies, especially the U.S. economy.

In counterpoint to Mr. Gilder, Mr. Ferguson argues that high-technology industries require increasingly capital-intensive cost structures, dominated by R&D, computer networks, highly flexible production systems, and global marketing and customer support organizations. But based on what Dr. Kogut sees in the strategic alliance data, he says the argument between large and small is a mistake. "This mistake is by no means minor in light of the importance and magnitude of the decisions facing Eastern Europe and the Soviet Union regarding the dissolution of their large enterprises into thousands of small companies."

The notion that competing large companies deter small companies from entering the industry ignores evidence that the rivalry among large companies differs qualitatively from that between large and small companies. Small and large companies often do not compete directly, and competition within an industry is partitioned by size categories. However, the entrance of small companies does dramatically impact maturing but innovative industries such as the semiconductor industry. Both small and large companies appear to benefit substantially from each other. The innovative activities of the new small companies pushes out the boundaries into new subfields and even to new major branches.

Start-up companies seek protective alliances with large incumbent companies in order to enhance their chances for growth and survival. The large companies seek to establish central positions in brokering and sharing knowledge in the development of new subfields.

The evolution of the semiconductor industry has displayed a cyclical pattern of new entries to the industry. The first burst occurred in the 1950s and early 1960s after the invention of the transistor. The dominant vacuum tube companies failed to extend their positions into this new technology, so start-up companies such as Fairchild Semiconductor and Texas Instruments expanded rapidly through the creation and adoption of new processes and product innovations.

But internationally, the semiconductor industry displayed a different pattern during this period. Large Japanese companies gained early access to key patents and proprietary technologies needed to build a domestic industry. Because technology went to the large companies of Japan and there was a tendency against technology sharing at that time, few start-ups entered the market in Japan. In Europe, most of the initial semiconductor production occurred by U.S. companies' subsidiaries. Gradually, European companies entered the market, although mostly in niche areas.

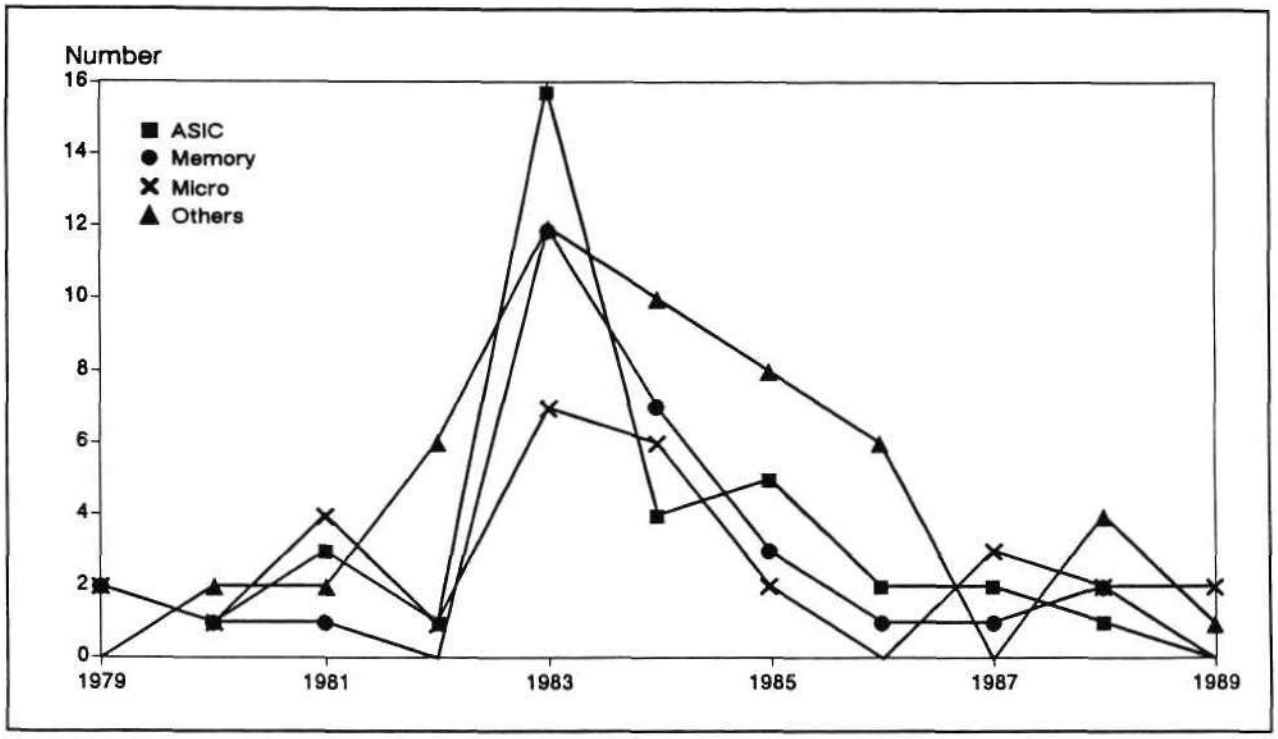
During the late 1960s and 1970s, start-up entries were slow. However, the computer industry in the United States grew, and the proliferation of desktop computers came later, which fostered a host of new specialty semiconductor opportunities. These opportunities led to a rash of start-up companies in the late 1970s and 1980s (see Figure 2). To a lesser extent, start-ups entered the semiconductor market in Europe and Japan during the same period. Many of the start-ups of this era were design centers without fabs.

As start-ups entered the subfields, they developed features that complemented existing products manufactured by established companies. For example, some of the semiconductors could increase microprocessor clock speeds. In order to take advantage of this feature, start-ups need access to proprietary information from the major companies. In establishing technology agreements with the major established companies, both the start-up company and the major company benefited. Start-up activity usually preceded the building of alliances by two or three years (see Table 1).

Major companies such as Intel or Motorola shared proprietary information with small companies because the technology of the small companies enhanced the performance of their own products. The large company could harness the higher niche R&D productivity of the smaller company, while the small company enhanced its chances for growth and survival. Both were betting on increased market share with the prospects of becoming an industry standard.

In strategic alliance development, it should be noted that not only must microcomponents be compatible with the microprocessor they support, but so must application-specific integrated circuits (ASICs) and various memory products such as SRAMs and EPROMs. This compatibility requires cooperation from the dominant company in order to acquire the proprietary knowledge and legal rights that result in a strategic alliance. The

FIGURE 2
Start-Ups by Device Type



Source: EIAJ, NYU, Dataquest (February 1991)

TABLE 1
Alliances Versus Start-Ups by Year

	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89
Alliances	21	35	52	88	153	232	300	420	325	139
Start-Up Entries	5	10	8	47	27	18	9	6	9	3

Source: EIAJ, NYU, Dataquest (February 1991)

proliferation of these supporting products moves the primary product ever closer to becoming an industry standard, as have the Motorola 68XXX microprocessors/microcontrollers and Intel's 80X86 microprocessors.

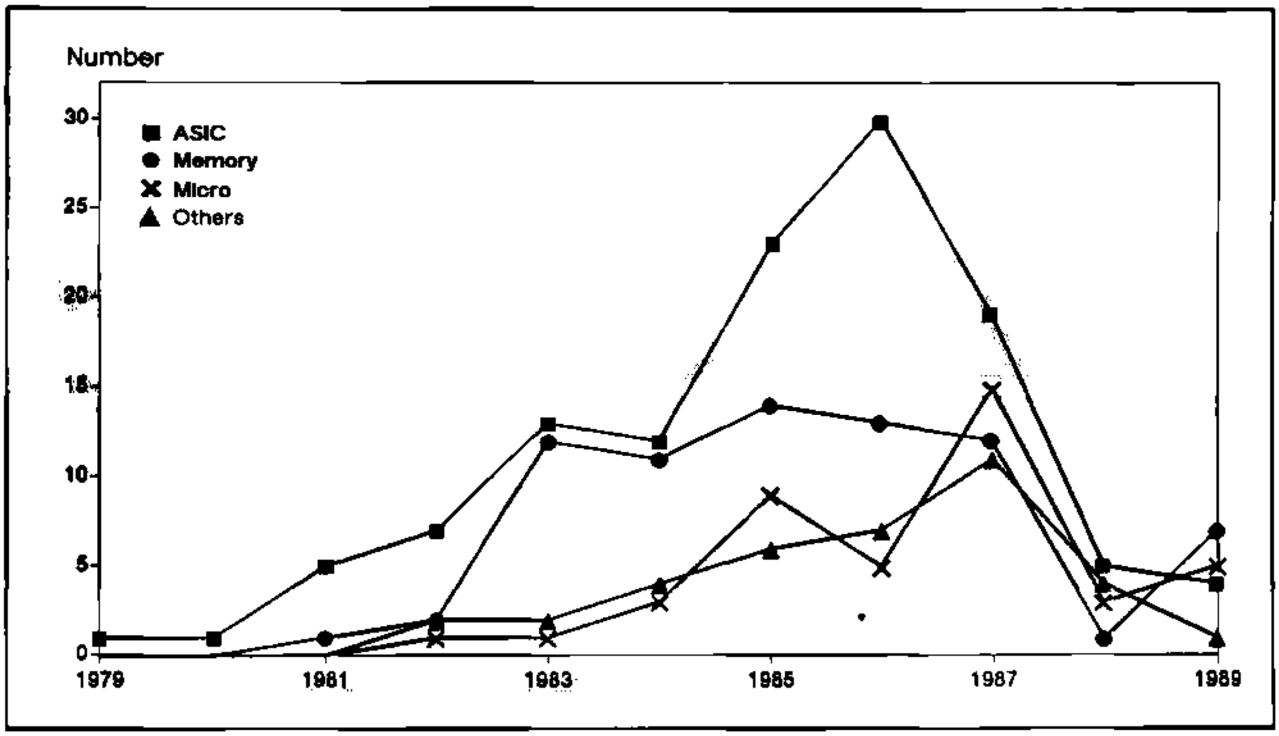
Given the depth of data, Dr. Kogut theorizes that alliances, through cooperation and centrality, have played a role in the evolution of the semiconductor industry as evidenced through the entry of start-ups. He tracked the entry of start-up companies by product type: ASIC, microcomponents, memory, analog, optoelectronics, discrete semiconductors, and gallium arsenide (GaAs).

By further tracking the pattern of alliances by type of product and establishing a network of centrality, Dr. Kogut captures the extent to which companies connect other companies to each other. He notes that in the 1980s he saw a combination of new microprocessor-related technologies that focused on customized integrated circuits (see Figure 3). He believes that this trend spawned an innovative wave that generated new opportunities for start-ups and established companies alike.

He suggests that the competitive uncertainty among the established companies spilled over into a race to encourage start-ups to innovate technologies compatible with their proprietary standards. By establishing cooperative relationships, incumbent companies signaled their willingness to share critical technologies or help new companies survive by providing manufacturing capacity. This, he says, induces the birth of new companies.

Dr. Kogut further suggests that the need for a major company to seek a strategic alliance diminishes as its product gains acceptance in the market and becomes an industry standard. For example,

FIGURE 3
Device-Specific Alliances by Year



Source: EIAJ, NYU, Dataquest (February 1991)

Intel and Motorola both have market acceptance of their microprocessors to the level of an industry standard. He says that these companies' dominant positions virtually have the industry locked into their standards, which is why their rate of strategic alliances is falling off. Barring new technological developments, the rate of strategic alliances will not increase (see Table 2).

National Semiconductor, by contrast, introduced a 32-bit microprocessor in the same time frame as did Motorola and Intel, but has not yet received the same level of market acceptance. National's rate of strategic alliance is still high, but there is a decreasing incentive for small companies to establish an alliance with National in this product area.

DATAQUEST ANALYSIS

Dataquest concurs with Dr. Kogut's analysis that large semiconductor companies do stimulate new company birth and development through the acceptance of strategic alliances. However, the relationship between small and large companies is delicate. Cooperation with start-ups and small

TABLE 2
Selected Companies' Alliance Shares (Percentage)*

Year	Intel	Motorola	National
1979	0	1.77	1.33
1980	0	1.87	1.49
1981	0.88	2.07	1.48
1982	1.81	2.04	1.13
1983	2.59	2.10	1.62
1984	3.46	2.06	2.81
1985	3.46	2.09	2.67
1986	2.87	2.01	2.57
1987	2.72	1.77	2.97
1988	2.50	1.61	3.42
1989	2.53	1.65	3.22

*Number of alliances of the company (cumulative)/total number of alliances (cumulative) x 100.
Source: EIAJ, NYU, Dataquest (February 1991)

companies as an extension of rivalry among large companies can be stable only as long as the rivalry persists under conditions of technological growth and innovation. As a dominant company emerges, cooperation is no longer a potent strategy for either the leader or the stragglers.

It also appears that the health of an industry and economy is the result of a delicate and evolutionary balance between cooperation and competition, between innovation and diffusion, and between small and large companies. Entry, growth, and exit are elements of the revival and persistence of industries and their subfields. These processes also reflect the ecological balance achieved through entrepreneurship of small companies and the cumulative knowledge and assets of larger companies. The policy position, then, cannot be for the promotion of any size of company but only for the appropriate and dynamic mixture of both large and small companies.

Marc Elliot

Dataquest offers consulting services to analyze strategic alliances or prospective alliances. Dataquest has compiled an extensive worldwide database of semiconductor alliances and has structured it to allow for full analysis.

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

SECOND QUARTER 1991 SEMICONDUCTOR INDUSTRY OUTLOOK: RECOVERY IN A MATURING INDUSTRY

INTRODUCTION

Following a year in which the worldwide semiconductor industry grew less than 2 percent, an industry recovery is under way that Dataquest believes will result in dollar-based consumption growth of 13.7 percent in 1991. This is equivalent to 9.6 percent growth if constant 1990 exchange rates are used against the dollar. With first quarter results available already for the North American and European markets (which grew at approximately 3 and 11 percent, respectively, from fourth quarter 1990), it is clear that a turnaround has occurred. We expect every quarter this year to have positive growth worldwide; however, this will not be true for every region.

We have lowered our long-term growth rate expectations for the worldwide industry to 12.6 percent from 1990 to 1995. (Our previous expectation was 14 percent.)

Key events and assumptions driving our short- and long-term forecasts are as follows:

- Memories, microcomponents, and MOS logic are leading the industry recovery in 1991.
- Fluctuations of European and Japanese currencies against the U.S. dollar are skewing 1991 dollar growth upward.
- The European and Asian semiconductor markets are the hotbeds of activity for both the near and long term.
- As electronic equipment becomes an ever-larger component of the worldwide economy, semiconductor growth rates are slowing.
- The historical cyclicality of the industry, while still visible, has moderated.

DATAQUEST FORECAST SCORECARD

How good have our forecasts been in the past? As shown in the scorecard in Table 1, our forecast accuracy has improved over the last several years. In fact, we called 1989 and 1990 almost right on. But even in our forecasts of 1987 and 1988, we called the direction and general magnitude correctly.

In February, we forecast that first quarter 1991 growth in the North American market would be 1 percent and that the European market would grow by 6 percent. The actuals, per the WSTS flash report, were 3 percent and 11 percent, respectively.

TABLE 1
Dataquest Forecast Scorecard: Forecast of Worldwide Industry Growth (Percent Growth—Forecast versus Actual*)

Year Being Forecast	Forecast Growth (%)	Actual Growth (%)
1987	18	24
1988	24	33
1989	10	12
1990	2	2
1991	15	??? Current forecast = 13.7

*The actual is determined at the completion of our final market share project in the second quarter of the year following the forecast year.
Note: The forecasts were made in October of the year preceding the forecast year.
Source: Dataquest (May 1991)

Semiconductor Group Newsletters 1991-05

0010420

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

SHORT-TERM OUTLOOK

Currency fluctuations are skewing our dollar-based growth outlook for 1991. As shown in Table 2, growth rates in local currencies are actually rather modest this year. The Japanese market will grow less than 9 percent in yen, but an astounding 17 percent in dollars. The European market will grow less than 10 percent in ECUs, but 15 percent in dollars. The North American and Asia/Pacific-Rest of World (ROW) markets, which we forecast only in dollars, will grow at 7.9 and 15.2 percent, respectively. All of this will yield dollar-based worldwide growth of 13.7 percent this year; using constant exchange rates, the growth will be only 9.6 percent.

Figure 1 shows our quarterly growth expectations worldwide. It is important to note, however, that we expect virtually all North American growth to occur in the first two quarters of the year. We are forecasting no growth in the last two quarters of 1991 in North America. The April WSTS flash report confirms our outlook for the second quarter. In Japan, we believe that the first quarter declined from fourth quarter 1990, and we forecast growth to pick up through the rest of the year. Europe, as mentioned earlier, had 11 percent growth in the first quarter. Even with slow growth in the second quarter and negative growth in the third quarter, Europe will have a good showing on an annualized basis. We forecast negative growth in the first quarter for Asia/Pacific-ROW, with strong growth in the second and third quarters.

A pickup in DRAM pricing and a strong PC market are current market drivers. Our contacts tell us that the PC market weakness being experienced in the North American market is not occurring in Europe and Asia. In fact, many companies are experiencing their strongest business from the PC area. For the remainder of this year, we expect the telecom market to carry European semiconductor consumption.

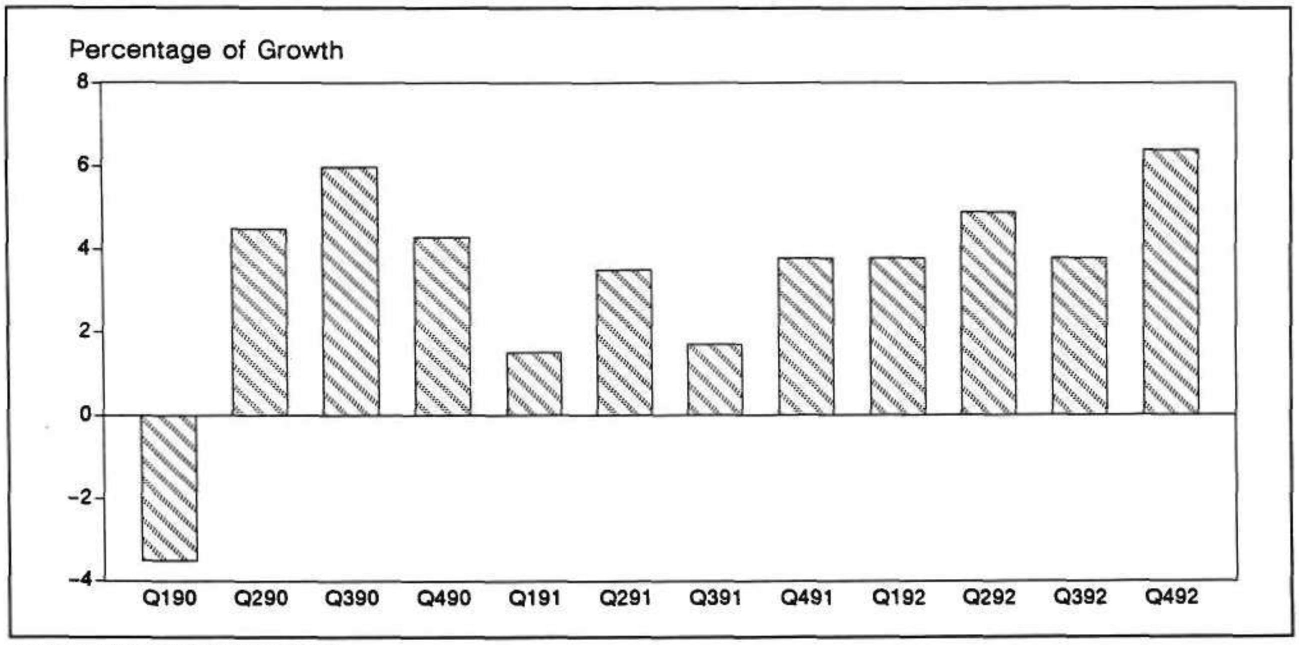
TABLE 2
Worldwide Semiconductor Consumption by Region (Factory Revenue in Dollars and Local Currencies)

Company:	All
Product:	Total Semiconductor
Region of Consumption:	Each
Distribution Channel:	NM
Application:	All
Specification:	All

	1990	1991	Percent Change 1990-1991	1995	CAGR (%) 1990-1995
North America ($M)	17,386	18,761	7.9	28,001	10.0
Japan ($M)	22,508	26,354	17.1	40,762	12.6
Japan (¥B)	3,241	3,529	8.9	5,458	11.0
Europe ($M)	10,661	12,274	15.1	20,764	14.3
Europe (EcuM)	8,384	9,206	9.8	15,573	13.2
Asia/Pacific-ROW ($M)	7,670	8,834	15.2	16,004	15.8
Worldwide ($M)	58,225	66,223	13.7	105,531	12.6
Worldwide ($M at Constant Exchange Rate)	58,225	63,818	9.6	101,574	11.8

NM = Not meaningful
Source: Dataquest (May 1991)

FIGURE 1
Worldwide Semiconductor Consumption Quarterly Growth (Percent Change in Dollars)



Source: Dataquest (May 1991)

LONG-TERM OUTLOOK

General Trends

From its beginnings in the mid-1950s, through 1990, the worldwide semiconductor industry grew at a compound annual growth rate (CAGR) of 18.8 percent. However, the fastest growth occurred between 1970 and 1980. Since 1980, growth has slowed; the 1980-through-1990 CAGR was only 15.2 percent.

Through most of its history, the industry has been cyclical, reaching peaks of growth every four to five years. The magnitude of the peaks and valleys has been very large, reaching peaks of as much as 40 percent growth and valleys of as much as a 15 percent decline.

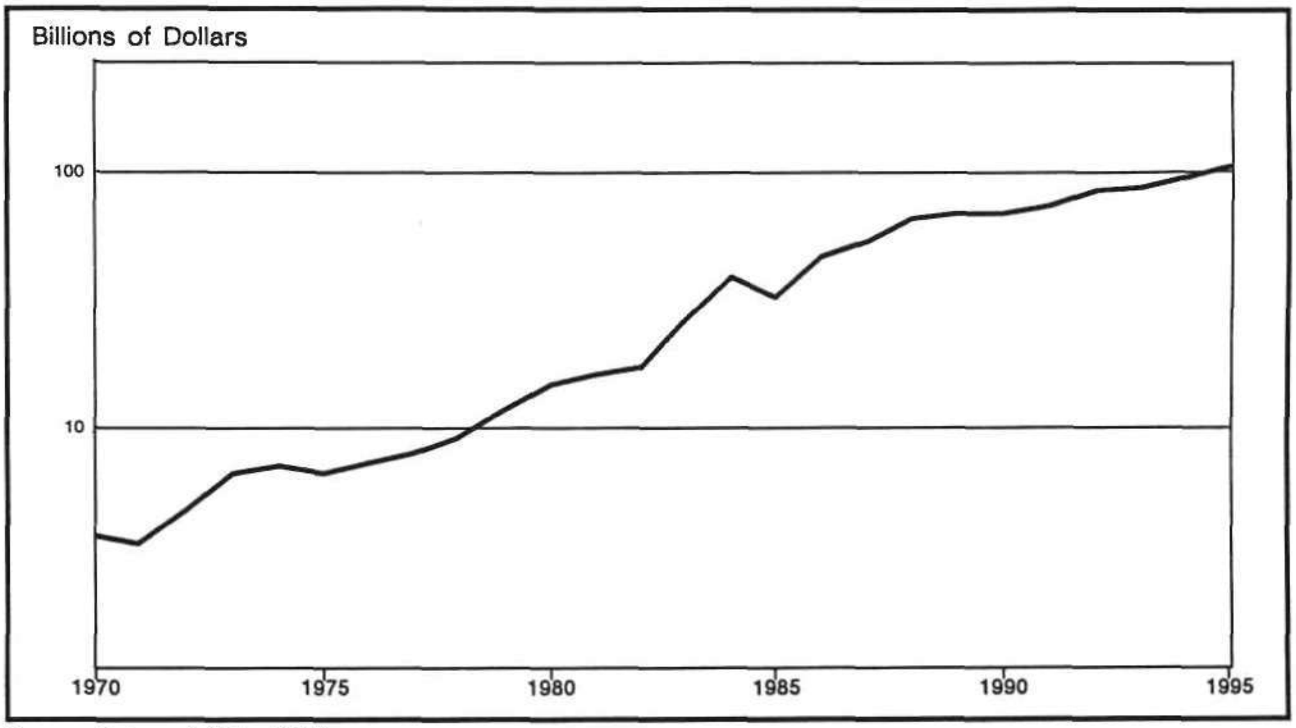
We believe that the long-term trend toward slower growth will continue. We are forecasting a CAGR of 12.6 percent from 1990 through 1995. In addition, we believe that the cyclicality of the industry, although still in evidence, will abate considerably in magnitude. We do not foresee annual growth approaching even the 25 to 30 percent range in any one year. Figure 2 shows the worldwide industry size in dollars from 1970 through 1995. Figure 3 shows the annual percentage of change for each year.

Reasons for Changes in Trends

Some reasons for generally slower growth and moderation of the silicon cycle are as follows:

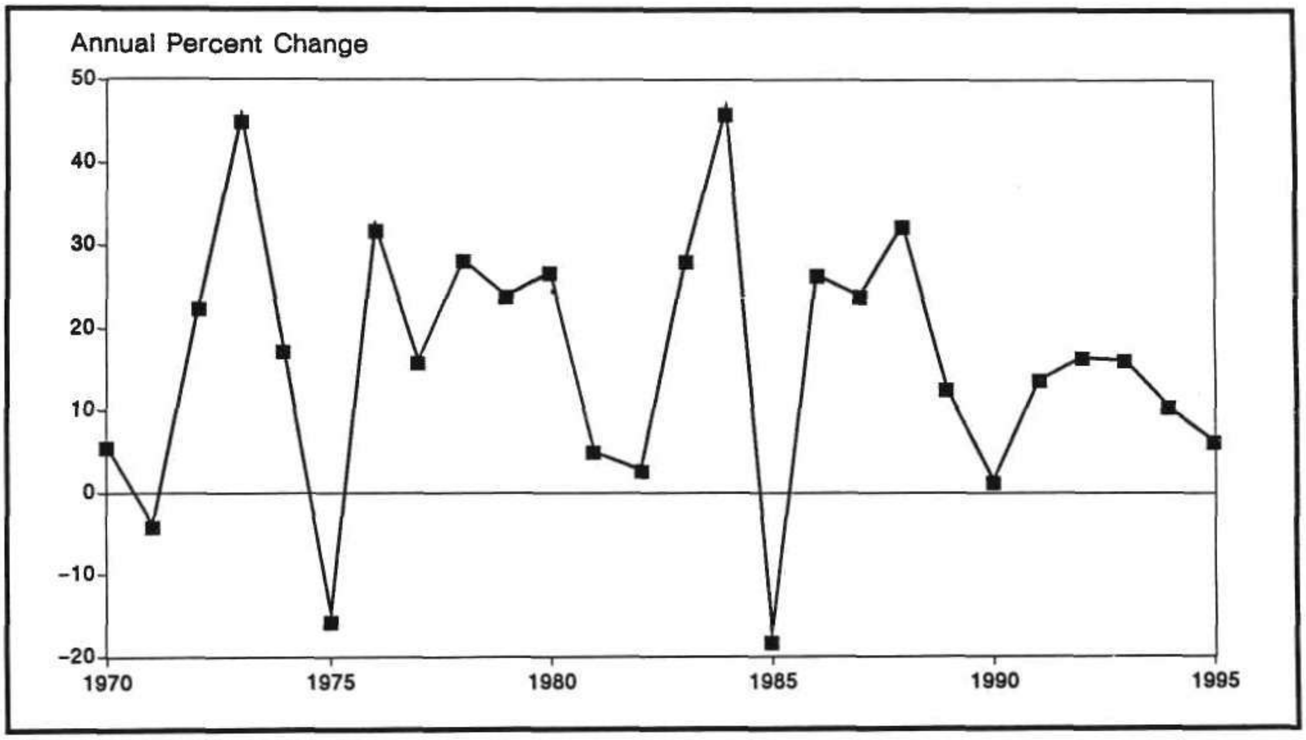
- In the United States, electronic equipment production is approaching 4 percent of GNP. As other industries have reached this rate, they have begun to grow in line with GNP growth rather than at a higher rate. In addition, many U.S. semiconductor and electronic equipment companies are building new manufacturing plants in Europe to capitalize on 1992 and the high growth that is currently being experienced and is expected to continue in that market. We forecast electronic equipment production in North America to grow at a 5.3 percent CAGR from 1990 through 1995.
- In general, most industrialized economies are now growing at a slower rate than in the 1980s. This is particularly true for the United States and Japan, both of which are moving manufacturing operations overseas to Europe and Asia. We forecast Japanese electronic equipment production to grow at a CAGR of 7.3 percent from 1990 through 1995. The biggest areas of activity during this period will be Europe and Asia/Pacific-ROW, with electronic equipment production CAGRs of 9.0 and 12.7 percent, respectively.

FIGURE 2
Worldwide Semiconductor Consumption Long-Term Trend
(Factory Revenue in Billions of U.S. Dollars)



Source: Dataquest (May 1991)

FIGURE 3
Worldwide Semiconductor Consumption Long-Term Trend
(Annual Percentage Change)



Source: Dataquest (May 1991)

- There is no single product visible to us that can fuel the industry in the way that the hand-held calculator and the personal computer did in their early years.
- Improved relationships between semiconductor vendors and users have led to better inventory control by users and better capacity planning by vendors. In the past, poor management of these two variables has led to double and triple ordering and severe overcapacity situations.

The Forecast

Table 3 shows our forecast by region from 1990 through 1995. We expect the next market peak to occur in the 1992-to-1993 time frame, in keeping with historical cyclicality and the traditional market drivers of U.S. presidential elections and the Olympic games. We believe that the market will soften slightly in 1994 and 1995. Throughout the forecast period, we expect Europe and Asia/Pacific-ROW to consistently outperform North America and Japan.

Table 4 shows our worldwide semiconductor forecast by product category. We expect MOS memory and MOS microcomponents to continue to be the fastest-growing product categories. Analog and MOS logic will also do well. (We include mixed-signal analog/digital integrated circuits, a very fast-growing technology, in the Analog category.) We expect bipolar digital memory and logic to continue to decline as this technology is replaced by high-speed CMOS and BiCMOS.

Dataquest Conclusions

The semiconductor industry of the 1990s will be different than that of the 1980s. Growth will be more moderate and less cyclical, as the electronics industry in general becomes a large enough component of the world economy to be driven by it, rather than to drive it.

Although growth rates will not be as high and as dynamic as in the past, opportunities still exist. The geographic regions of greatest opportunity will be Europe and Asia, driven by growing economies,

Table 3
Worldwide Semiconductor Consumption by Region (Factory Revenue in Millions of Dollars)

Company:	All
Product:	Total Semiconductor
Region of Consumption:	Each
Distribution Channel:	NM
Application:	All
Specification:	All

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
North America	17,386	18,761	21,386	24,810	26,895	28,001	10.0
Percent Change	-3.1	7.9	14.0	16.0	8.4	4.1	
Japan	22,508	26,354	30,762	34,655	38,200	40,762	12.6
Percent Change	-2.1	17.1	16.7	12.7	10.2	6.7	
Europe	10,661	12,274	14,416	17,313	19,326	20,764	14.3
Percent Change	9.3	15.1	17.5	20.1	11.6	7.4	
Asia/Pacific-ROW	7,670	8,834	10,625	13,025	14,804	16,004	15.8
Percent Change	17.6	15.2	20.3	22.6	13.7	8.1	
Total Worldwide	58,225	66,223	77,189	89,803	99,225	105,531	12.6
Percent Change	1.8	13.7	16.6	16.3	10.5	6.4	

NM = Not meaningful
Source: Dataquest (May 1991)

TABLE 4
Worldwide Semiconductor Consumption by Product Category (Factory Revenue in Millions of U.S. Dollars)

Company:	All
Product:	Each
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	All

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Total Semiconductor	58,225	66,223	77,189	89,803	99,225	105,531	12.6
Percent Change	1.8	13.7	16.6	16.3	10.5	6.4	
Total IC	47,303	54,103	64,232	75,522	83,934	89,840	13.7
Percent Change	0.8	14.4	18.7	17.6	11.1	7.0	
Bipolar Digital	4,440	4,624	4,679	4,683	4,480	4,256	-0.8
Percent Change	-1.6	4.1	1.2	0.1	-4.3	-5.0	
Bipolar Memory	459	440	434	433	402	375	-4.0
Percent Change	-15.0	-4.1	-1.4	-0.2	-7.2	-6.7	
Bipolar Logic	3,981	4,184	4,245	4,250	4,078	3,881	-0.5
Percent Change	0.3	5.1	1.5	0.1	-4.0	-4.8	
MOS Digital	32,292	37,709	46,294	55,628	62,243	66,906	15.7
Percent Change	-2.2	16.8	22.8	20.2	11.9	7.5	
MOS Memory	13,091	14,974	18,798	23,001	26,078	28,283	16.7
Percent Change	-20.0	14.4	25.5	22.4	13.4	8.5	
MOS Micro-component	10,068	12,118	14,907	17,917	20,076	21,604	16.5
Percent Change	22.8	20.4	23.0	20.2	12.1	7.6	
MOS Logic	9,133	10,617	12,589	14,710	16,089	17,019	13.3
Percent Change	7.9	16.2	18.6	16.8	9.4	5.8	
Analog	10,571	11,770	13,259	15,211	17,211	18,678	12.1
Percent Change	12.6	11.3	12.7	14.7	13.1	8.5	
Total Discrete	8,235	9,112	9,703	10,721	11,342	11,513	6.9
Percent Change	7.5	10.6	6.5	10.4	5.8	1.5	
Total Optoelectronic	2,687	3,008	3,254	3,560	3,949	4,178	9.2
Percent Change	2.3	11.9	8.2	9.4	10.9	5.8	

NM = Not meaningful
Source: Dataquest (May 1991)

communications standardization, and both new and reindustrialization. The applications with greatest opportunity will be personal communications, personal data processing equipment (such as laptop and palm-top PCs, personal faxes), workstations, and—particularly in Europe—transportation.

Patricia S. Cox

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

FINAL 1990 SEMICONDUCTOR MARKET SHARES

INTRODUCTION

The number one rule of the semiconductor game asserted itself forcefully in 1990: What goes up must come down. Companies that derive large portions of their revenue from highly volatile commodity products will eventually see their business decline and their market share decrease as rapidly as they had previously grown. The case in point is MOS memory, which was responsible for much of the semiconductor industry's growth in 1988 and 1989. The market share gains made by memory suppliers in those years fell by the wayside (in most cases) in 1990, allowing other companies to move up in the ranking list.

MICROCOMPONENTS: THE 1990 MARKET DRIVER

Although the memory market did not disappear in 1990, steep price declines made it an unpleasant market to be in. The top three semiconductor vendors in 1990—NEC, Toshiba, and Hitachi—each derived 35 percent or more of their 1990 semiconductor revenue from MOS memory products. In 1990, this ratio slipped by 3 to 6 percentage points. Although the same effect can be seen for the fourth and fifth ranked companies—Motorola and Intel—these companies received only 12 and 18 percent, respectively, of their 1989 revenue from MOS memory. Figure 1 compares 1989 and 1990 reliance on MOS memory by these companies.

In 1990, these top five companies increased the percentage of total semiconductor revenue from MOS microcomponents. In the case of Intel, which went up in the rankings from number eight to number five, the portion of total semiconductor revenue that came from microcomponents grew from 79 to 86 percent. These comparisons can be seen in Figure 2.

The effect of MOS microcomponents on the industry as a whole can be seen in Figure 3, which shows that were it not for the dramatic growth of microcomponents, the semiconductor industry would have declined by 2 percent in 1990, rather than growing 2 percent.

DIFFERENCES IN REGIONAL COMPANIES

It is very clear that vastly different product strategies are being followed by each regional grouping of companies. The largest portion of North American companies' 1990 revenue—27 percent—came from microcomponents, while the largest portions of Japanese companies' revenue were from MOS memory (28 percent) and the combined grouping of bipolar digital, discrete, and optoelectronics (29 percent). European companies, on the other hand, are heavily dependent on bipolar digital/discrete/opto (36 percent) and analog (30 percent); their revenue from the fastest-growing segments of the semiconductor industry (in the long term)—MOS memory and microcomponents—totaled only 21 percent of their semiconductor revenue. Asia/Pacific companies' revenue was very heavily skewed in favor of memory, with 63 percent of their revenue coming from that product category.

Figure 4 illustrates the product portfolios by regional company base. From this analysis, it appears that the most evenly balanced portfolios belong to the North American and Japanese companies, with percentage point spreads of only 13 and 16 percentage points, respectively, between the largest and smallest categories.

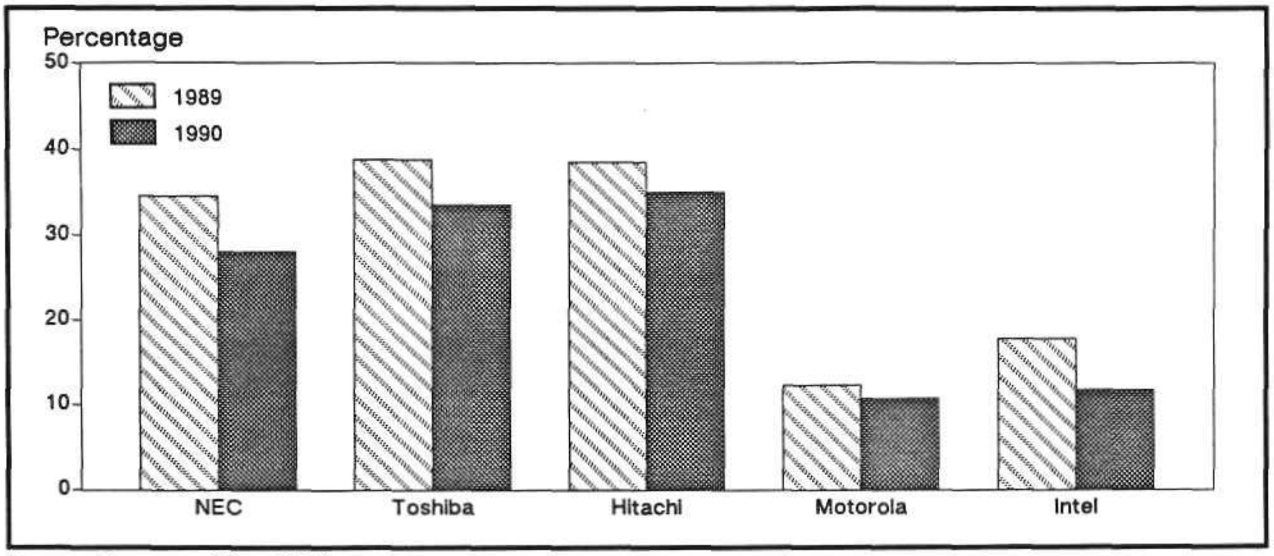
Although it might initially appear that European companies' portfolios are less well balanced, their targeted application markets differ from North American and Japanese companies in that a higher percentage of their output is aimed at the consumer

Semiconductor Group Newsletters 1991-06

0010456

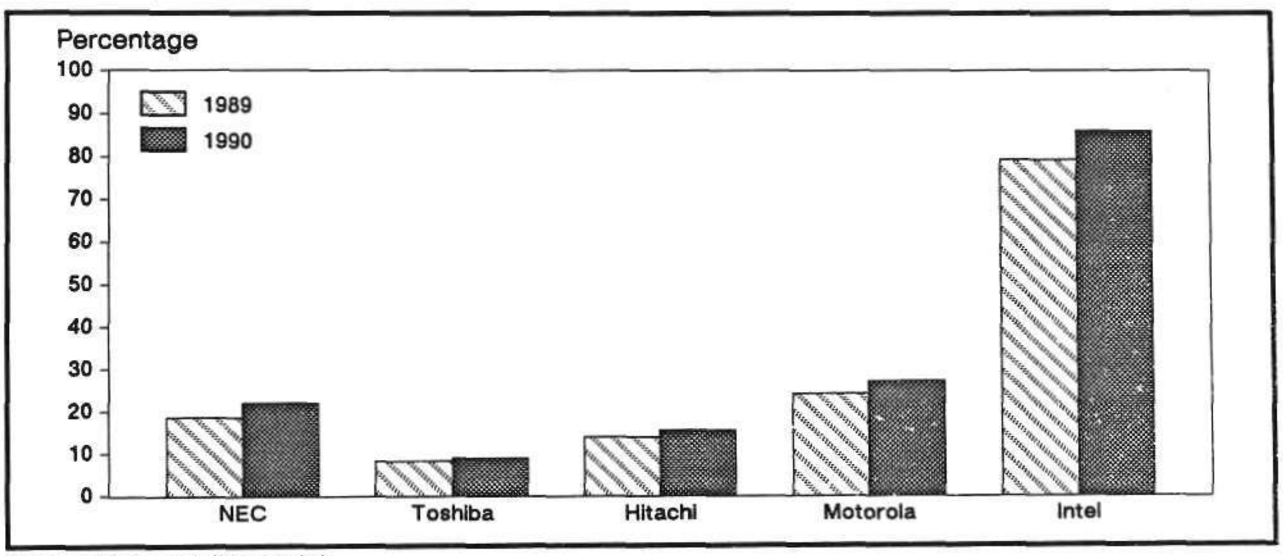
Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398 / (408) 437-8000 / Telex 171973 / Fax (408) 437-0292

FIGURE 1
Top Five 1990 Semiconductor Suppliers' Reliance on MOS Memory (Percentage of Total Semiconductor)



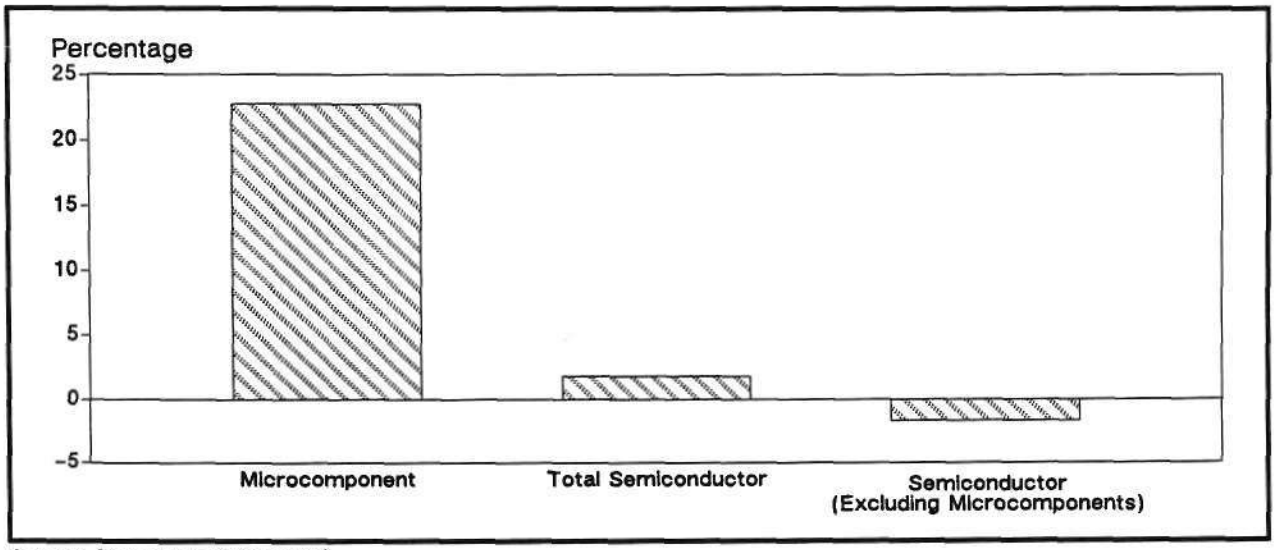
Source: Dataquest (May 1991)

FIGURE 2
Top Five Semiconductor Suppliers' Reliance on MOS Microcomponents (Percentage of Total Semiconductor)



Source: Dataquest (May 1991)

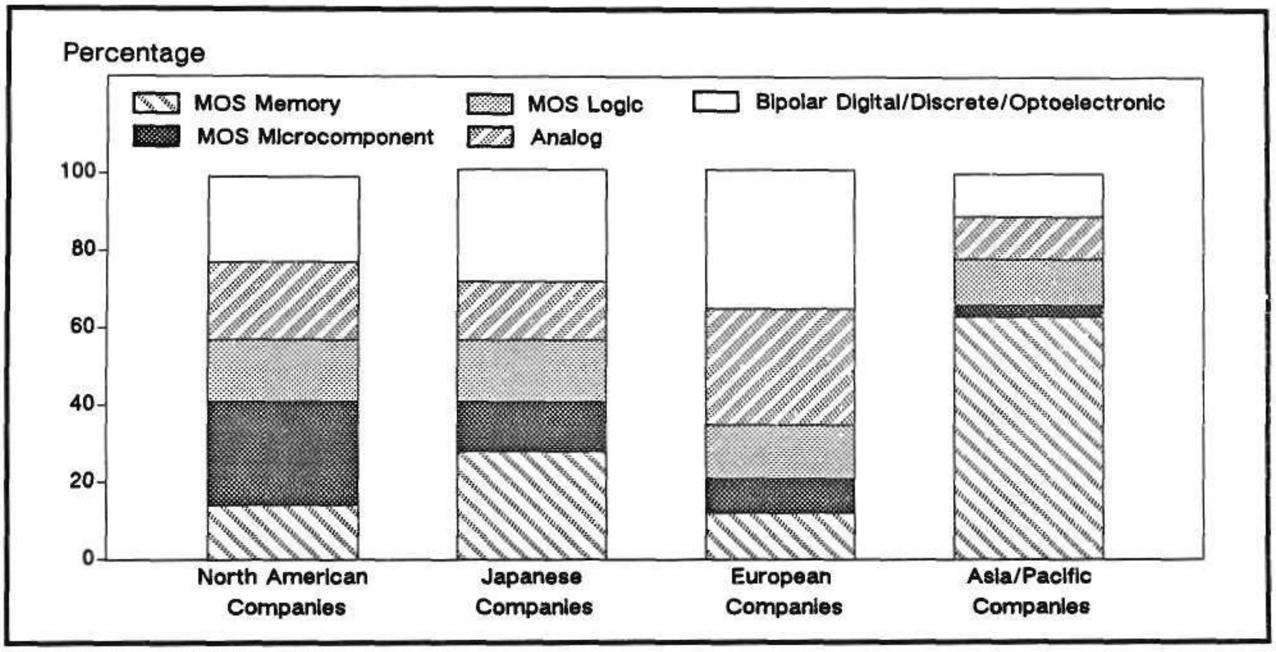
FIGURE 3
MOS Microcomponents: The Industry Driver
(Percent Growth in 1990)



Source: Dataquest (May 1991)

Source: Dataquest (May 1991)

FIGURE 4
1990 Product Portfolios by Company Base
(Percentage of Dollar Revenue by Product Category)



Source: Dataquest (May 1991)

and telecommunications industries, which use large quantities of discrete and analog chips.

The Asia/Pacific company statistics are skewed by Samsung, whose sales account for 62 percent of this group. Because Samsung has become one of the world's largest DRAM suppliers, it is not surprising that MOS memory accounts for 63 percent of Asia/Pacific company semiconductor revenue.

1990 RANKINGS AND MARKET SHARE

Table 1 is an analysis of the worldwide semiconductor market by regional supplier base and regional consumption market. This table shows that in 1990 North American companies held 37 percent of the worldwide semiconductor market, Japanese companies held 49 percent, European companies held 11 percent, and Asia/Pacific companies held 4 percent.

Table 2 is a breakdown of the semiconductor market by product category for 1989 and 1990. The market grew a total of only 1.8 percent, but as previously alluded to, MOS microcomponents grew by 22.8 percent. Analog ICs, the second fastest-growing market, grew 12.6 percent. (We have included mixed-signal analog/digital ICs in the analog category.)

Table 1
Estimated Final 1990 Semiconductor Market Share Analysis (Factory Revenue in Millions of U.S. Dollars)

Company:	Each Regional Base
Product:	Total Semiconductor
Region of Consumption:	Each
Distribution Channel:	NM
Application:	All
Specification:	All

	Regional Market				
Company Base	North America	Japan	Europe	Asia/ Pacific-ROW	World
North America ($M)	11,942	2,402	4,492	2,701	21,537
Percent of Regional Market	69	11	42	35	37
Percent of Company Sales	55	11	21	13	100
Japan ($M)	3,777	19,825	1,814	2,961	28,377
Percent of Regional Market	22	88	17	39	49
Percent of Company Sales	13	70	6	10	100
Europe ($M)	1,074	164	4,117	851	6,206
Percent of Regional Market	6	1	39	11	11
Percent of Company Sales	17	3	66	14	100
Asia/Pacific ($M)	593	117	238	1,157	2,105
Percent of Regional Market	3	1	2	15	4
Percent of Company Sales	28	6	11	55	100
World ($M)	17,386	22,508	10,661	7,670	58,255
Percent of Regional Market	100	100	100	100	100
Percent of Company Sales	30	39	18	13	100

NM = Not meaningful
Source: Dataquest (May 1991)

TABLE 2
Estimated Semiconductor Consumption
(Factory Revenue in Millions of U.S. Dollars)

Company:	All
Product:	Each
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	All

	1989	1990	Percent Change
Total Semiconductor	57,213	58,225	1.8
Total Integrated Circuit	46,924	47,303	0.8
Bipolar Digital	4,510	4,440	-1.6
Bipolar Memory	540	459	-15.0
Bipolar Logic	3,970	3,981	0.3
MOS Digital	33,024	32,292	-2.2
MOS Memory	16,361	13,091	-20.0
MOS Microcomponent	8,202	10,068	22.8
MOS Logic	8,461	9,133	7.9
Analog	9,390	10,571	12.6
Discrete	7,662	8,235	7.5
Optoelectronic	2,627	2,687	2.3

NM = Not meaningful
Source: Dataquest (May 1991)

The top 40 semiconductor companies' worldwide rankings and revenue are shown in Table 3.

DATAQUEST CONCLUSIONS

The memory market will recover, and companies with major commitments in this market will have a chance to regain semiconductor market share. However, in 1990 Dataquest saw that a strong marketing strategy in other product areas can pay off handsomely. We continue to believe that companies with balanced product portfolios in conjunction with volatile commodity exposure will gain market share over the long term.

Patricia S. Cox

Note: Detailed market share data books have been completed and mailed to binderholders of the SIS, JSIS, ESIS, ASETS, and NASM services.

TABLE 3
Estimated Market Share Ranking
(Factory Revenue in Millions of U.S. Dollars)

Company:	Top 40
Product:	Total Semiconductor
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	All

1990 Rank	1989 Rank		1989 Revenue	1990 Revenue	Percent Change	1990 Market Share (%)
1	1	NEC	5,015	4,898	-2	8.4
2	2	Toshiba	4,930	4,843	-2	8.3
3	3	Hitachi	3,974	3,893	-2	6.7
4	4	Motorola	3,319	3,694	11	6.3
5	8	Intel	2,430	3,171	30	5.4
6	5	Fujitsu	2,963	2,880	-3	4.9
7	6	Texas Instruments	2,787	2,574	-8	4.4
8	7	Mitsubishi	2,579	2,319	-10	4.0
9	10	Philips	1,716	2,011	17	3.5
10	9	Matsushita	1,882	1,942	3	3.3
11	11	National Semiconductor	1,618	1,719	6	3.0
12	13	SGS-Thomson	1,301	1,463	12	2.5
13	12	Sanyo	1,365	1,381	1	2.4
14	15	Sharp	1,230	1,325	8	2.3
15	14	Samsung	1,260	1,315	4	2.3
16	16	Siemens	1,194	1,224	3	2.1
17	19	Sony	1,077	1,146	6	2.0
18	17	Oki	1,154	1,074	-7	1.8
19	18	Advanced Micro Devices	1,100	1,053	-4	1.8
20	20	AT&T	873	861	-1	1.5
21	21	Harris	830	800	-4	1.4
22	22	Rohm	740	774	5	1.3
23	23	LSI Logic	512	598	17	1.0
24	26	Sanken	387	407	5	0.7
25	NM	GEC Plessey	0	390	NM	0.7
26	28	Fuji Electric	362	385	6	0.7

(Continued)

TABLE 3 (Continued)
Estimated Market Share Ranking
(Factory Revenue in Millions of U.S. Dollars)

Company:	Top 40
Product:	Total Semiconductor
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	All

1990 Rank	1989 Rank		1989 Revenue	1990 Revenue	Percent Change	1990 Market Share (%)
27	29	Analog Devices	357	381	7	0.7
28	25	ITT	390	371	-5	0.6
29	31	VLSI Technology	286	324	13	0.6
30	30	Telefunken Electronic	299	295	-1	0.5
31	24	Micron Technology	395	286	-28	0.5
32	32	Hewlett Packard	269	279	4	0.5
33	35	Chips & Technologies	240	265	10	0.5
34	40	International Rectifier	190	225	18	0.4
35	39	Cypress Semiconductor	196	223	14	0.4
36	42	General Instrument	170	214	26	0.4
37	27	Seiko Epson	368	213	-42	0.4
38	NA	Shindengen Electric	NA	209	NA	0.4
39	33	NMB Semiconductor	247	201	-19	0.3
40	43	Rockwell	165	200	21	0.3
		All Others	7,043	6,399	-9	11.0
		North American Companies	19,978	21,537	8	37.0
		Japanese Companies	29,809	28,377	-5	48.7
		European Companies	5,443	6,206	14	10.7
		Asia/Pacific Companies	1,983	2,105	6	3.6
		Total Market	57,213	58,225	2	100.0

NA = Not available
NM = Not meaningful
Source: Dataquest (May 1991)

EDITION

Dataquest
a company of The Dun & Bradstreet Corporation

Dataquest Perspective

Special Edition

July 22, 1991

Market Analysis

Market Analysis

Dataquest's 1990 Electronics Industry Market Shares

Every year, Dataquest surveys both vendors and users in most major high-technology industries to collect market share and market sizing data. This article presents a summary of the 1990 market share results and is designed to provide an overview of the major players and major events of 1990 in the high-technology markets of telecommunications; semiconductor equipment, manufacturing, and materials; semiconductor devices; business and technical computer systems; personal computers; software; document imaging systems; CAD/CAM/CAE; computer storage; display terminals; electronic printers; and plain paper copiers.

The Markets

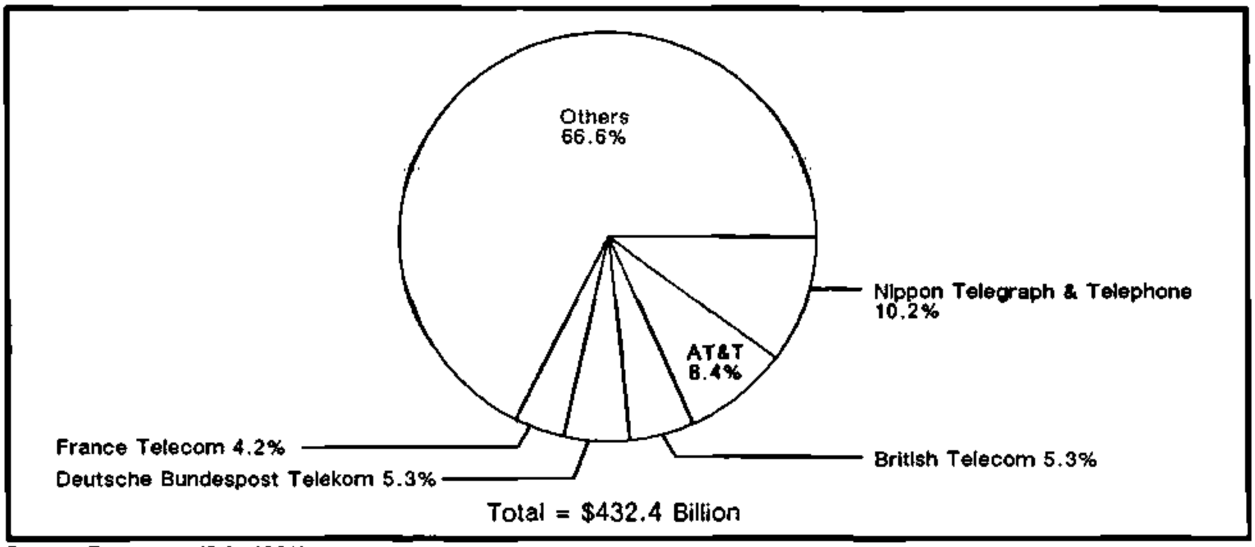
Telecommunications

The revenue market shares shown in Figure 1 reflect the total telecommunications market, including network services and equipment sales. The total available market for telecommunications was $432.4 billion in 1990. As is typical in this industry, the vast majority (more than 78 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 are representative of network providers—postal, telegraph, and telephone organizations (PTTs)—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 equipment-related revenue of slightly more than $44 billion, which is almost exactly the total telecommunications-related revenue of NTT (see Figure 2).

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

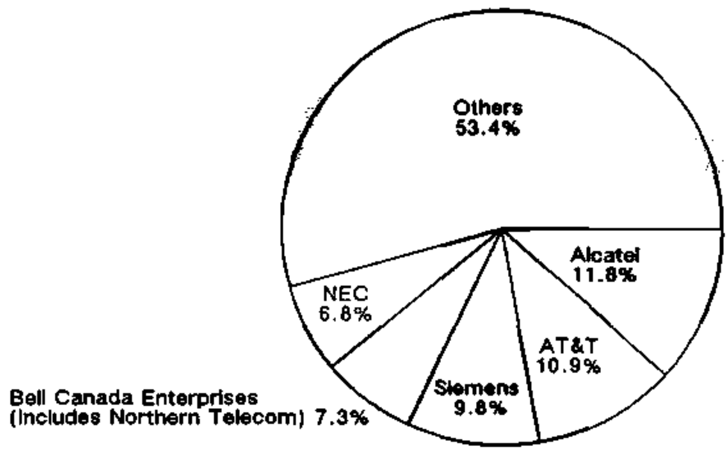
The 1990s will be an exciting time for the telecommunications industry, especially in the area of personal communications. The continuing globalization of the industry, utilization of communications standards such as ISDN, and

Figure 1
Estimated 1990 Worldwide Telecommunications Equipment and Services Revenue



Source: Dataquest (July 1991)

Figure 2
Estimated 1990 Worldwide Telecommunications Equipment Revenue



Source: Dataquest (July 1991)

ongoing mergers and acquisitions set the stage for an intense and dynamic business environment.

Semiconductor Equipment, Manufacturing, and Materials

In 1990, the worldwide market for semiconductor wafer fab equipment was $5.8 billion, down 3 percent from its 1989 level of $5,996 million. Figure 3 displays the top five participants by percent of market share in 1990.

In 1990, four of the top five players in the semiconductor equipment market were of Japanese origin. Applied Materials, a U.S. company that ranked number two with revenue of $462 million, was the only non-Japanese company in the top five. In the 1960s and 1970s, the wafer fab equipment market was dominated by U.S. companies. As the industry matured in the 1980s, however, one of the major trends that emerged was a steady gain in worldwide market share for Japanese equipment companies. The steady gain was due to the growth of a vigorous domestic semiconductor device manufacturing industry in Japan. In 1990, this industry accounted for $2.9 billion of a $5.8 billion worldwide wafer fab equipment market.

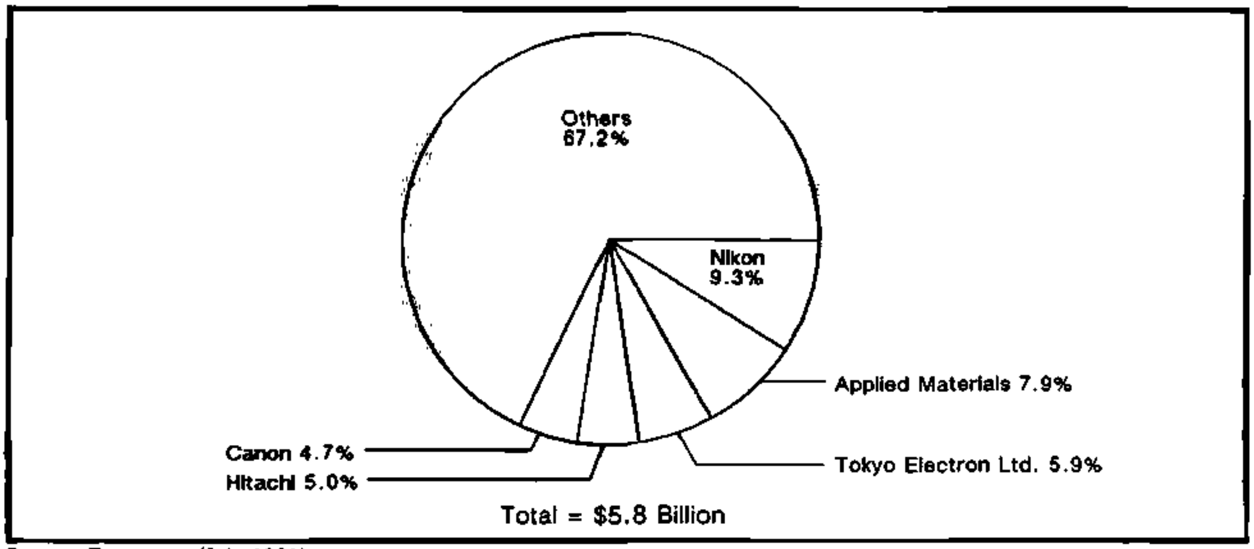
Semiconductor Devices

The number one rule of the semiconductor game asserted itself forcefully in 1990: What goes up must come down. Companies that derive large portions of their revenue from highly volatile commodity products eventually will see their business decline and their market share decrease as rapidly as they had previously grown. A case in point is MOS memory, which was responsible for much of the semiconductor industry's growth in 1988 and 1989. The market share gains made by memory suppliers in those years fell by the wayside (in most cases), allowing other companies to move up in the ranking list (see Figure 4).

Although the memory market did not disappear in 1990, steep price declines made it an unpleasant market to be in. The top three semiconductor vendors in 1990—NEC, Toshiba, and Hitachi—each derived 35 percent or more of their 1989 semiconductor revenue from MOS memory products. In 1990, this ratio slipped 3 to 6 percentage points. Although the same effect can be seen for the fourth- and fifth-ranked companies—Motorola and Intel—these companies received only 12 and 18 percent, respectively, of their 1989 revenue from MOS memory.

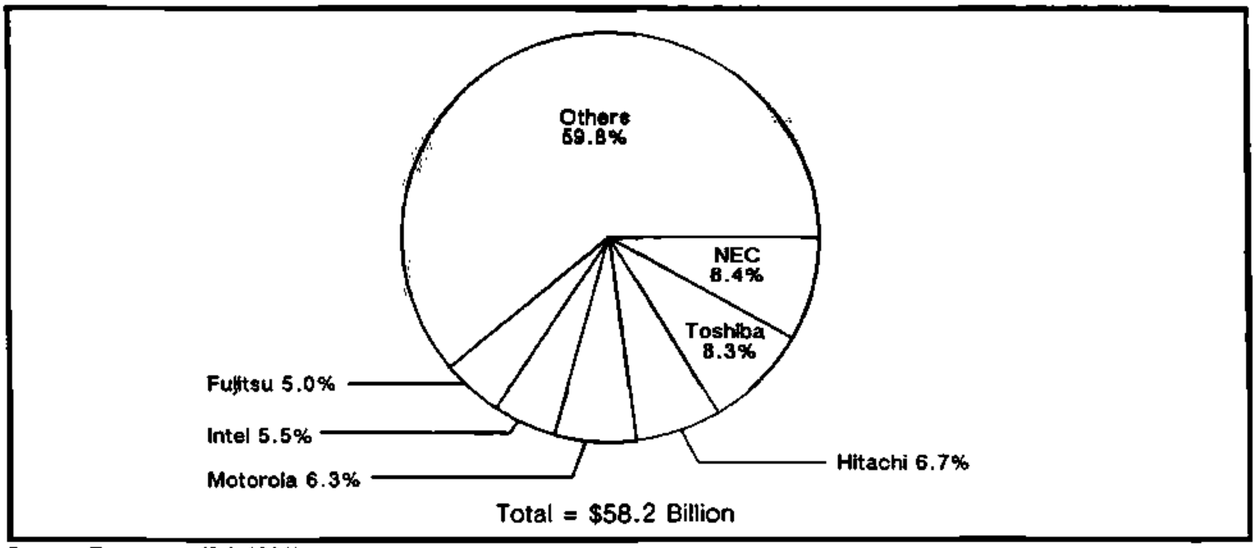
In 1990, these top five companies increased the percentage of total semiconductor revenue from MOS microcomponents. In the case of Intel, which went up in the rankings from number eight to number five, the portion of total semiconductor revenue that came from microcomponents grew from 79 to 86 percent. If it were not for the dramatic growth of microcomponents, the semiconductor industry would have

Figure 3
Estimated 1990 Total Semiconductor Equipment, Manufacturing, and Materials Factory Revenue



Source: Dataquest (July 1991)

Figure 4
Estimated 1990 Total Semiconductor Factory Revenue



Source: Dataquest (July1991)

declined by 2 percent in 1990, rather than having grown by 2 percent.

It is very clear that vastly different product strategies are being followed by each regional grouping of companies. The largest portion of North American companies' 1990 revenue—27 percent—came from microcomponents, while the largest portions of Japanese companies' revenue were from MOS memory (28 percent) and the combined grouping of bipolar digital, discrete, and optoelectronics (29 percent). European companies, on the other hand, are heavily dependent on bipolar digital, discrete, and optoelectronics (36 percent) and analog (30 percent); their revenue from the fastest-growing segments (in the long term) of the semiconductor industry—MOS memory and microcomponents—totaled only 21 percent of their semiconductor revenue. The Asia/Pacific companies' revenue was very heavily skewed in favor of memory, with 63 percent of their revenue coming from that product category.

The memory market eventually will recover, and companies with major commitments in this market will have a chance to regain semiconductor market share. However, in 1990, Dataquest saw that a strong marketing strategy in other product areas can pay off handsomely. We continue to believe that companies with balanced product portfolios in conjunction with volatile commodity exposure will gain market share over the long term.

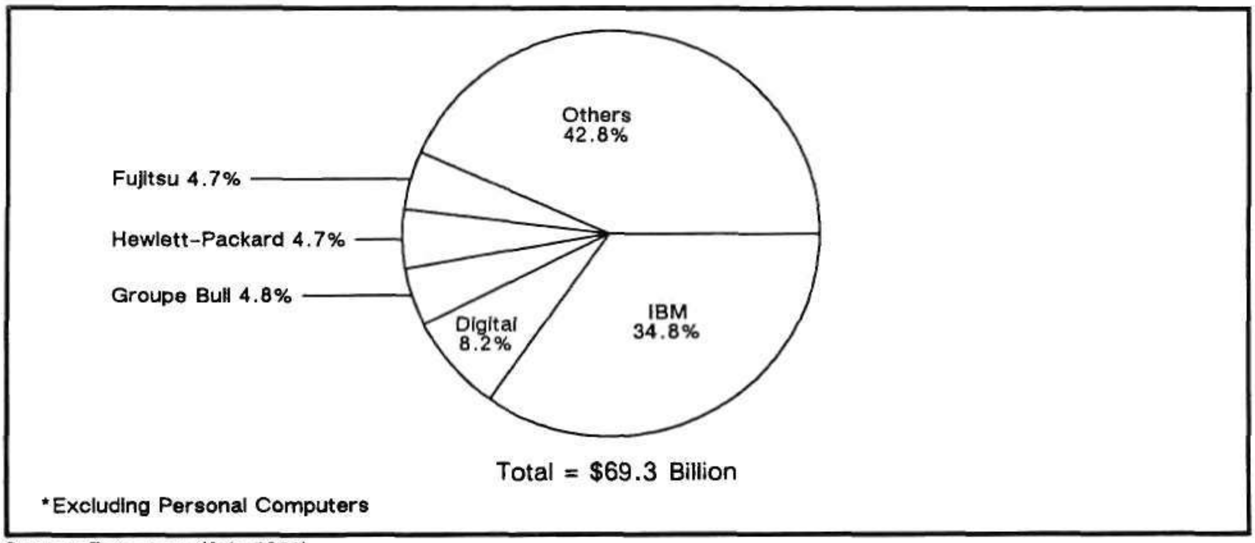
Business and Technical Computer Systems

The year 1990 was a tough one for the computer systems industry. The economic downturn in the United States and the threat of war in the Middle East combined with economic slowing in all regions of the world to slow the worldwide computer systems market growth. In total, the market grew only 6.4 percent over 1989, a rate lower than the 7.9 percent forecast for 1990.

The top five vendors' estimated 1990 factory revenue and market share are shown in Figure 5. IBM continued to hold the lead but lost about 1.4 percent in market share over 1989. With many major vendors having flat or declining revenue for the year, a number of the top vendors lost market share. Although remaining in the second-ranked position, traditional minicomputer vendor Digital Equipment Corporation has seen its share fall from 9.0 percent in 1989 to 8.2 percent in 1990. Digital struggled to maintain the traditionally profitable proprietary VAX line while transitioning to more open UNIX-based systems that have much narrower margins.

Of the top five vendors, only Hewlett-Packard and Fujitsu increased their market share from 1989 to 1990. Fujitsu went from 4.5 percent in 1989 to 4.7 percent in 1990. If the acquisition of ICL had been completed in 1990, Fujitsu's total computer systems revenue would have been $4.0 billion, moving Fujitsu into third place with a 5.8 percent market share. Other vendors making gains in 1990 were Hitachi and Sun Microsystems. Hitachi's gain was fueled by growth in the mainframe product segment. From 1989 to 1990, Hitachi's mainframe revenue increased 12.5 percent (including revenue from HDS in both 1989 and 1990). Sun Microsystems' move into the top ten has been based on the strength of virtually a single product line—workstations. The workstation product segment has been the hottest segment of the market for a number years, and Sun has been at the top of the workstation market for the last several years.

Figure 5
Estimated 1990 Worldwide Business and Technical Computer Systems Factory Revenue



Source: Dataquest (July 1991)

Personal Computers

In 1990, the Notebook PC gained notoriety. At COMDEX/Fall '90, 37 vendors introduced "notebook" computers. Also in 1990, prices fell the fastest in the shortest period of time. See Figure 6 for a display of the market leaders in 1990.

As 1990 came to a close, the market was left with an unstable pricing structure, shaky margins for vendors and dealers, and an economy struggling to stay on the positive side of growth.

HP validated the hand-held computer market with a bang. In April, the HP 95LX was introduced; Dataquest estimates that 300,000 could be sold by year-end. Pen-based PCs are the newest interest, with GRiD expanding the GRiDPad line and NCR entering the market. Operating systems are fueling the excitement with GO Corporation introducing the PenPoint operating system and Microsoft introducing PenWindows. By the end of the year, Dataquest expects several more entrants as PC vendors scramble for positioning in this potentially large market.

The desktop PC market is expected to crest in the United States, as portables eat into an already sluggish market and replacement sales continue to decrease.

The notebook PC market should be the most difficult market this year, as intense competition and obsolescence are precariously balanced. The 80386SL microprocessor will rapidly replace the 80386SX in the notebook segment. Vendors must balance demands for today's notebook sales with the risk of holding warehouses of 80306SX-based notebooks when the 80386SL-based notebook PC is available in volume.

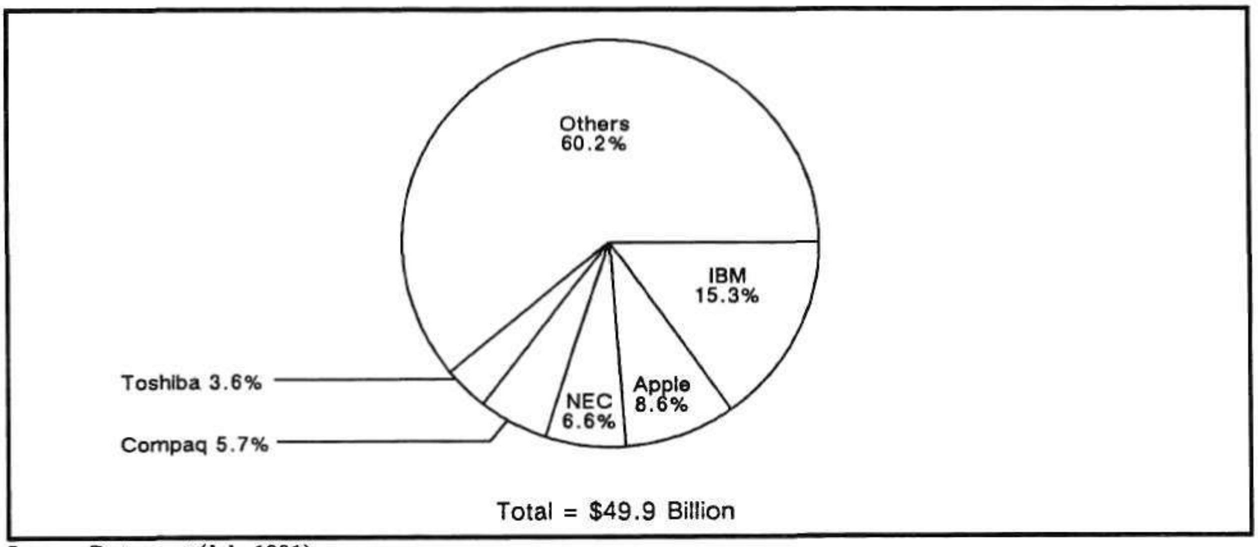
In the laptop DC and notebook segments, entropy is growing, causing further price confusion.

Dataquest expects Apple to increase its market share by units with new, lower-priced PCs and Compaq to increase market share with its notebook and high-end PCs. We also expect HP to increase market share with its new hand-held PC, IBM to increase market share with its assault on distribution channels, and Zenith Data Systems (a company of Groupe Bull) to increase market share as it emerges from a sleepy 1990 with new, well-designed laptop and notebook PCs.

Software

Windows was the star of the show in 1990, grabbing the attention of users and driving vendors to provide Windows products. Also monumental in that year was IBM and Microsoft's fight over the fate of operating software. IBM was intent on providing its own Presentation Manager (PM), not using Windows as the ubiquitous graphical user interface. It is interesting to note that while Microsoft is

Figure 6
Estimated 1990 Worldwide Personal Computer Factory Revenue



Source: Dataquest (July 1991)

aggressively promoting Windows over PM and implementing a strategy of cross-platform availability, it is still actively maintaining its present relationship with IBM. See Figure 7 for a display of the major players in 1990.

In 1990, Borland embarked on an aggressive marketing campaign in the spreadsheet market that successfully wooed a large part of the Lotus 1-2-3 installed base to Borland's QuattroPro. Through its dynamic marketing actions, Borland changed the competitive etiquette of this market, catching Lotus completely off guard. To no one's surprise, Lotus lost significant market share as a result. Also, Borland applied its new marketing techniques to Paradox, its relational database, with success. Other companies are copying Borland's style.

Also on the cutting edge of change, Borland broke away from traditional methods of selling products in this market. The company continued to sell products via the two-tier channel, while concentrating on direct sales through an aggressive direct-mail marketing campaign. Borland's innovation proved fruitful.

Of all the important events in 1990, Dataquest believes that Windows 3.0 will have the most significant effect on PC software for years to come. PC software as a market will be impacted by Borland International's product design and marketing innovations. The increasing growth of the direct market indicates that PC software is becoming more of a commodity.

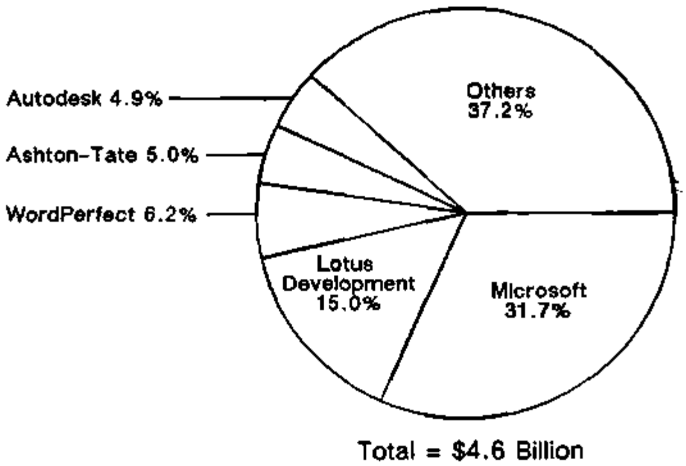
Document Imaging Systems

Dataquest defines document image management systems (DIMS) as computer systems that convert paper documents into digital images via scanning that can be viewed at a workstation, stored on random-access media, transmitted across networks, and printed. During tight times such as these, when many businesses must make cuts in budget and staff to stay afloat, DIMS seem to offer a viable way to be more productive using fewer resources. In the business document imaging system market, several key vendors' introduction of software enabling PCs to run document imaging applications promises to extend image management capabilities deeper into organizations.

To date, only IBM, Digital Equipment, and Wang Laboratories among the computer systems vendors have had measurable success in document imaging. Others, such as Bull, Hewlett-Packard, NCR, and Unisys, are moving slowly but steadily. FileNet, a company that specializes in providing document imaging systems, ranked second in terms of DIMS revenue in 1990 (see Figure 8).

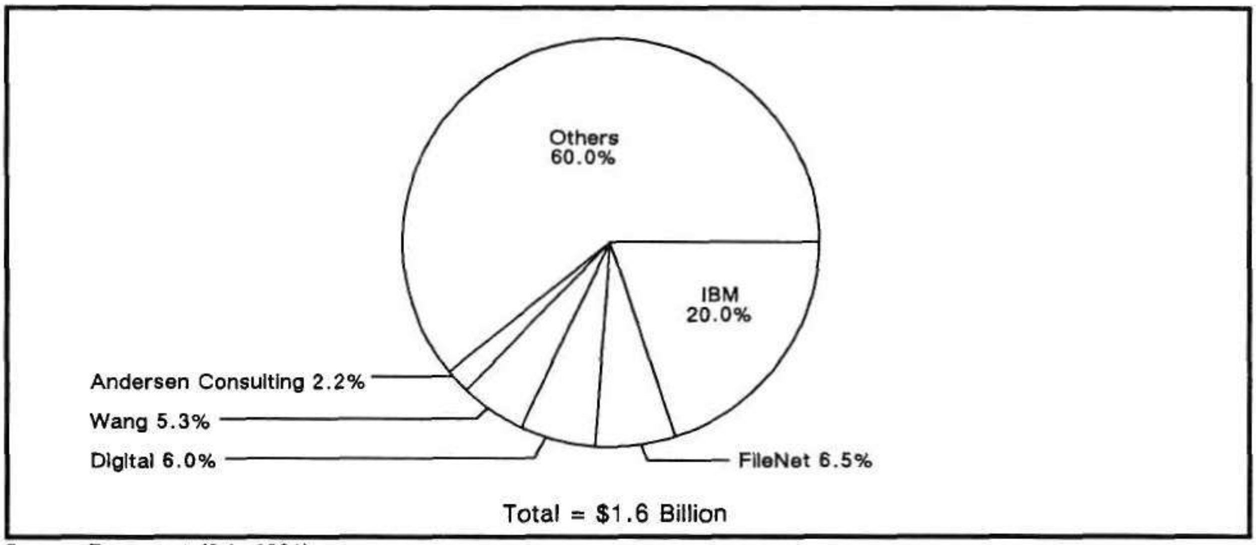
Technical document image management systems (TDIMS) are used to image wide-format drawings and documents. TDIMS shipments grew by nearly 14 percent between 1989 and 1990, and revenue skyrocketed by 46 percent. The top five market leaders in this marketplace are Optigraphics, Intergraph, GTX, Litton/Integrated Automation, and FormTek (see Figure 9).

Figure 7
Estimated 1990 Worldwide PC Software Factory Revenue*



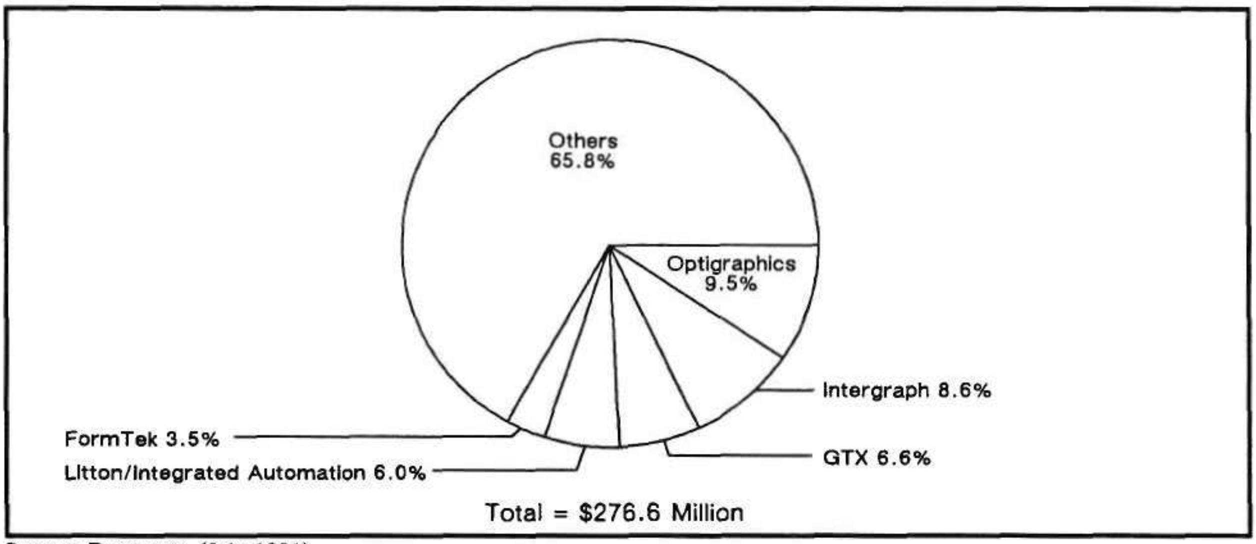
Source: Dataquest (July 1991)

Figure 8
Estimated 1990 Vendor Revenue—Business Document Image Management Systems



Source: Dataquest (July 1991)

Figure 9
Estimated 1990 Vendor Revenue—Technical Document Image Management Systems



Source: Dataquest (July 1991)

Although some of the industries served by TDIMS are experiencing hard times, this enabling technology continues to make inroads into engineering and document management groups across a broad number of industries.

Despite a year that was slower than expected in terms of overall TDIMS shipments, revenue was much higher than anticipated, and the TDIMS market continues to build momentum. This is a time when most TDIMS vendors and integrators are still getting it together—learning from pilot installations, building second-generation products, continuing to improve enabling technologies such as raster-to-vector conversion, and building a systems-implementation knowledge base.

CAD/CAM/CAE

In 1990, the CAD/CAM/CAE market grew 14.6 percent to $14.4 billion. The biggest gains in this market went either to vendors that had established CAD/CAM/CAE market share or to vendors that were very innovative. The biggest CAD/CAM/CAE vendors benefited from the growing importance placed by users on long-term supplier viability; buyers were willing to commit to using more design tools, but not without strategic alliances with leading vendors. The year was not a study in big vendors getting bigger, however. Users were also active in testing and buying some of the newest technology from all vendor sources, big and small. See Figure 10 for the major TDIMS vendors' 1990 market share.

The fastest-growing and best niche vendors in this maturing market reaped the rewards of developing joint marketing agreements with the top systems integration vendors. Products that enhance design, analysis, and quality control functions grew particularly well.

Instability in the electronic design automation (EDA) industry continued to create market uncertainty that affected growth. Several major players in the EDA industry weathered significant product transitions, others began to attack new markets, and many are being forced to revamp their business models.

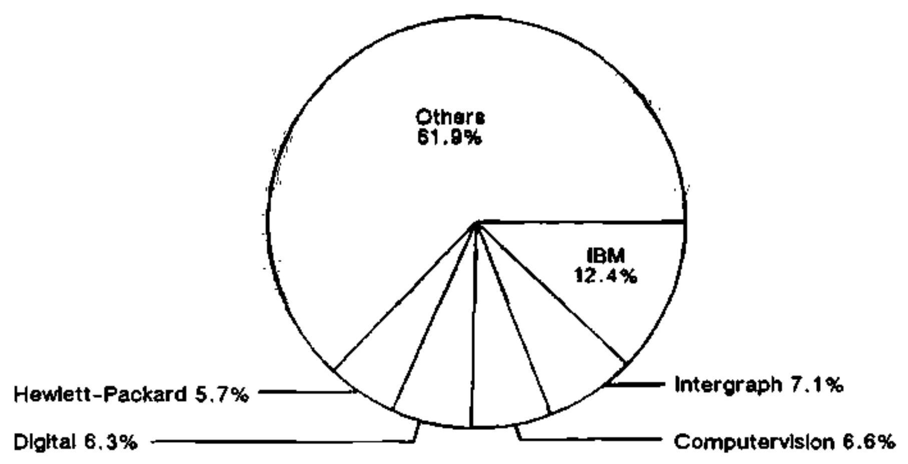
The European market continued to grow faster than expected, and it should continue to grow faster than the worldwide average. Opportunities for CAD/CAM/CAE in Eastern Europe will grow as the area moves to a Western-style, market-driven economy. Opportunities include both sales to existing companies for design of products to satisfy the enlarged domestic market and tool sales to Eastern European companies to assist their drive toward greater productivity and competitiveness.

Computer Storage

The computer storage market ended the year ahead of our previous projections. Worldwide factory revenue grew to $21.1 billion, an increase of 18 percent. Sales of 3.5-inch rigid disk drives (RDD) exploded beyond expectations, driving 1990 revenue in this segment to $5.6 billion, up 78 percent over 1989 revenue. The 3.5-inch RDD segment is the largest segment of the computer storage market and also the fastest growing.

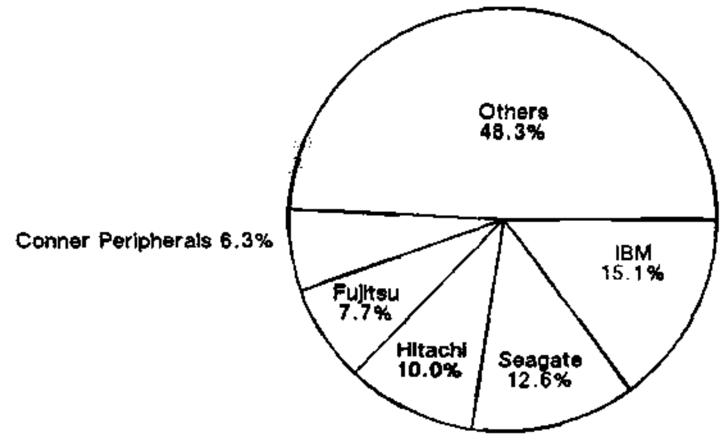
Figure 11 shows the estimated 1990 computer storage market shares. The top five companies are the same as in 1989; however, significant changes occurred during 1990. IBM remained in first place, albeit with a lower share than the previous year because of a large portion of its sales in the slower-growing high-end markets. Seagate overtook Hitachi for the number two spot, largely due to the growth of the 3.5-inch

Figure 10
Estimated 1990 CAD/CAM/CAE Worldwide Market Shares



Source: Dataquest (July 1991)

Figure 11
Estimated 1990 Worldwide Computer Storage Factory Revenue



Source: Dataquest (July 1991)

RDD market and an increased share of the 5.25-inch RDD market. Fujitsu does not participate in the 3.5-inch RDD market and lost market share during 1990. Conner Peripherals grew from 4 percent market share in 1989 to 6.3 percent in 1990.

Dataquest expects the 3.5-inch RDD segment to grow from its current 27 percent of the computer storage market to nearly 55 percent by 1995 and to greatly influence future total computer storage market shares. The key players in the 3.5-inch RDD segment are Conner, IBM, Maxtor, Quantum, Seagate, and Western Digital (in alphabetical order). The list of key players for 1991 will show the same names, but the positions will vary again.

Display Terminals

The top five leading worldwide display terminal vendors captured 52.3 percent of the total market (see Figure 12). IBM led this market with 22.6 percent market share, resulting from the continued success of its AS/400 product lines and the growth of its ANSI terminal business. Wyse, together with its subsidiary Link Technologies, maintained its leadership position in the still growing ASCII/ANSI/PC sector of the display terminal market.

Dataquest believes that the ASCII/ANSI/PC sector will continue to grow in market share. Color will play an increasingly significant role in the IBM 3270 and 5250 markets, but only a minor role in the ASCII/ANSI/PC market. The total ASCII/ANSI/PC market is expected to have a 5.9 percent compound annual growth rate (CAGR) through 1995.

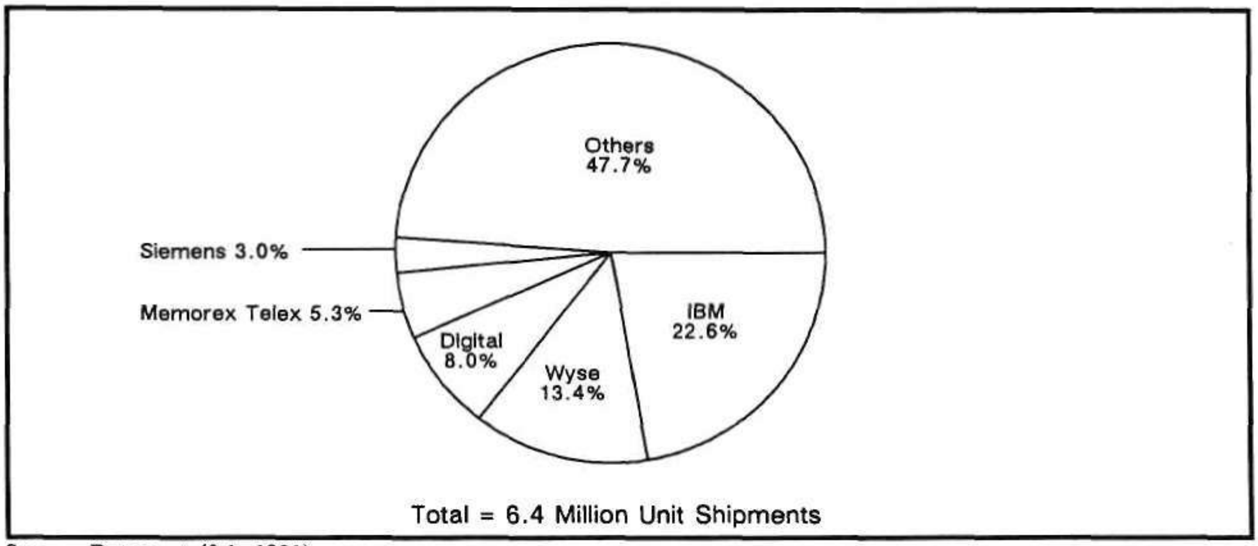
Electronic Printers

In some respects, the 1990 North American electronic printer market was a mirror image of 1989. There was only a slight growth in total factory revenue, and the market leaders and their rankings remained the same as in 1989. Figure 13 shows factory revenue of the major vendors of electronic printers.

In other respects, 1990 was a pivotal point in the market. It demonstrated Dataquest's previous assessments of the market. The serial printer market leveled off—serial dot matrix printers were being replaced by serial ink jet printers. Serial printers (which dominated the market in the 1980s) were being replaced by page printers. Page printers have become the dominant force in the printer market because they enable the user to advance to faster and higher-quality printing.

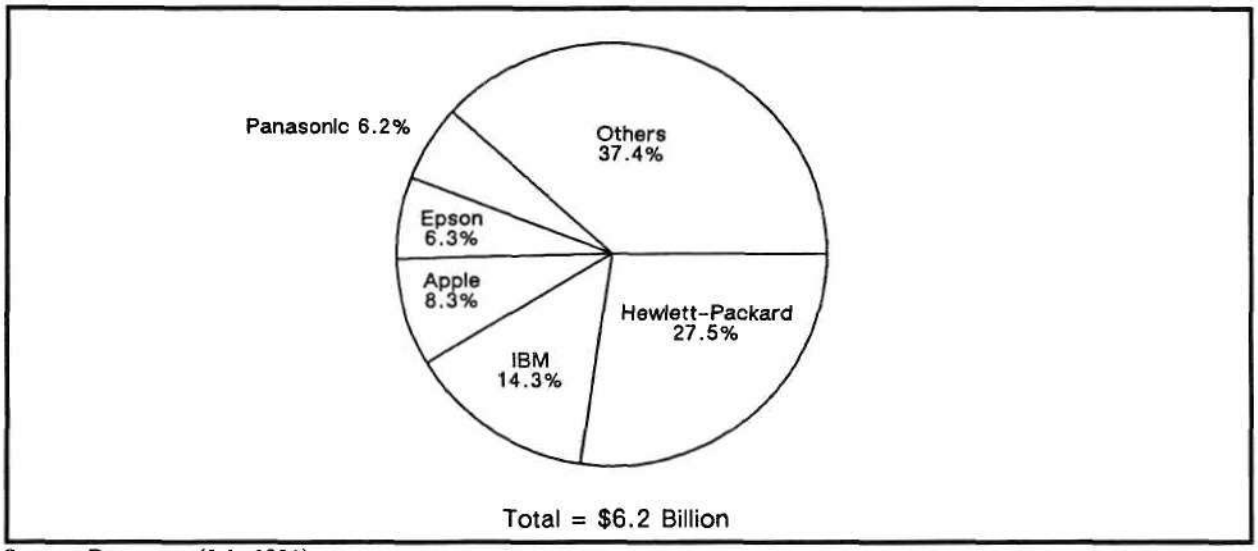
During 1990, page printers surpassed the 50 percent mark of total North American market revenue, and our projections are that this portion will expand to 60 percent by 1995. The

Figure 12
Estimated 1990 Worldwide Display Terminal Shipments



Source: Dataquest (July 1991)

Figure 13
Estimated 1990 North American Electronic Printer Factory Revenue



Source: Dataquest (July 1991)

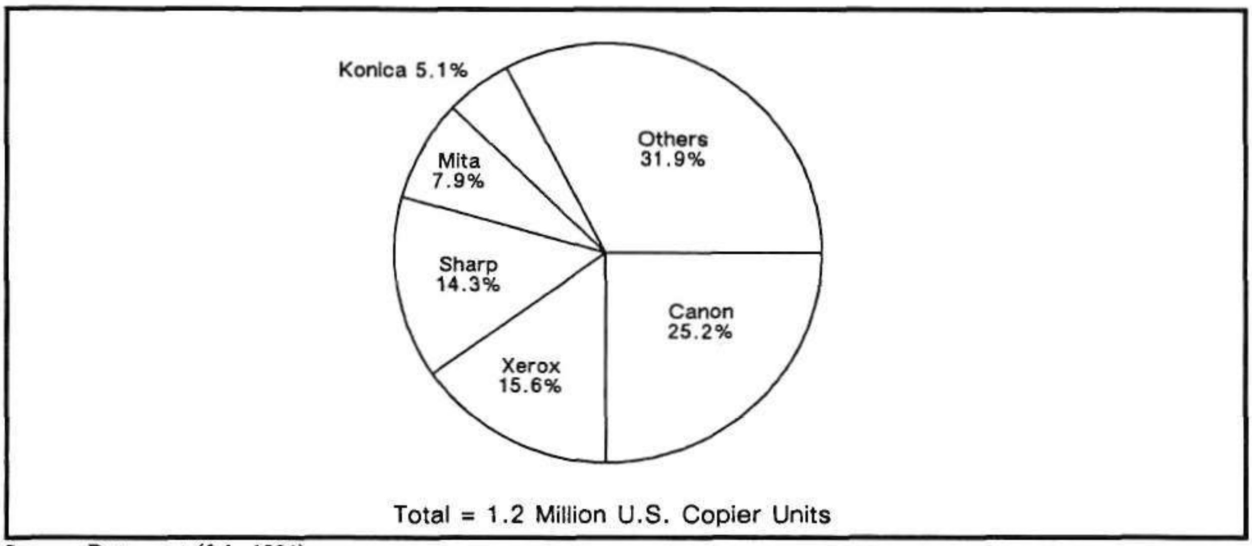
top three players in the total market (HP, IBM, and Apple) were also the market leaders in the page printer market—with 70 percent of that market.

Again in 1990, HP was clearly the winner in market share. HP had the dominant market share in both the ink jet and page printer markets, the fastest-growing segments of the electronic printer market.

Plain Paper Copiers

Once again, the clear winner in unit placements/shipments was Canon, followed by Xerox and Sharp. Canon's strength has traditionally been in the very low end of the copier market,

Figure 14
Estimated 1990 U.S. Plain Paper Copier (Placements)



Source: Dataquest (July 1991)

but the company is making a pronounced transition into a powerhouse in the midrange and upper end of the market. Xerox posted its seventh straight year of market share improvement. Although this improvement averages only about 1 percent per year, it does indicate a company that has made a remarkable turnaround in improvement of its market position. Sharp, which traditionally has had a good reputation in the low end of the market, expanded its capabilities in the midrange of the copier market. Figure 14 shows Dataquest's estimates of the 1990 U.S. market shares.

Although it is a relatively mature marketplace, there are still a number of dramatic changes taking place in the copier market. In the high end of the market, digital front ends that can be networked as output devices are being incorporated in order to improve the economies/efficiencies of the way documents are produced in high volume. This charge is being led by Xerox and Kodak.

In the midrange segments, traditionally dominated by independent dealers, we see increased competition as these dealers try to maintain their viability in the market. In the low end (a commodity market with little or no hardware differentiation), severe price cutting has led to margin erosion, with the result that dealers are giving less emphasis to this segment.

Dataquest's 1991 Electronics Industry Forecast

The electronics industry will continue to experience basic structural changes as we progress into the 1990s. These fundamental structural changes are being driven by globalization of telecommunication networks, maturation of sectors of the computer industry, ongoing expansion in the Asia/Pacific region, and continued company consolidations and alliances.

Although the 1990s started slowly with a burdening recession and war in the Persian Gulf, things are appearing to pick up according to significant indicators. Dataquest believes that the recession has hit rock bottom and is bouncing upward to recovery. This optimistic outlook is supported by the following U.S. government announcements of economic and business activity for the month of May:

- Industrial production is up 0.5 percent, the second consecutive monthly increase.
- Capacity utilization is up 0.2 percentage points to 78.7 percent.
- Nonfarm payrolls are up 58,000, which is the first increase in 11 months.
- Housing starts are up 0.1 percent.

- Retail sales are up 1.0 percent.
- Consumer borrowing is up 2.8 percent.

According to The Dun & Bradstreet Corporation, real gross national product (GNP) is expected to grow at only 0.2 percent in 1991, down from 1 percent in 1990. However, to get a true picture of 1991 GNP growth, we need to examine the quarterly data. The Gulf War was the major culprit in the first quarter, forcing first-quarter GNP growth to decline by 2.6 percent. However, things should begin to heat up in the remaining quarters: 1.5 percent for the second quarter, 3.8 percent for the third quarter, and 3.6 percent for the fourth quarter. Furthermore, real GNP will increase to 3.4 percent in 1992, the highest it has been in the past three years. A recovering GNP should lead to reduced inflation rates, a decline in unemployment, and increased consumer confidence.

In addition, government reports have suggested that the housing market is beginning to recover (housing starts were up 0.1 percent in May), companies are planning more hiring activities, and factory orders are beginning to build momentum. Also, according to the federal government, there is a steady drop in the number of people who are seeking unemployment benefits. This fact implies that new hires are beginning to offset layoffs.

In 1991, according to Dun & Bradstreet, capital equipment spending growth over 1990, as a percentage of GNP, is forecast to be a negative 0.8 percent. However, a closer examination of this figure is also needed to get an accurate picture. Growth for the first quarter was negative 18.2 percent; second quarter, 2.8 percent; third quarter, 7.5 percent; and fourth quarter, 10.1 percent. Apart from the strong dip in the first quarter, these figures clearly display the building momentum of capital equipment spending. This positive trend will continue; equipment spending is forecast to jump up to 8.3 percent for 1992.

The Markets

Telecommunications

Whether it be voice, text, 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 demands for telecommunications will prosper well into the next century.

Forecast growth for the telecommunications industry as a whole remains mixed. Overall, the telecommunications market should grow at a compound annual growth rate (CAGR) of 7.1 percent until 1995 (see Table 1). The greatest influence on this market's growth is attributed to local and long distance calling services. In 1991, this segment will generate $150.6 billion, accounting for 86 percent of all North American telecommunications revenue. Although smaller, the equipment side of this market will grow more rapidly at a CAGR of 8.6 percent. Of this segment, customer premises equipment will grow faster than public equipment, at a CAGR of 14.8 percent compared with 4.1 percent. In Europe, total telecommunications sales are expected to parallel the U.S. rate. Also, equipment revenue growth is expected to be about half that of the United States.

The primary factors driving the telecommunications industry include globalization of worldwide networks, markets, and standards; rapid movement to a digital telecommunications network; transition from an engineering perspective to a marketing focus; and continued consolidations and alliances.

In the last decade, the telecommunications landscape was altered drastically: It became truly international. The ramifications of recent events taking place in Europe, alone, are monumental. Meeting the needs of these dynamic markets

Table 1
Worldwide Telecommunications Forecast by Region (End-User Revenue in Millions of Dollars)

	1990	1991	1995	CAGR (%) 1990-1995
North America	207,431	220,932	285,387	6.6
Europe	110,066	118,652	157,274	7.4
Japan	56,853	60,407	77,458	6.4
Asia/Pacific-ROW	58,019	63,076	90,331	9.3
Total Worldwide	432,370	463,067	610,450	7.1

Source: Dataquest (July 1991)

will require the globalization of networks and standards. Dataquest believes that outstanding opportunities exist for expansion in Europe and the Pacific Rim regions.

Furthermore, digitization of the networks creates strong opportunities. As a result of a digital network, bandwidth (data-carrying capability) will no longer be an issue or constraint. Simultaneous video, data, and voice transmission sharing the same medium will become a reality once the needed standards are passed and in place.

The acceptance of the Integrated Services Digital Network (ISDN) has been slower than anticipated. However, its use is expected to increase at a steady pace from the existing 206,000 access lines in service in 1991 to 1.1 million lines in service in 1995, representing a CAGR of 52 percent. ISDN is broadly supported by the industry, all critical standards have been implemented, field trials are presently being conducted in selected locations, and initial "pockets" of local services are currently available.

As we move into the new decade, the telecommunications industry will continue to shift its engineering focus to a more predominant marketing focus. The elements of success will be determined by customer service and support, solution-based applications, personal communications, strategic distribution, and account management.

Further mergers, acquisitions, and alliances will continue in the 1990s. These consolidations will occur partly as a result of competition, but also as a result of globalization.

Semiconductor Equipment, Manufacturing, and Materials

For the wafer fabrication equipment market, Dataquest is cautiously optimistic about the near-term outlook. The short-term outlook is clouded by the current worldwide macroeconomic and political uncertainties. However, in the long term, Dataquest believes that the wafer fabrication equipment market will enjoy healthy growth through 1995. Wafer fabrication equipment companies with global presence, financial muscle, and innovative customer-driven technology solutions can be optimistic about their long-term future in an increasingly chip-pervasive world.

Japan is the largest regional wafer fabrication equipment market in the world. In 1990, the market for wafer fab equipment in Japan was $2.94 billion, up 5 percent from its 1989 level of $2.80 billion. Japan represents the leading production region for high-volume advanced devices such as 4Mb DRAMs, 1Mb SRAMs, gate arrays, and embedded microcontrollers for Japan's burgeoning equipment industry. Hence, the Japanese wafer fab equipment market drives the requirements of high throughput and leading-edge process technology. Through sheer size and momentum, the Japanese wafer fabrication equipment market is expected to continue to prevail as the largest during the next five years, although it will grow at the slowest rate among the four major geographical markets.

North America as a region did not add many large production fabs in 1990. The 1990 wafer fab market in North America was $1.60 billion, down 4 percent from its 1989 level of $1.64 billion. Fab capacity expansion, upgrades, and offshore Japanese fabs in North America accounted for the bulk of the 1990 market. The United States is expected to continue to be the second largest wafer fab equipment market in the world.

In 1990, the wafer fab equipment market in Europe was $758 million, up 5 percent from the 1989 market of $720 million. In 1990, most of the wafer fab equipment market activities revolved around offshore Japanese and North American fabs locating in Europe to better serve their customer base and to position themselves as potential partners for 1992. These offshore European fabs were typically clones of parent North American and Japanese fabs. The European wafer fab equipment market will enjoy healthy growth during the next five years as Japanese, U.S., and Asian semiconductor companies set up Europe-based fabs to cater to a unified European market as well as large blocs of countries in Eastern Europe.

Semiconductor Devices

Dataquest believes that the long-term trend toward slower growth will continue for the semiconductor market in the 1990s. We are forecasting a worldwide CAGR of 12.6 percent from 1990 to 1995 (see Table 2). In addition, we believe that the cyclicality of the industry, although still in evidence, will abate considerably in magnitude. We do not foresee annual growth approaching even the 25 to 30 percent range in any one year. Key events and assumptions driving our short- and long-term forecasts are based on the following factors:

- Memories, microcomponents, and MOS logic are leading the industry recovery in 1991.

Table 2
Worldwide Semiconductor Consumption Forecast by Region
(Factory Revenue in Millions of Dollars)

	1990	1991	1995	CAGR (%) 1990-1995
North America	17,386	18,761	28,001	10
Europe	10,661	12,274	20,764	14.3
Japan	22,508	26,354	40,762	12.6
Asia/Pacific-ROW	7,670	8,834	16,004	15.8
Total Worldwide	58,225	66,223	105,531	12.6

Source: Dataquest (July 1991)

- Fluctuations against the U.S. dollar are skewing 1991 dollar growth upward.
- The European and Asian semiconductor markets are the hotbeds of activity for both the near and long term.
- As electronic equipment becomes an ever-larger component of the worldwide economy, semiconductor growth rates are slowing.
- The historical cyclicality of the industry, while still visible, has moderated.

Dataquest expects the next market peak to occur in 1992 or 1993, in keeping with historical cyclicality and the traditional market drivers of U.S. presidential elections and the Olympic games. We believe that the market will soften slightly in 1994 and 1995. Although semiconductor penetration is expected to increase in electronic equipment, the overall electronic equipment market is maturing and experiencing slower growth, and relationships between semiconductor suppliers and users are smoothing out the traditional volatility in the demand curve.

Throughout the forecast period, we expect Europe and Asia/Pacific-Rest of World (ROW) to consistently outperform North America and Japan. Europe and Asia will be driven by growing economies, communications standardization, and both new industrialization and reindustrialization. The applications with greatest opportunity will be personal communications, personal data processing equipment (such as laptop and palmtop PCs, and personal faxes), workstations, and—particularly in Europe—transportation.

Competitive pressure in the semiconductor industry is increasing as well. More and more microprocessors have become proprietary, with only a few vendors producing state-of-the-art devices.

Business and Technical Computer Systems

In the near term, the computer systems industry is not expected to perform much better than it did in 1990. Dataquest believes that Europe will not continue to experience the explosive market growth that it did in the recent past. However, we expect Japan to grow at a slightly higher rate than North America and Europe, fueled by the workstation and supercomputer product segments. Over the next five years, we believe that the market will grow at a 5.3 percent CAGR (see Table 3).

The supercomputer segment will show the second highest growth rate of any product segment, with a CAGR of 12.0 percent. Supercomputers will remain a small portion of the total market, with growth most likely fueled by a flow of systems into Eastern Europe assisted by U.S. and Japanese government subsidiaries.

The workstation segment will show the most growth over the next five-year period, with a CAGR of 25.8 percent. The gain in this segment will be apparent in both the technical and commercial markets. Growth in the commercial workstation market is projected at 62.4 percent over the next five years. However, this growth is dependent on the availability of applications and development of distribution channels. Workstations will continue to face stiff competition from PCs as PC functionality increases, forcing workstation prices even lower.

The mainframe market is expected to decline by the end of 1995, with a CAGR of negative 1.1 percent. Dataquest believes that big-ticket purchases will continue to be postponed and even canceled. Many users instead will be opting for lower-cost solutions such as PCs and workstations.

The midrange segment will continue to grow slowly, with a 3.0 percent CAGR over the five-

Table 3
Worldwide Business and Technical Computer Systems* Market Forecast by Region
(Factory Revenue in Millions of Dollars)

	1990	1991	1995	CAGR (%) 1990-1995
North America	29,350	29,860	36,851	4.7
Europe	24,479	25,106	31,354	5.1
Japan	13,245	13,547	17,145	5.3
Asia/Pacific-ROW	2,272	2,577	4,350	13.9
Total Worldwide	69,346	71,090	89,700	5.3

*Excluding personal computers
Source: Dataquest (July 1991)

year period. Within the midrange market, we expect to continue to see falling ASPs. This segment is being squeezed by both workstations and networked PCs. As the large midrange suppliers—namely Digital and Hewlett-Packard—transition their product lines from the older proprietary systems to the newer open systems, margins will become ever smaller.

Software

Over the course of the last year, several hardware vendors—among them Digital Equipment Corporation, Wang Laboratories, and Apple Computer—have stated that they are repositioning themselves as software companies. Yet other vendors—including Sun Microsystems and Compaq—are looking to reduce their reliance on hardware products. A surge in software activity, often in the form of alliances with existing software vendors, has begun.

Another significant trend that has increased the impetus of the course of the last year has been the development of strategic software architectures. Ranging from relatively proprietary initiatives like SAA within IBM to much more open and esoteric strategies like that from Patriot Partners, software architectures have the potential to significantly impact the software industry. Particularly when they encompass object management capabilities, these software architectures will revolutionize the way that software is written and, as a consequence, vastly increase the number of software packages that are developed.

Dataquest primarily focuses on two specific segments of the software market: Personal Computer Software and Office Software. Personal computer software is utilized by more individuals than any other group of software products. Office software is highly strategic to the end-user community that implements it and to the vendor community that supplies it.

PC Software

In 1990, Windows grabbed the attention of the market, compelling major vendors to provide Windows products. Dataquest expects Windows-based DOS to exceed character-based DOS in worldwide unit sales after 1993. Windows 3.0 will have the most effect on PC software technology in the years to come.

Microsoft has reached a point where it believes that it can position itself in direct conflict with IBM's intentions. IBM wants the Presentation Manager (PM), not Windows, to be the graphical user interface used on every desktop. Although Microsoft is still facilitating a relationship with IBM, it is at the same time aggressively promoting Windows over the PM and is implementing a strategy of cross-platform availability. Dataquest believes that Microsoft will be successful. Through the mechanism of OS/2, Microsoft 3.0 will place the Windows interface on any computing environment that comes into use, whether it be its own or another vendor's.

Ashton-Tate, the Torrance, California-based publisher of dBASE IV, was recently purchased by arch-rival Borland International. Ashton-Tate used to be the market leader in relational database software, but release of a malfunctioning dBASE IV in late 1988 caused several bad quarters for the company. Though in the process of recovery, Ashton-Tate was still ripe for purchase. Borland acquired not only the dBASE product line, but more importantly, the dBASE customer list, which will serve Borland well in the 1990s.

Office Software

Overall, 1990 was a good year for office software. Dataquest expects this healthy trend to continue. The total worldwide office software market will grow to $2.9 billion in 1995 from $1.4 billion in 1990, representing a CAGR of 15.6 percent (see Table 4).

However, manufacturer-based office software is on the decline. Still lagging behind the PC independent software vendors (ISVs) in terms of features of productivity tools—specifically, the standalone variety—the systems vendors dominating this market have relied on their expertise in integration and enterprise-solution orientation to remain competitive. Although this may prove to be the case in the longer term, current trends indicate that neither end users nor vendors believe that systems vendors have the monopoly on enterprise solutions.

Although UNIX experienced high growth in 1990, the UNIX-based segment ultimately remains vulnerable to the fact that UNIX does not equate to open systems. Although this segment is expected to continue its healthy growth, vendors operating in this segment need to provide substantial added value, at least equal to that provided by vendors in the other segments, in order to continue to entice users to the UNIX platform. Business-solution orientation and increased penetration of large accounts would be among the highest imperatives, ensuring continued strength.

As for PC LAN-based office software, this segment remains the dark horse. Although this segment must be a critical component of all office software vendors' strategies, the segment is awaiting impetus from the PC ISVs' entry. Ultimately, office software will be dominated by connected LANs.

Document Imaging Systems

In 1990, the document imaging industry experienced a good year; the overall value of the worldwide document imaging market was $1.8 billion. Revenue for sales of document imaging systems into business and commercial markets grew by nearly 29 percent, and technical document imaging systems revenue increased 45.6 percent.

Dataquest defines document image management systems (DIMS) as computer systems that convert paper documents into digital (bit-map/raster) images that can be viewed at a workstation, stored on random-access media, transmitted across networks, and printed.

Dataquest's overall forecast for the worldwide document imaging industry is growth to $7 billion by 1995 (see Table 5). We expect business document imaging systems to account for roughly 76 percent of the market and technical systems to make up the remaining 24 percent.

Table 4
Worldwide Office Software Forecast by Region
(If-Sold License Revenue in Millions of Dollars)

	1990	1991	1995	CAGR (%) 1990-1995
United States	808	892	1,587	14.5
Europe	491	586	1,066	16.8
ROW	108	130	245	17.8
Total Worldwide	1,407	1,608	2,899	15.6

Source: Dataquest (July 1991)

Table 5
Worldwide Document Imaging Systems Forecast by Region
(Factory Revenue in Millions of Dollars)

	1990	1991	1995	CAGR (%) 1990-1995
United States	1,007	1,441	3,467	28
Europe	406	517	1,350	27.1
ROW	173	230	506	23.9
Total Worldwide	1,586	2,188	5,323	27.4

Source: Dataquest (July 1991)

Factors driving growth in this market include the following:

- The entry of almost all U.S. computer systems companies into the market has legitimized it, driven development forward, and raised user awareness of the technology's potential.
- The growing use of industry-standard PCs as desktop imaging platforms will bring the power of document imaging to more users throughout the decade.
- The focus of providing software solutions to paper storage and retrieval problems will make systems continually more useful.
- The increasingly popular client/server computing model is an ideal architecture for department-size imaging systems, the fastest-growing segment.
- Advances in enabling technologies, such as LAN, compression/decompression, work flow software, optical storage, optical character recognition, full-text retrieval, bar coding, and hand-print character recognition will move document imaging forward.
- Strategic alliances between business and technical document imaging vendors will produce systems capable of managing both small- and wide-format documents and drawings from a common database. The rise of multimedia computing will blend images as a common data element into all of the work that people do on computers by the end of the decade.

CAD/CAM/CAE

The worldwide CAD/CAM/CAE market will maintain consistent, steady growth over the next five years at a CAGR of 12.9 percent. Please refer to Table 6 for further information.

The market will be driven by the following factors:

- CAD/CAM/CAE systems will continue to give buyers a competitive edge. As time-to-market requirements shrink, demand for design automation tools will also increase.
- Market demand will be limited by vendors' inability to fully meet the demand for integrated systems; no vendor will completely solve the systems integration puzzle. Successful vendors will need to invest in systems integration, ensuring that hardware and software work together.
- Incremental progress in delivering open systems and standards to this market will also constrain market demand. When more open systems arrive on the market, the value of CAD tools to many users will become more pronounced. Standards will fuel growth in this market and also encourage third-party software suppliers to enter the market.
- The "late majority" for CAD/CAM/CAE will be coming to the market over the next five years, driving additional growth. However, conservative buyers will favor market leaders. These conservative buyers are the late majority buyers who do not buy until the weight of the majority seems to legitimize the product. Therefore, for vendors, the value of having high market share as well as financial clout will increase.

Computer Storage

Worldwide computer storage factory revenue grew to $21.1 billion during 1990, representing an increase of nearly 18 percent. The market grew more than expected, primarily as a result of increased demand for 3.5-inch rigid disk drives. Rigid disk drive revenue grew to 80 percent of total computer storage revenue during 1990. Within the rigid disk drive market, 3.5-inch drives dominated last year and are expected to continue to do so throughout the forecast period.

New technologies being developed in the computer storage industry will enable the computer equipment manufacturers to incorporate four to five times the storage capacity in their 1995 models, compared with their 1990 models. Dataquest expects this increased storage capacity to be available at nearly the same cost as in 1990.

Dataquest's forecast for the computer storage market is for a 5.6 percent CAGR through 1995 (see Table 7). Rigid disk drive revenue grew to 80 percent of total computer storage revenue during 1990 and is expected to remain at that level. The flexible disk drive and tape drive portions of the market are expected to decline slowly in the years ahead as the optical disk drive portion increases.

Display Terminals

Worldwide display terminal unit shipments grew by 3.3 percent in 1990. However, a sharp decrease in shipments of the relatively expensive IBM 3270-compatible terminals, coupled with the declining prices in the ASCII/ANSI/PC segment, resulted in a 10.5 percent decrease in factory revenue for the display terminal market.

During 1990, growth in the microprocessor-based UNIX and DOS multiuser systems and

Table 6
CAD/CAM/CAE Market Forecast by Region (Factory Revenue in Millions of Dollars)

	1990	1991	1995	CAGR (%) 1990-1995
North America	5,003	5,378	8,276	10.6
Europe	4,893	5,616	9,199	13.5
Japan	3,573	4,240	6,681	13.9
Asia/Pacific-ROW	563	709	1,535	23.7
Total Worldwide	14,031	15,943	25,692	12.9

Source: Dataquest (July 1991)

Table 7
Computer Storage Market Forecast by Region (Factory Revenue in Billions of Dollars)

	1990	1991	1995	CAGR (%) 1990-1995
North America	11.0	11.4	12.4	2.6
Europe	4.8	5.4	6.7	6.9
Japan	3.5	4.1	5.8	10.3
Asia/Pacific-ROW	1.8	2.1	2.9	9.6
Total Worldwide	21.1	23.0	27.8	5.6

Source: Dataquest (July 1991)

data communications networks markets created an 8.0 percent increase in demand for ASCII/ANSI/PC display terminals. Expansion of the IBM AS/400 market resulted in a 17 percent increase in IBM 5250-compatible display terminal unit shipments.

Dataquest forecasts the worldwide display terminal market to grow at a CAGR of 0.3 percent, remaining at its steady $4.6 billion level (see Table 8). However, there will be significant changes within the display terminal market. It is expected that ASCII/ANSI/PC terminals will dominate the market by 1995, while IBM 5250-compatible display terminals are expected to maintain their current portion of the market at the expense of the IBM 3270-compatible and asynchronous/synchronous markets.

Electronic Printers

During 1990, North American factory revenue grew by less than 1 percent for the electronic printer market. Unit shipments were less than Dataquest had expected, especially in the higher-value (price per unit) page and line printer segments. Fewer than anticipated unit shipments and accelerated price decreases contributed to the slow revenue growth.

Unit shipments grew by 8.5 percent during 1990. Serial printer unit shipments were up only slightly from 1989, and line printer shipments actually decreased nearly 20 percent. Page printers continued to be dominant components of the printer market, with unit shipment growth of nearly 70 percent during 1990.

Dataquest's forecast for the North American electronic printer market is a 5.6 percent CAGR through 1995 (see Table 9). Page printers currently represent about 25 percent of the market in both unit shipments and revenue. By 1995, the page printer portion is expected to grow to nearly 40 and 60 percent, respectively, of the total unit and revenue market.

The use of color is gaining market acceptance. Printing speeds and quality continue to increase, and more and more businesses are using electronic printers and desktop publishing. Growth rates of total printing capabilities will be in double digits during the forecast period.

In the past, the standalone PC dominated the electronic printer growth path. Now, the electronic printer market profile is changing. In the years ahead, work group clusters, LANs, and file servers/networks will enable rapid growth in printing capabilities, utilizing high-end specialty printers. In addition, there will be increased demand for personal slower-speed (1- to 4-ppm) printers. In total, these networks will increase the overall ratio of PCs to electronic printers, thus contributing to slower market growth rates than what was experienced in the last half of the 1980s.

Table 8
Worldwide Display Terminal Market Forecast (Factory Revenue in Billions of Dollars)

	1990	1991	1995	CAGR (%) 1990-1995
Total Worldwide	4.6	4.5	4.6	0.3

Source: Dataquest (July 1991)

Table 9
North American Electronic Printer Market Forecast (Factory Revenue in Billions of Dollars)

	1990	1991	1995	CAGR (%) 1990-1995
North America	6.2	6.8	8.2	5.6

Source: Dataquest (July 1991)

Table 10
U.S. Plain Paper Copier Market Forecast
(End-User, Service, and Rental Revenue in Billions of Dollars)

	1990	1991	1995	CAGR (%) 1990-1995
United States	14.6	15.1	15.2	0.8

Source: Dataquest (July 1991)

Plain Paper Copiers

During 1990, revenue increased by 6.2 percent, while placements (new and rental units) grew by 3.3 percent. Rental revenue grew by more than 10 percent, which pushed total revenue slightly above our previous projections.

Competition in this market remains intense, as manufacturers try to maintain or improve their market share. Dataquest forecasts a number of dramatic changes to this mature market. At the very high end of the copier spectrum, light lens copiers are being supplanted by machines with digital front ends, which eventually will be networked as output devices for demand publishing operations. At the lower end of the copier market, we expect a continuing healthy personal copier market as distribution through nontraditional copier channels improves.

Dataquest forecasts the U.S. plain paper copier market to grow at a CAGR of 0.8 percent (see Table 10). Dataquest believes that the percentage of total pages printed is gradually being shifted away from the traditional copier market into that of the desktop laser printers. This trend is expected to continue and will contribute to many new changes in the copier marketplace as manufacturers try to differentiate their products' performance and reliability.

For More Information . . .

On semiconductors .... Pat Cox (408) 437-8265
On computer hardware and software .... Ken Thornton (408) 437-8112
On telecommunications .... Ken Newbury (408) 437-8255
On peripherals .... Paul Wittrock (408) 437-8073
About other Dataquest publications .... Sales (408) 437-8621
About upcoming Dataquest conferences .... Conferences (408) 437-8245
About your subscription .... Customer Service (408) 437-8402
Via fax request .... Fax (408) 437-0292

Dataquest
a company of The Dun & Bradstreet Corporation

Dataquest Perspective

Special Edition

October 28, 1991

Market Analysis

0011610

Market Analysis

Worldwide Semiconductor Industry Forecast: Fourth Quarter 1991

Summary

Dataquest expects the worldwide semiconductor market to grow 13.5 percent in 1992, up from 9.3 percent growth in 1991, and to further grow 15.7 percent in 1993 (see Figure 1). Recovery of the U.S. economy will stimulate worldwide systems production, which in turn will stimulate semiconductor consumption. In the short term, the cyclical upturn of the data processing market will help boost MOS memories' contribution to overall growth and help firm the foundation of microcomponent growth. In the long term, semiconductor market growth will be driven by networking the stock of data processing capability, computer-based graphics, and image-based processing, placing new demands on processing power and the associated complement of memory capacity.

Dataquest's Semiconductor Forecast Methodology

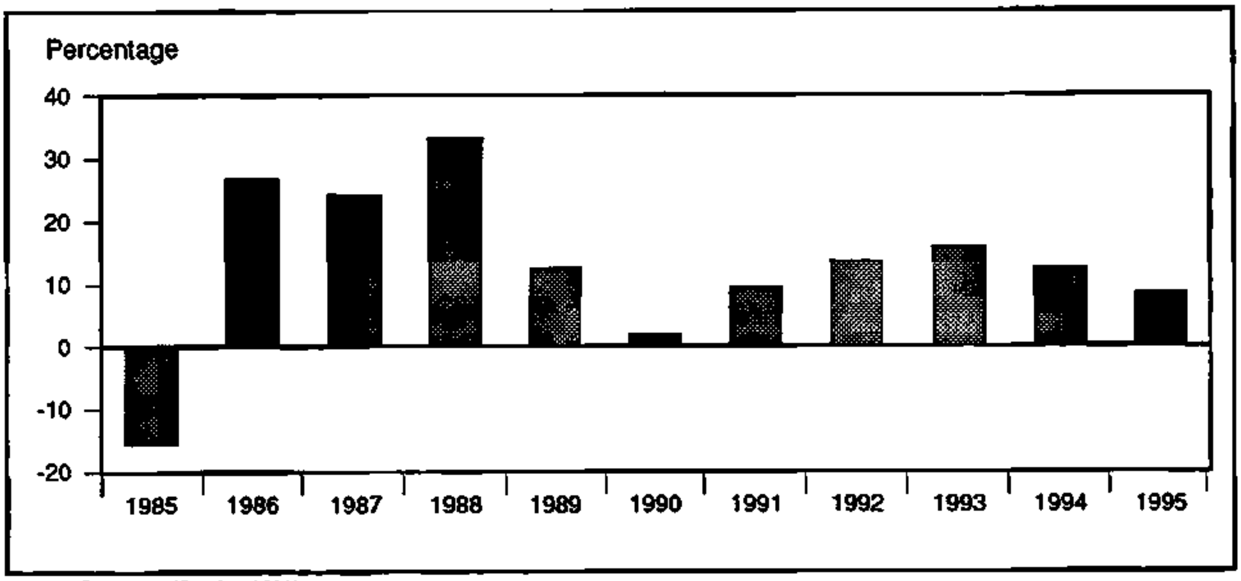
Dataquest's semiconductor forecast methodology leverages the resources of its parent, The Dun & Bradstreet Corporation, as well as the considerable internal resources of Dataquest.

Dun & Bradstreet information is used to develop the macroeconomic forecasts for the world's major economies. This forecast identifies trends in the economic health of the world's leading consumers and producers of electronic equipment. Using this forecast in conjunction with input from Dataquest's regional offices, Dataquest identifies the likelihood of whether a particular region or country will increase or decrease its consumption of electronic equipment.

Dataquest's Semiconductor Applications Market group, along with Dataquest's various electronics systems groups, provides a long-range outlook for the overall growth of the electronic equipment market. Semiconductor content ratios are developed by region to reflect the growing penetration of semiconductors into electronic equipment. This establishes a five-year compound annual growth rate (CAGR) for total semiconductors for a five-year period from a demand-side perspective.

Dataquest's worldwide Semiconductor service and its Semiconductor Equipment, Materials, and Manufacturing service, in conjunction with its various regional offices, collaborate to formulate expectations of semiconductor market short-range fluctuations around the long-range trend. Tactical market issues and anticipated semiconductor materials demand significantly impact the

Figure 1
Worldwide Semiconductor Consumption (Factory Revenue, Dollar-Based Annual Growth)



Source: Dataquest (October 1991)

short-range forecast out to 12 months. Semiconductor equipment purchases and semiconductor device trends drive the forecast in the 12- to 24-month time frame. Semiconductor fab facilities and long-term semiconductor device trends have the greatest impact on the forecast period covering two to five years.

The final step in the forecast process is to reconcile expected fluctuations in the electronics market and trends in the semiconductor industry so that the fluctuations do not inexplicably diverge from semiconductor industry trends. Dataquest anticipates that, in the absence of shocks to the market, market fluctuations converge toward the long-term trend.

Forecast Assumptions

The worldwide economic climate is expected to improve in 1992. The Dun & Bradstreet Corporation forecasts the following outlook for the Group of Seven (G7) countries (see Figure 2):

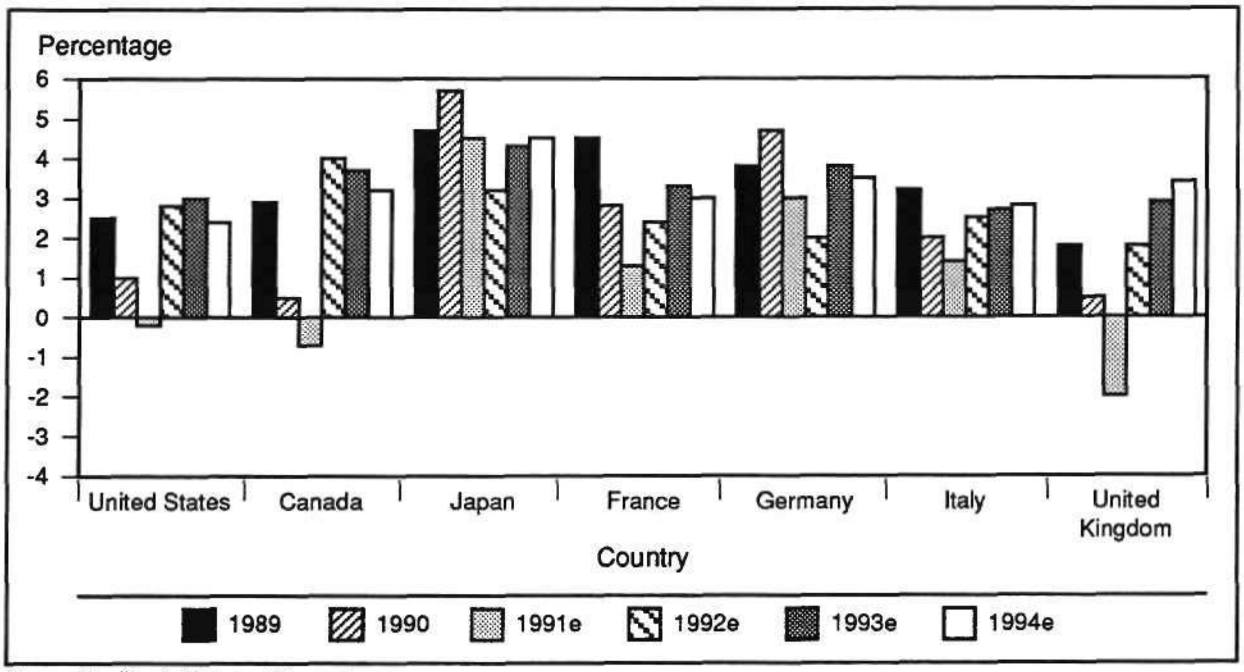
- The U.S., Canada, and U.K. economies will register negative real economic growth in 1991 but recover at rates of 2.8, 4.0, and 1.8 percent real gross national product/gross domestic product (GNP/GDP), respectively, in 1992.
- Real GNP/GDP growth is expected to accelerate in France and Italy during 1992, from 1.3 percent in 1991 to 2.4 percent and from 1.4 percent in 1991 to 2.5 percent, respectively.
- Real GNP/GDP growth is expected to decelerate in Germany and Japan during 1992, from 3.0 percent in 1991 to 2.0 percent and from 4.5 percent in 1991 to 3.2 percent, respectively. The cost burden of Germany's reunification and the rise in Japan's cost of capital are moderating these countries' short-term growth prospects. Both economies are expected to reaccelerate in 1993.

Growth in the G7 economies is expected to converge toward the countries' respective steady-state rates through 1994.

The improved economic prospects bode well for the semiconductor industry outlook, given that computers and related electronic gear represent a significant share of the G7 economies' business fixed investment.

Acceleration of worldwide systems production growth—to 9.0 percent in 1992 from 5.4 percent in 1991—will be accompanied by the

Figure 2
G7 Countries' Estimated Economic Outlook
Real GNP/GDP Growth, Local Currencies



Source: The Dun & Bradstreet Corporation resumption of economic growth (see Figure 3), as shown by the following factors:

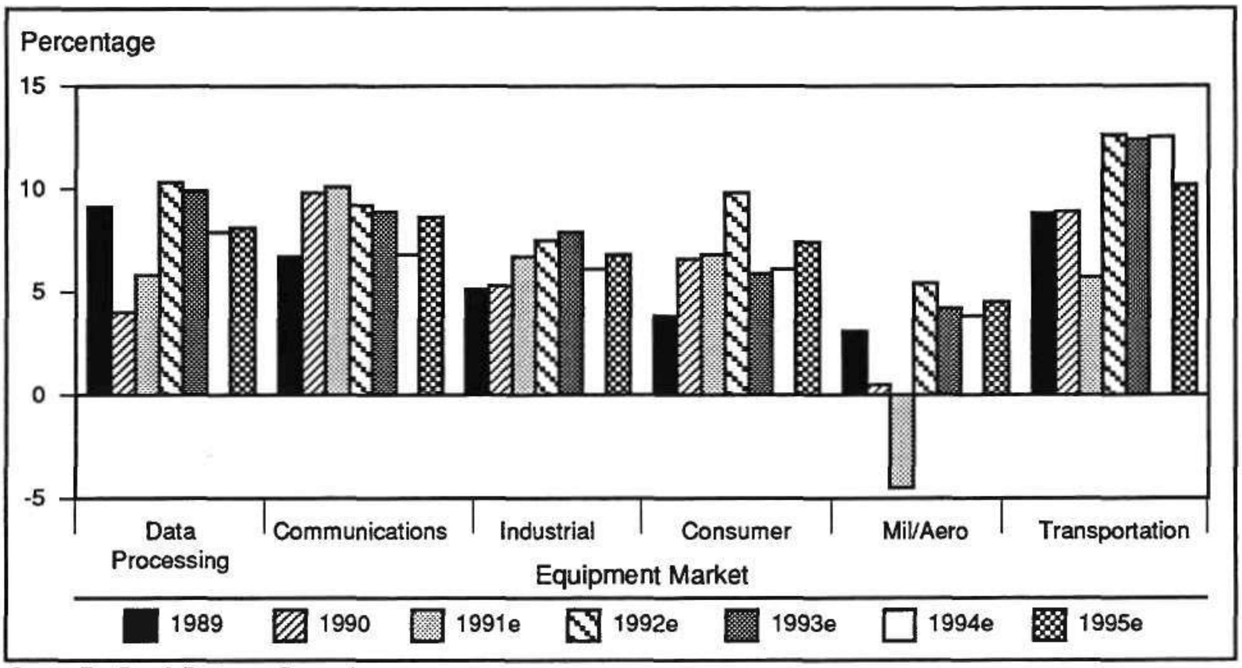
- Business conditions in the data processing and consumer markets are expected to show significant improvement as businesses and households begin to relax their budget constraints
  - Data processing up 10.3 percent in 1992 from 5.8 percent in 1991
  - Consumer up 9.8 percent in 1992 versus 6.8 percent in 1991
- Transportation electronics production growth is expected to more than double—to 12.6 percent in 1992 from 5.7 percent in 1991—spurred by increased consumer spending, combined with increasing share of electronic systems' added value to new vehicles.
- Communications and industrial electronics growth are expected to remain positive and stable. Spending on medical electronics and analytical instruments helped bolster the industrial segment from recession-induced decreased spending on measuring and controlling electronics.
- Military/civilian aerospace electronics was hit hard by Washington budget cuts in 1991, but this segment is expected to resume modest growth (at a permanently lower dollar level) as western defense agencies upgrade existing systems with more sophisticated electronics.

Semiconductor Outlook: Overview

Dataquest expects the worldwide semiconductor market to grow 9.3 percent in 1991 to $63.6 billion, up from $58.2 billion in 1990, and 12.1 percent in 1992 to $72.2 billion (see Table 1). (Note that Table 1 expresses the value and growth of the Japan and Europe markets in local currencies' terms. In addition to valuing the worldwide market assuming *current* exchange rates, the worldwide market is valued in U.S. dollars, assuming *constant* 1990 exchange rates, which removes the effects of exchange rate variation on growth.)

Our October 1991 forecast represents a downward revision to our May 1991 forecast when we forecast the market to grow 13.7 percent in 1991 and 16.6 percent in 1992. *Approximately 65 percent of the revision in 1991 and 50 percent of the revision in 1992 is accounted for by appreciation of the U.S. dollar against the Japanese yen and major European currencies since the May forecast.*

Figure 3
Worldwide Electronics Production
(Factory Revenue, Dollar-Based Annual Growth)



Source: The Dun & Bradstreet Corporation

Table 1
Worldwide Semiconductor Consumption by Region—1990-1995
(Factory Revenue in U.S. Dollars and Local Currencies)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
North America ($M)	17,386	18,483	20,728	23,888	26,758	28,816	10.6
Annual Growth (%)	-3.1	6.3	12.1	15.2	12.0	7.7	
Japan ($M)	22,508	25,544	29,524	33,341	37,208	40,232	12.3
Annual Growth (%)	-2.1	13.5	15.6	12.9	11.6	8.1	
Japan (¥B)	3,241	3,501	4,074	4,601	5,135	5,552	11.4
Annual Growth (%)	2.1	8.0	16.4	12.9	11.6	8.1	
Exchange Rate: ¥ per U.S.$1	144.00	137.06	138.00	138.00	138.00	138.00	
Europe ($M)	10,661	10,828	11,556	13,777	15,335	16,368	9.0
Annual Growth (%)	9.3	1.6	6.7	19.2	11.3	6.7	
Europe (EcuM)	8,380	8,890	9,799	11,683	13,004	13,880	10.6
Annual Growth (%)	-6.0	6.1	10.2	19.2	11.3	6.7	
Exchange Rate: Ecu per U.S.$1	0.786	0.821	0.848	0.848	0.848	0.848	
Asia/Pacific-ROW ($M)	7,670	8,792	10,405	12,532	14,486	16,246	16.2
Annual Growth (%)	17.6	14.6	18.3	20.4	15.6	12.1	
Worldwide ($M)	58,225	63,647	72,213	83,538	93,787	101,662	11.8
Annual Growth (%)	1.8	9.3	13.5	15.7	12.3	8.4	
Worldwide ($M in 1990 U.S.$1 Exchange Rates)	58,225	62,899	71,894	83,235	93,446	101,276	11.7
Annual Growth (%)	0.7	8.0	14.3	15.8	12.3	8.4	

Source: Dataquest (October 1991)

Although 1991 is shaping up as a modest-growth year—worldwide market growth averaged 19.1 percent per annum in the 1985 through 1990 period—it is nonetheless a rebound over last year's 1.8 percent growth.

Growth in 1991 was hampered by the following three factors:

- Deeper- and broader-than-expected U.S.-led economic recession
- The recession's growth-arresting affect on computer spending
- Military spending cuts

Growth is forecast to accelerate through 1993 but will be constrained by the relatively moderate rate of overall economic recovery and the effects of saturation and maturity in the relatively developed markets.

Semiconductor Outlook: Regions

North America

The North America systems and semiconductor markets were hit hard by the economic recession of 1991. Both 1992 and 1993 are expected to be years of accelerating growth as businesses resume computer and related equipment spending in an environment of renewed vigor in fixed investment. The following three factors will tend to restrain semiconductor growth below the peak rates experienced in the last decade:

- Two-thirds of desktops have computers on them—After 30 years of innovation and booming sales, there are inevitably fewer opportunities for investment.
- The computer market's share of U.S. capital investment more than *doubled*, from less than 3 percent in 1977 to about 7 percent in

the mid-1980s, but has remained unchanged since then.

- Previously, new systems—those *without* close substitutes—enabled the computer industry to increase its share of capital spending faster than overall investment fell.

These factors should *not* be construed to mean that opportunities for further semiconductor penetration are absent through the forecast horizon. Indeed, the next round of computer and computer-related equipment spending will involve connectivity/networking and higher-level graphics and image-based processing. Both of these areas represent the new frontier for microcomponents and the associated memory complement and for analog and mixed-signal ASIC.

Japan

Japan's growth was hit hard in the first quarter of 1991 by the combined effect of a recession that was already under way in the United States and complicated by the Gulf war. We expect Japan's market to revive in 1992 in response to the resumption of chip and systems export growth to the United States and Europe. Renewed vigor in the computer arena will help firm MOS memories, while advances in camcorders, large-screen TVs, wireless and car telephones, and robot systems designs will boost microcontroller unit (MCU), MOS logic, and analog device growth.

Japanese manufacturers will use the remainder of 1991 to position themselves to take full advantage of the market's upturn in 1992.

Europe

A recession in the United Kingdom plus the reunification-induced drag on the German economy restrained Europe semiconductor market growth in 1991. However, appreciation of the U.S. dollar against the major European currencies masks the true situation of the market: In dollar terms, the market is expected to decelerate to 1.6 percent growth in 1991 from 9.3 percent growth in 1990. In European currency unit (Ecu) terms—a good proxy for a weighted basket of European currencies—market growth is expected to *resume expansion* at a rate of 6.1 percent in 1991 from a 6.0 percent *shrinkage* in 1990 and to accelerate to 10.2 percent growth in 1992.

Improved overall business conditions will help firm up indigenous PC production and consumption in 1992, which will translate into improved prospects for ASICs, microcomponents, and, in particular, MOS memories. In the long term, however, the ASIC market will be fraught with severe average selling price (ASP) pressure stemming from increasing integration and smaller production volumes per design.

Asia/Pacific-Rest of World

Growth in Asia/Pacific-Rest of World (ROW) is and will continue to be fueled by domestic companies' investment, but more importantly from foreign direct investment. The inflow of foreign capital, combined with the relative immaturity of the industry, shields the semiconductor business from the wide swings in activity that tend to rock the other, more established regions. Even so, memory and microcomponent consumption have been severely hurt by the softness of PC business, while analog consumption has felt the pinch of households' curtailed consumer electronics purchases.

Dataquest expects semiconductor consumption growth to accelerate in 1992 and 1993 as the western export markets stimulate data processing and consumer electronics production.

Semiconductor Outlook: Devices

Table 2 presents worldwide detail of the semiconductor device forecast. Volatile pricing make MOS memories the swing factor accounting for year-to-year changes in overall market growth. Microcomponents provide more stable growth in both the short and long term. Overall, worldwide revenue growth is expected to accelerate in 1992 following recovery of the systems markets and peak in 1993. We expect growth to moderate in 1994 and 1995.

Bipolar Digital

The bipolar logic market was hit hard in 1991 by the recession: Businesses postponed major purchases of mainframe and high-end computer equipment, the largest users of these devices. Standard logic, as a share of total bipolar logic, declined at a faster-than-expected rate, also in response to slower-than-expected market conditions.

Compounding the recession's cyclical effects are important structural and technological dynamics: Through 1995, bipolar logic will continue to be replaced by CMOS, BiCMOS, and GaAs ICs as these devices become more cost competitive. Also, as chip functionality and integration increase, unit volumes of ASIC designs will decrease; that is, ASIC manufacturers face the

Table 2
Worldwide Semiconductor Consumption by Device—1990-1995
(Factory Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Total Semiconductor	58,225	63,648	72,211	83,537	93,786	101,661	11.8
Annual Growth (%)	1.8	9.3	13.5	15.7	12.3	8.4	
Total IC	47,303	51,863	59,672	69,840	79,106	86,141	12.7
Annual Growth (%)	0.8	9.6	15.1	17.0	13.3	8.9	
Bipolar Digital	4,440	4,095	3,966	3,843	3,637	3,390	-5.3
Annual Growth (%)	-1.6	-7.8	-3.2	-3.1	-5.4	-6.8	
Bipolar Memory	459	414	407	407	378	352	-5.2
Annual Growth (%)	-15.0	-9.8	-1.7	0.0	-7.1	-6.9	
Bipolar Logic	3,981	3,681	3,559	3,436	3,259	3,038	-5.3
Annual Growth (%)	0.3	-7.5	-3.3	-3.5	-5.2	-6.8	
MOS Digital	32,292	35,926	42,496	50,980	58,661	64,546	14.9
Annual Growth (%)	-2.2	11.3	18.3	20.0	15.1	10.0	
MOS Memory	13,091	13,418	15,958	19,378	22,583	24,447	13.3
Annual Growth (%)	-20.0	2.5	18.9	21.4	16.5	8.3	
MOS Microcomponent	10,068	12,063	14,494	17,465	19,982	22,216	17.2
Annual Growth (%)	22.8	19.8	20.2	20.5	14.4	11.2	
MOS Logic	9,133	10,445	12,044	14,137	16,096	17,883	14.4
Annual Growth (%)	7.9	14.4	15.3	17.4	13.9	11.1	
Analog	10,571	11,842	13,210	15,017	16,808	18,205	11.5
Annual Growth (%)	12.6	12.0	11.6	13.7	11.9	8.3	
Total Discrete	8,235	8,777	9,241	10,040	10,656	11,172	6.3
Annual Growth (%)	7.5	6.6	5.3	8.6	6.1	4.8	
Total Optoelectronic	2,687	3,008	3,298	3,657	4,024	4,348	10.1
Annual Growth (%)	2.3	11.9	9.6	10.9	10.0	8.1	

Source: Dataquest (October 1991)

prospect of increasingly complex chips and smaller volume production runs.

Bipolar logic's remaining life cycle will be driven by the quick-processing and switching requirements of centralized, high-end computer systems.

MOS Memory

Slow DRAM bit growth in 1991, which in turn added to ASP softness, combined to make 1991 revenue only marginally improved over 1990. Weak market conditions have also permitted users to extend the 1Mb life cycle until higher density per-bit prices fall to appropriate levels. The anticipated recovery of computer production in addition to the emergence of memory-intensive PC applications—including more powerful operating systems, user-friendly graphical user interfaces, and digital video—will help drive DRAM bit growth in 1992 and beyond. The emerging generation of laptop, hand-held, and pen-based PCs is also expected to give renewed vigor to the DRAM market.

Softness in the PC market, vendors in oversupply, and customers selling off inventory have combined to make for very slow SRAM bit growth and rapidly falling ASPs. Slowing bit growth and Korean/Taiwanese manufacturers "buying" market share will constrain revenue growth. Actual future revenue growth may be further constrained as manufacturers follow through with plans to switch fab capacity to SRAM devices, exacerbating an existing overcapacity situation. On the positive side, expected growth will be bolstered by further application of caches in PCs, and slow SRAM bit growth will be fueled by new applications in consumer markets.

The nonvolatile memory market will be bolstered by continued penetration of flash memories but at the expense of EEPROM market growth. We expect flash growth to accelerate in the forecast period, fueled by consumer and data processing applications. Acceptance of palm-top and pen-based computers and the substitution of memory cards for disk drives for the task of mass storage will be critical to flash's future growth. In the long term, consumer acceptance of electronic photography will be the wild card that adds a superlative increment to growth.

MOS Microcomponents

Notwithstanding the slowdown in PC shipments, microcomponents is expected to be the fastest-growing device family in 1991, 1992, and, on average, through 1995. Two factors contribute to this situation. Intel's proprietary position in the 80486 MPUs places a floor underneath prices and MCUs are steadily penetrating consumer electronics and telecommunications. Furthermore, Dataquest expects microcomponent growth to be fueled by the trend toward higher-performance PCs that include multimedia and networking functions, which in turn will require a higher level of dedicated processing power for implementation.

Market revenue will be boosted by Intel's proprietary edge in the MPU market with its 80486 chip. Helping to constrain revenue growth, however, will be ASP pressure originating from competitive alternate sources to an Intel-based PC (for example, the AMD-led price pressure in 80386 MPU applications).

MOS Logic

Workstations, laptop PCs, and telecom applications are the driving forces behind today's MOS logic growth, although the lackluster showing in the PC arena at large tends to drag unit and revenue growth below what it would be otherwise. The recession has spelled lower unit volumes per ASIC design, putting a further squeeze on manufacturers' profit margins. We look to field-programmable gate arrays, MOS gate arrays, CBICs, and application-specific standard products to drive future device growth and to MOS full-custom chips to restrain growth.

Analog

Dataquest's analog forecast remains essentially unchanged from the May forecast. As 1991 draws to a close, Dataquest will be looking to consumer confidence to improve, forming a firm foundation for 1992 growth. Beyond peak growth in 1993, analog as a product family faces the prospect of decelerating growth resulting from product maturity in large segments of the market plus decelerating growth in some (mature) end markets. Integration of analog functions to MPU and digital signal processing chips, however, will provide continued vitality to analog technology. We expect telecom-specific applications and computer-related mass-storage and graphics applications to be the areas driving incremental growth.

Dataquest Perspective

Dataquest expects the 1990 through 1995 period to be characterized by relatively moderate market growth: Average growth in the 1990 through 1995 period is forecast to be 11.7 percent per annum versus 19.1 percent per annum in the 1985 through 1990 period. Part of this growth deceleration is a result of the moderation of the major world economies' growth prospects vis-à-vis the decade of the 1980s. More important, however, are the combined effects of the maturing end-use markets on the demand-side and the increasing incremental costs associated with marginal changes in manufacturing technology and system/chip performance.

In the 1980s, the workplace and households in the world's major industrialized economies could be characterized as a vacuum waiting to be (further) filled by the breath of solid-state technology. The void was filled with desktop processing systems and VCRs, systems that were unrivaled by close product substitutes.

The task of the 1990s will be to continue to *add* to the stock of electronic gear but also (and at least as important) to enhance the stock's productivity through, for example, networking and image-based processing. Both these areas are new and fruitful ground for cost-competitive, innovative, and technology-oriented semiconductor companies. But because of the relative complexity of these systems, their investment profiles will likely be more smooth—less "peaked" than, for instance, the booming PC market of the 1980s.

Semiconductor manufacturers are advised not to miss out on the plodding progress the workplace segment is making toward connectivity and image-based processing while waiting for the next PC boom. ■

By Terrance A. Birkholz

The Downside and Upside to Our '92 Forecast

Dataquest's semiconductor forecast for 1992 calls for 13.5 percent growth in worldwide device sales, up from 9.3 percent growth in 1991. A critical assumption of the forecast is an improvement in the semiconductor end-use markets—data processing, consumer, communications, industrial, military/aerospace, and transportation. Our forecast assumes that a moderate recovery in the major end-use markets will be well under way by the first quarter of 1992.

This assumption has a downside. Currently, there are few signs of a recovery in most of the semiconductor end-use segments. If the major end-use markets, i.e., data processing or consumer, fail to turn up soon, as we have assumed in our forecast, then our estimated growth for the worldwide semiconductor industry in 1992 may be too high.

On the other hand, there is also an upside to our forecast. The semiconductor end-use markets have historically seen strong growth as the electronic equipment industry pulled out of a recession. If history repeats itself and there is a strong recovery in end-use markets rather than the moderate growth assumed in our forecast, then our estimated growth for the worldwide semiconductor industry in 1992 may be too low.

Perhaps the best methodology for bracketing the upside and downside of our forecast is to consider different outcomes in terms of probabilities (see Table 1). In order to better understand the qualitative arguments for assigning these probabilities, a more careful review of the factors driving individual end-use markets must be considered.

Applications

Data Processing

Data processing applications accounted for 45.3 percent of the semiconductors shipped in 1990 (see Figure 1). This segment includes mainframe computers, minicomputers, workstations, personal computers, and peripheral equipment. It is quite obvious from the size of this end-use market that the health of the semiconductor industry is tied very closely to the fortunes of the data processing equipment industry.

Table 1
1992 Semiconductor Forecast Probability Distribution

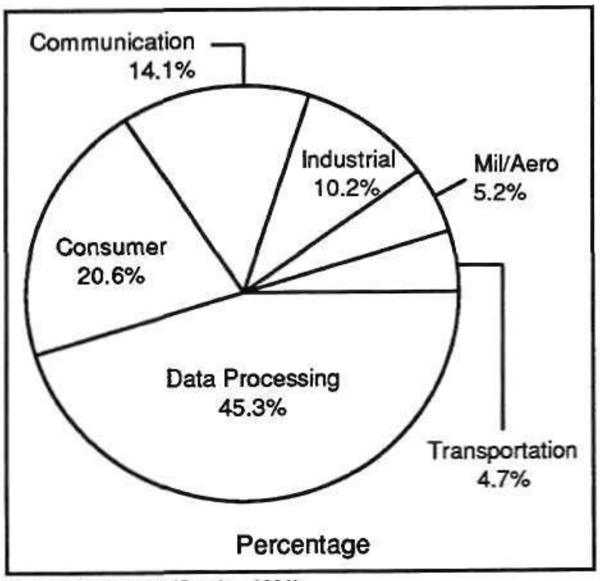
Annual Growth Rate (%)	Probability
<9	0.15
≥9 but <12	0.25
≥12 but ≤15	0.50
>15	0.10
Total	1.00

Source: Dataquest (October 1991)

Dataquest believes that business conditions in data processing will show improvement in 1992 as businesses begin to relax their budgets. Data processing is forecast to grow 10.3 percent in 1992 versus 5.8 percent in 1991.

To achieve our estimated growth in 1992, the computer equipment cycle must begin to turn up in the fourth quarter of 1991. However, August data from the U.S. Department of Commerce (DOC) on office and computing equipment are still giving mixed signals (see Table 2). Orders were up 9.0 percent in August 1991 versus monthly orders a year ago. Yet, last year's data were very weak because of the Mideast crisis, so 9.0 percent growth over an August 1990 base cannot be viewed as a strong positive signal.

Figure 1
Semiconductor End Use by Application Segment



Source: Dataquest (October 1991)

Table 2
Office and Computing Equipment Data
U.S. Department of Commerce
Monthly 1991 Growth Rate versus Same Month in 1990

	June 1991	July 1991	August 1991
Orders	4	-13	9
Shipments	-3	1	-1
Backlog	1	-4	-1
Inventory	-16	-14	-16
Production	-5	-1	-3

Source: U.S. Department of Commerce

An optimistic note in the DOC data is the inventory cycle. Inventories were depleted at an 11 percent clip, while shipments declined by 1 percent. At some point, we anticipate that computer companies will be forced to begin ramping production in order to replenish their inventories. Assuming that inventory levels are very lean, a strong recovery in data processing will cause semiconductor demand to snap back, and growth could well surpass the 13.5 percent we have forecast.

But the bottom line is that orders for data processing equipment have been weak through the third quarter of 1991. And although it is a little early to be an alarmist, if orders continue to run at current levels through the fourth quarter, we expect our forecast to be optimistic. Needless to say, any delay in an upturn for data processing will only push the semiconductor industry recovery out further.

Consumer

Consumer applications accounted for 20.6 percent of the semiconductors shipped in 1990 (see Figure 1). Consumer electronics is forecast to grow 9.8 percent in 1992 according to Dataquest. To achieve this growth, U.S. consumers will have to increase their spending within the next several quarters.

Yet the Conference Board, a private business research firm, reported that the level of consumer confidence in the United States continued to deteriorate in September (see Figure 2). The survey showed that, compared with a month ago, consumers are a good deal less positive in their assessment of prevailing conditions and also somewhat less optimistic in their expectations for the months ahead. The consumer confidence index is well below its level of just prior to the beginning of the Mideast crisis. Moreover, employment data released on October 3 show little improvement in the U.S. unemployment rate, which is stuck in the 6.7 percent area.

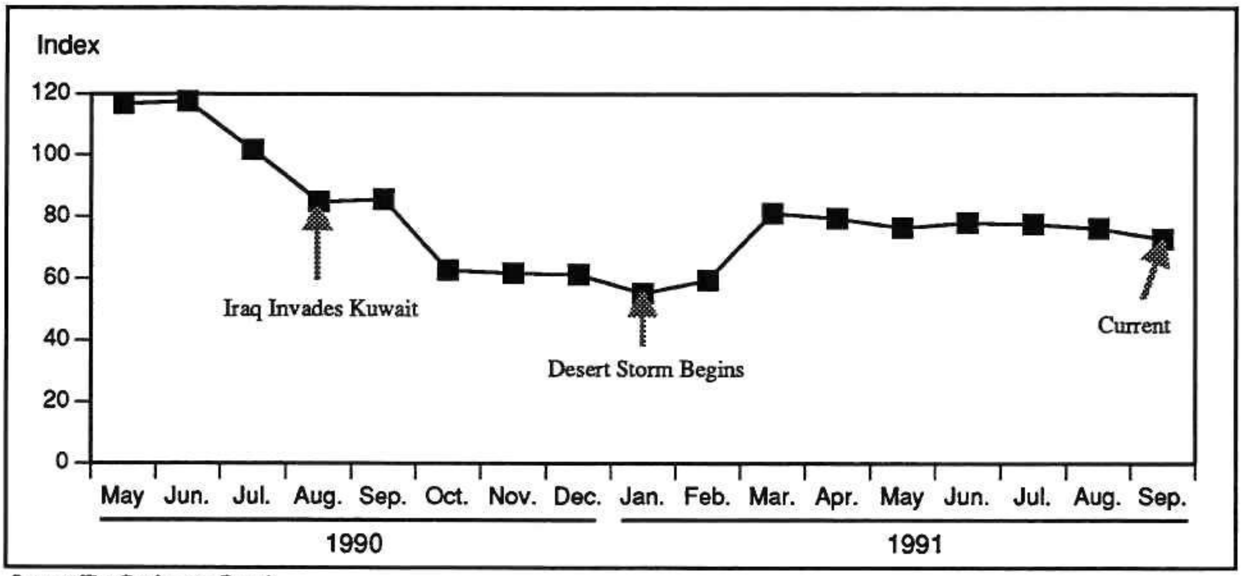
In Japan and Germany, consumers have maintained a strong level of spending through 1991, although their continued spending into 1992 is questionable considering that, according to The Dun & Bradstreet Corporation, both economies are decelerating. In Japan, the growth in gross national product (GNP) is expected to fall from 4.5 percent in 1991 to 3.2 percent in 1992; in Germany, growth in GNP is forecast to fall from 3.0 to 2.0 percent.

It can be argued that an uneven recovery in the United States and the weakening economic climate in Japan and Germany will delay consumer electronic equipment purchases. However, the consumer is getting help. Monetary policymakers in both the United States and Japan are loosening the reins. Interest rates have fallen to a 20-year low in the United States and are creeping lower in Japan. Stock market activity in both countries also seems to be pointing to better times: The U.S. market is reaching an all-time high, and the Japanese market has stabilized and is moving higher. This factor bodes well for consumer confidence; the demand for consumer electronics could well surpass our expectations. If this happened, our 1992 forecast would err on the conservative side.

Communication

Communication applications accounted for 14.1 percent of the semiconductors shipped in 1990 (see Figure 1). This end market, albeit small, remains a bright spot in terms of drivers for the semiconductor industry. The largest segment of communications equipment is telecommunications. Because of the weak global economic climate, there has been a slowdown in the ordering patterns of long distance and

Figure 2
Consumer Confidence Index



Source: The Conference Board

cellular companies in the industrialized countries. It appears that companies are delaying purchases of switching equipment at this time and are settling for stripped-down versions of some switching equipment until volumes pick up.

On a positive note, the fastest-growing regional markets for telecommunications equipment are the less-developed countries, and there has been no slowdown in this segment. Many of developing countries are quickly upgrading their antiquated analog systems with digital lines. Smaller segments of the communications equipment market—i.e., LANs and personal communication—are also experiencing strong growth.

Industrial

Industrial applications accounted for 10.2 percent of the semiconductors shipped in 1990 (see Figure 1). The industrial segment is expected to show marginal growth in 1992. Spending on medical electronics and analytical instruments helped bolster the industrial segment through 1991 and should perform well through 1992. The measure and control electronics segment is in a recession, and Dataquest expects little increased spending in this segment in 1992.

Mil/Aero

Mil/aero applications accounted for 5.2 percent of the semiconductors shipped in 1990 (see Figure 1). The mil/aero segment will provide little growth for semiconductor demand any time soon. U.S. President George Bush's recent announcement concerning changes in the U.S. government's nuclear strategy is expected to put several programs in immediate jeopardy of losing funding. The rail-mobile MX missile program, Boeing's Short Range Attack Missile, the U.S. Navy's nuclear-armed Tomahawk cruise missile, and perhaps the B-2 bomber are all expected to suffer when Congress evaluates the defense budget.

Automotive

Automotive applications accounted for 4.7 percent of the semiconductors shipped in 1990 (see Figure 1). The automotive segment is expected to improve during the next several months. U.S. domestic auto sales are forecast to increase from the depressed level of 6.0 million in August to 6.5 million in October and November according to Morgan Stanley, a New York investment bank. The big problem in the automotive segment is the consumer with his disastrous real disposable income and lack of consumer confidence.

On a more positive note for the semiconductor industry, there was a 20-year low in auto inventories at the end of model year 1991. According to industry estimates, in early September the 1992 models had only a 50-day supply when 65 days is normal. Therefore, a small increase in demand by the consumer is expected to cause auto manufacturers to ramp their production, increasing the demand for automotive electronics.

Dataquest Perspective

The growth in semiconductor demand is forecast to accelerate in 1992. But, in order to achieve the forecast growth rates, the major semiconductor end-use markets—the data processing and consumer segments—need to begin showing more life soon.

The fourth quarter of 1991 will be pivotal. If the U.S. economy pulls itself out of recession and if Japan and Germany experience only a moderate deceleration of their economies, then our 1992 forecast is very reasonable. In fact, Dataquest's forecast may be conservative if the major end-use markets perform better than our expectations. ■

By Mark FitzGerald

For More Information . . .

On the topics in this issue .... Semiconductor Group (408) 437-8196
About on-line access .... On-Line Service (408) 437-8576
About other Dataquest publications .... Sales (408) 437-8246
About upcoming Dataquest conferences .... Conferences (408) 437-8245
About your subscription .... Customer Service (408) 437-8402
Via fax request .... Fax (408) 437-0292

Dataquest
a company of The Dun & Bradstreet Corporation

Dataquest Perspective

Special Edition

December 16, 1991

Conferences and Exhibitions

DQ Feature—Semiconductor Industry Conference '91: A Dataquest Perspective

This article looks at the highlights of Dataquest's 1991 Semiconductor Industry Conference. It will give readers a taste of what they missed if they did not attend the October conference in Monterey.

By Marc Elliot

Conferences and Exhibitions

Semiconductor Industry Conference '91: A Dataquest Perspective

Semiconductors and Applications

Semiconductor producers will have to compete in a market where their customers' products—computers and electronic equipment—are becoming commodities. They will have to remain technically competitive under an exponentially growing cost curve and at the same time reliably provide the highest-quality products, at the lowest price, on time, with unparalleled service. Similarly, the semiconductor equipment and materials manufacturers will need to work closely with their customers—the semiconductor producers.

Nevertheless, although the market is becoming more demanding, there are opportunities. Portable electronics products, personal communications products, network communications products, and multimedia products offer the best market opportunities. At the semiconductor level, this means that higher integration of functions is how system makers hope to differentiate their products. These topics were discussed at Dataquest's 17th annual Semiconductor Industry Conference held at the Monterey, California, Convention Center on October 14 and 15.

Dataquest's John Jackson, vice president and director of the Semiconductor Group, opened the conference with the observation that it has been a tumultuous year since the last Dataquest Semiconductor Industry Conference in October 1990. The market has been subjected to the whims of war and economic slump as the world experienced the Gulf war and recessions in the United States and the United Kingdom. The collapse of communism in the USSR and the opening of Eastern European borders have placed new demands on the free world economies. Germany, the strongest of the European economies, is fighting an economic slide caused by reunification costs. All of these unforeseen influences have had a dramatic impact on the electronics industry and, subsequently, on the semiconductor and equipment industries.

Electronics Industry Issues

Gene Norrett, Dataquest's corporate vice president and director of Marketing, set the theme for the conference by noting that the electronics industry is in transition, undergoing significant changes. It is maturing and thus requires companies to change how they are doing business, to focus resources on core capabilities, to build functional relationships, and to target the growth markets.

Mr. Norrett observed that some of the trends are unsettling. For example, the growth rate for the desktop PC market—one of the largest

John Jackson (Vice President and Director of the Semiconductor Group, Dataquest) and Geno Ori (Senior Vice President and Director of Customer Relations, Motorola Semiconductor Products Sector) discuss the day's program.

consumers of semiconductors—is flattening. Mainframes are being impinged upon by workstations, which are also eating into parts of the high end of the PC market, all of which causes a blurring in the distinction between categories.

> *"So be close to your customer, your customer's customer, and the end user."*
>
> Gene Norrett, Dataquest

But there are directions and signposts to point the way through the 1990s. Notebook and hand-held PCs are growing rapidly, and high-performance PCs can compete with workstations. Performance, portability, individual use, communication, integration, and multimedia are all characteristic of the products of the 1990s. Graphically oriented, software-driven, easy-to-use products are what the end users will expect. "So be close to your customer, your customer's customer, and the end user," concluded Mr. Norrett.

The Road to Quality

"Quality is what your customer says it is," commented Geno Ori, Motorola Incorporated Semiconductor Products Sector senior vice president and director of Customer Relations. Mr. Ori recounted that Motorola started the process that ultimately led the company to the Malcolm Baldrige award in 1979. Managers at an annual management meeting were trying to determine how to gain better Motorola acceptance, when one manager noted that the "product quality stinks." Bob Galvin, who was chairman and CEO at the time, made it clear he had a personal and emotional commitment to quality.

Mr. Ori said it was hard to reorient the established company culture, but the company had embarked on an extensive training program. Design for quality, design for manufacturability, cycle time management, and statistical process control became standard courses for employees. Motorola then developed a program to achieve quality. The key elements of the program are as follows:

- Develop a plan of five or six easily understood pivotal strategies
- Develop a formal or informal organizational structure to implement the plan
- Set goals to improve quality tenfold and when achieved, do it again
- Focus on the market and the customer
- Place services and support closer to the customer
- Develop a common system of vendor evaluation for the company's worldwide procurement organization
- Develop a worldwide communications capability

Out of the program came the goal of Six Sigma, which amount to 3.4 defects per 1 million opportunities. This objective is applied to all company operations including administrative processes, as well as design and manufacturing processes. Mr. Ori also said that it is essential to develop communication between the company and customer at all levels. "If we can have a two-day monthly (accounting) closing, why can't we share how we do that with our customers? It's getting together to solve a common problem," Mr. Ori said.

Evaluating Suppliers

One ingredient in achieving quality is through the suppliers. Gene Richter, executive director of Corporate Procurement for Hewlett-Packard (HP) Company, described how HP developed an extensive supplier-measurement system. He noted that some suppliers appear to have a short-term view of supplying customers. " 'Tell

Gene Richter (Executive Director of Corporate Procurement, Hewlett-Packard) relaxed before speaking at the conference.

me how I'm measured, and I'll tell you how I behave' is how many suppliers seem to react," said Mr. Richter. This apparent attitude indicates a lack of consistency in service and product quality, he observed.

HP holds regular periodic, aggressive proactive evaluations that involve the management of both companies. The company evaluates semiconductor suppliers on technology, quality, responsiveness, delivery, and cost. Suppliers are scored in each category and compared with other suppliers of the same product types. Without disclosing competitors' names, HP shows each supplier where it ranks among all the suppliers. Mr. Richter outlined the following expectations for each category:

- Technology expectations
  - New technology
  - Mutual engineering
  - Commitment to R&D
- Quality expectations
  - Process control
  - Demonstrate product reliability by test as requested
  - Documentation—Advance notice of process/product changes
  - Responsiveness to alerts and corrective action requests
- Responsiveness expectations
  - High-level management commitment to HP
  - Effective worldwide factory and field support for all HP entities
  - Long-term product support
  - Flexibility to changes
- Delivery expectations
  - On-time delivery
  - Lead time
  - Packaging
  - Backup shipment strategy
- Cost of ownership expectations
  - Worldwide price leadership
  - Continuous cost reductions through process improvements

Semiconductor Manufacturing

SEMATECH is alive, well, and making significant contributions, reported Dr. William Spencer, SEMATECH president and CEO. However, the United States is facing a serious uphill struggle. Manufacturing is a major technical issue facing U.S. industry today. About 30 percent of the automobiles across the United States are of foreign manufacture; in California, the percentage rises to 50 percent. All consumer electronics come from outside the United States.

From being the largest manufacturer in the world, U.S. manufacturing has declined to where the country is manufacturing only 25 percent of the goods consumed here, reported Dr. Spencer. Even if the foreign goods are produced in the United States, the money goes to Japan. Only 1 U.S. bank is in the top 40 banks worldwide.

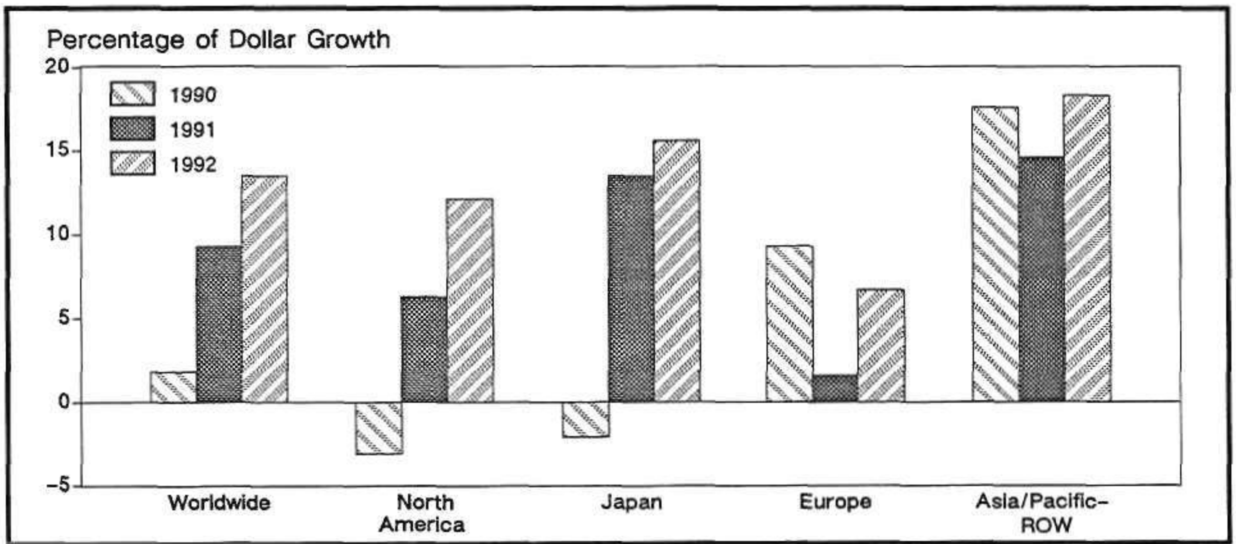
SEMATECH was formed to address the premanufacturing issues of manufacturing infrastructure and quality management. It will meet all its objectives by the end of 1992, said Dr. Spencer. But the SEMATECH demise, reported by one newspaper, is premature because of the rapid rate of technology change. Of all the accomplishments, the building of cooperation is the most important. This is a forum for the exchange of ideas.

Dr. Spencer forecast that in the next century, a fab will cost over $2 billion; and with the manufacturing efficiencies of these megafabs, only about two dozen will be needed. He believes that niche markets will no longer be safe because more capable tools will be able to produce full-custom products in zero time. What SEMATECH is striving for is to accelerate technology, to reduce the current three-year development cycle to two years in order for U.S. companies to be competitive in the semiconductor market.

The Semiconductor Outlook

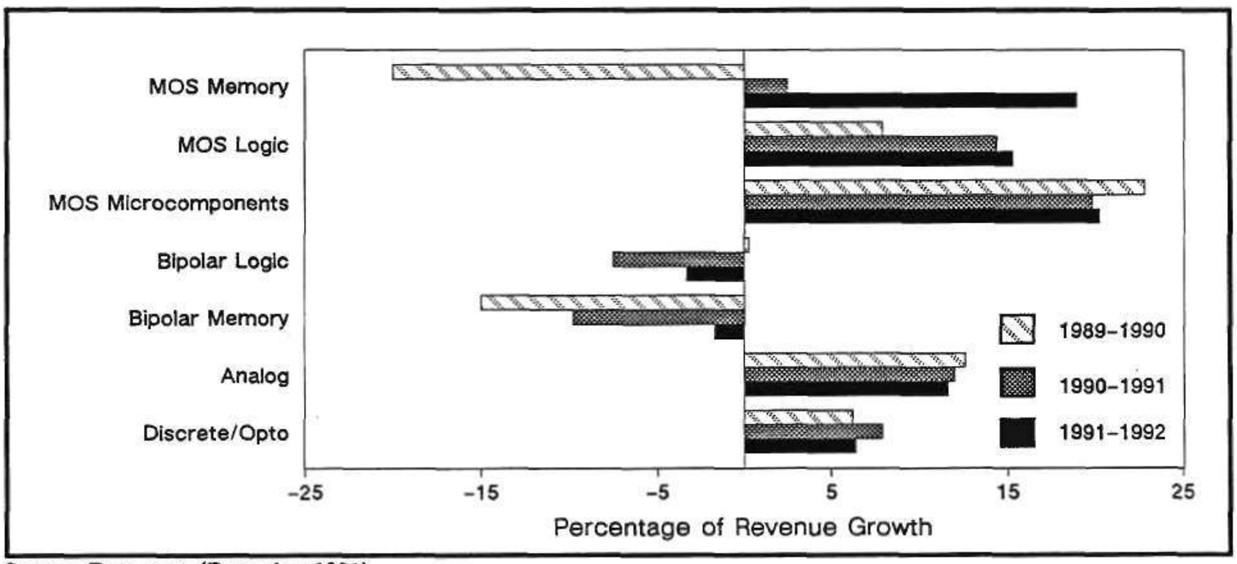
Jerry Banks, Dataquest principal analyst and director, reported that semiconductor consumption would grow 9.3 percent in 1991 and 13.5 percent in 1992. The near-term growth is driven by forecast economic recoveries in both the United States and the United Kingdom, together with strong economies in the major electronic equipment-consuming countries. Dataquest expects the semiconductor market growth rate to peak in 1993 at 15.7 percent. The overall forecast compound annual growth rate (CAGR)

Figure 1
Worldwide Semiconductor Revenue Growth Forecast by Region



Source: Dataquest (December 1991)

Figure 2
Semiconductor Product Growth Forecast



Source: Dataquest (December 1991)

for the period of 1990 to 1995 is 11.8 percent—a far cry from the 19.1 percent achieved during the five-year period of 1985 to 1990.

Although the semiconductor market is showing signs of maturing as shown in Figure 1 (evidenced by a slower CAGR through 1995), strong absolute dollar growth will still occur on an annual basis. As seen in Figure 2, Dataquest is forecasting that semiconductor consumption will surpass the $100 billion mark in 1995. The real challenge in the 1990s is not just how to grow revenue but rather how to achieve profitability.

Networking for Competitive Advantage

In the past, companies were vertically structured organizations, reported Stan Bruederle, Dataquest vice president and director, in his talk entitled "A New Way of Looking at the Electronics Industry—Networking for Competitive Advantage." "My objective is to suggest that we are moving from what I would call a vertically structured industry, with large companies supported by a network of suppliers of raw materials competing against each other, to what I would call a networked structure. This is where groups of specialized companies form alliances with other specialized companies to address an array of market opportunities."

Mr. Bruederle observed that companies with flexible alliances, as opposed to vertical structures, are rapidly gaining market share against the vertical organizations. He cited Apple Computer Inc., Compaq Computer Corporation, and Sun Microsystems Inc. as examples of companies that had rapidly increased market share by using a network strategy. They depend on outside companies for some of the capabilities they sell or use within their systems.

Mr. Bruederle said that as the result of the commoditization of computers, companies are beginning to change the way they view their businesses. What is happening is that the decreasing price of the commodity products opens the opportunity for new applications. Computer companies are being challenged to behave more like consumer electronics companies. Because few companies can compete in all applications, develop all the needed technologies, or operate effectively in all the distribution channels, it is necessary to build network alliances. Such networked companies, Mr. Bruederle believes, will continue to grow and prosper.

Multimedia

"Multimedia is the third wave of computing," declared Marc Canter, founder and president of MacroMind, a seven-year-old multimedia software company. "The first era was the text-based era. The second era of computing was the graphical user interface—what we call the GUI era. Finally, we are heading into the third era of multimedia computing, in which the computer will have video, animation, and sound. It will be pen-based, it will be portable, it will be on a network, it will have a very fast SCSI on it, and it will have more mips and storage than you know what to do with."

Mr. Canter said that the technology needed for multimedia is here today. The problem with computers is that they are hard to use. The way the human adapts to the software is the

Mark Canter (president and CEO, MacroMind) spoke on multimedia.

key point where man and technology come together. The kinds of hardware Mr. Canter considers necessary, besides higher-speed processors and more memory, are stronger graphics and networking capabilities. Also, he believes that standards need to be refined—software standards, interface standards, digital/video standards, and digital/audio standards.

Mr. Canter observed that in the computer industry, 80 percent of all money is spent on hardware, 15 percent is spent on software, and 5 percent is spent on repair and maintenance. He contrasted this to the entertainment industry where the TVs, VCRs, CD players, and stereo systems command a far smaller percentage of the total industry income compared with the entertainment media—the content of a CD or VCR tape. In the computer industry, the content, or data, has had little value. With multimedia, he suggests that the value will be in the content; that there is already a merger in progress between publishing and entertainment; and that the real money will come from the content of the interactive CDs or other media.

Communications Trends

Stagg Newman, assistant vice president of technology of Pacific Telesis Group, told conference attendees that personal communication, image communication, and distributed processing are the drivers for communications equipment into the future. The four enabling technologies that will allow the move to the future are already here. They are digitization, speech and image processing, fiber optics, and intelligent control. He demonstrated the difference in audio transmission a decade ago, the present, and the future with Integrated Services Digital Network.

Having different phone numbers for office, fax, secretary, home, telex, e-mail, and cellular telephone can become confusing and cumbersome. Mr. Newman thinks that we are rapidly approaching the time when people will be issued one identifier number. Through that number, the system would be able to track us from place to place, city to city, or around the world. The future system will provide call directing, provide call screening, and allocate the billing. Also, he foresees scratch pads that send messages, wireless telephone exchanges in businesses, cellular notebook PCs, and video pagers.

The tetherless communications systems will be good for the semiconductor industry, said Mr. Newman. Telephones will need more processing power and sophisticated ASICs. He noted that the growth rate for communications chips is strong and will continue to be strong.

Matching User Needs

Dataquest's John Jackson moderated a panel that discussed the topic entitled "Direction of Strategic Semiconductors: Will they Match User Needs?" The panelists were Wilf Corrigan, chairman and CEO of LSI Logic; H. Egawa, senior vice president and director of Toshiba Corporation; Craig Barrett, executive vice president of Intel Corporation; and Morris Jones, senior vice president of Chips & Technologies Inc.

> *"Product flexibility is going to be critically important."*
>
> Morris Jones, Chips & Technologies

Mr. Corrigan saw the current market condition as an illustration that there is not only an excess capacity of semiconductors but also an excess of technological capacity. "The issue over the next five years is that the semiconductor technology is actually running ahead of the applications, and, to some extent, the user base is awash with semiconductor technology," he said. "I think the problem really is creating the needs for the technology rather than the silicon technology responding to the needs of the customers. Because, if the customer can define it, one way or the other, the semiconductor industry can produce the silicon in relatively short order. It only needs the definition of the need."

"Product flexibility is going to be critically important," said Mr. Jones. He thinks that many customers find themselves in the quandary of whether to use existing standards, although they may not precisely meet their needs, or go for their own specific ASIC solution with its higher risk. He believes that part of the answer is that the strategy of the future will have software as an integral part of the solution to add flexibility. "Most future products that we look

Wilf Corrigan (Chairman/CEO, LSI Logic Corp.), Morris Jones (Senior Vice President of Technology, Chips & Technologies Inc.), Craig Barrett (Executive Vice President, Intel Corporation), and H. Egawa (Senior Vice President and Director, Toshiba Corporation) formed a panel to discuss how chips will meet user needs in the future.

at implementing and designing are far too complex to be done in hardware alone," he said. "At Chips, we view that the future products will be highly integrated single-chip products, and they are going to offer ranges of flexibility through both hardware and software microcode."

Mr. Barrett said, "I see our challenge as twofold: we can either sell commodity products . . . those products that other people can manufacture that are either identical to or the equivalent of. The option that you have is to add some value to the transistors you make, and then get value-added pricing rather than manufacturing pricing." He identified four ways to add value: applications expertise gained from customers and end users, an efficient product design, a leading-edge fabrication process, and the upgrade and add-on distribution channel. He also commented that the semiconductor industry was on a technology treadmill—that the pattern of doubling transistor density every year to year and a half on a chip of silicon was true. "We will have 100-million-transistor logic chips by the year 2000; we will probably have billion-transistor memory chips or gigabit memory chips by the year 2000. But the object for us, as manufacturers, is to figure out how to add value and get a differentiated price for it."

Mr. Egawa noted that memory is a typical commodity product with a large market, but a difficult product area in which to maintain a stable business. He noted that the DRAM product line had strong growth through 1988, but it has slowed somewhat in the period of 1988 to 1991, and he thinks it will be even slower through 1995. The forecast is ". . . for stable growth of the DRAM business for the years 1991 to 1995. But the stable business of the DRAM is never realized." The only solutions he sees are for partnerships to be formed between vendors and customers that would allow closer monitoring of production, or to differentiate products for specialty applications.

Investor's Perspective

Tom Thornhill, vice president and semiconductor analyst for Montgomery Securities and luncheon speaker for the conference, noted that his perspective on the industry focused on where value is created, where it is added, how it can be defended, and the investment implications. "The electronics industry, because of the rate of change of technology, is particularly susceptible to shifts in value added," he said.

The ability to add value has shifted away from the PC companies, and their ability to differentiate product has declined. In this market, there has been a significant shift in the balance of

Gene Norrett (Corporate Vice President of Marketing, Dataquest), Peter Stevenson (Senior Engineer, IBM), Sam Young (Director of Memories, Dataquest), John Melgalvis (Competitive Assessment-Procurement, IBM), and Mark Giudici (Associate Director, Dataquest) socialize at the evening reception.

value-added from systems companies to semiconductor suppliers. Mr. Thornhill commented that perhaps there had been even a larger shift to the software suppliers.

As more systems features are integrated on the silicon with the processor, it is the silicon supplier that increasingly defines the largest element of value-added in the hardware. He questioned whether the component suppliers as a group would be able to capture and hold this value-added element, or whether it will be competed away. "If it can be captured, the semiconductor industry will have the opportunity to earn a return on innovation over the next cycle and significantly increase the average return on capital," said Mr. Thornhill.

Application Markets

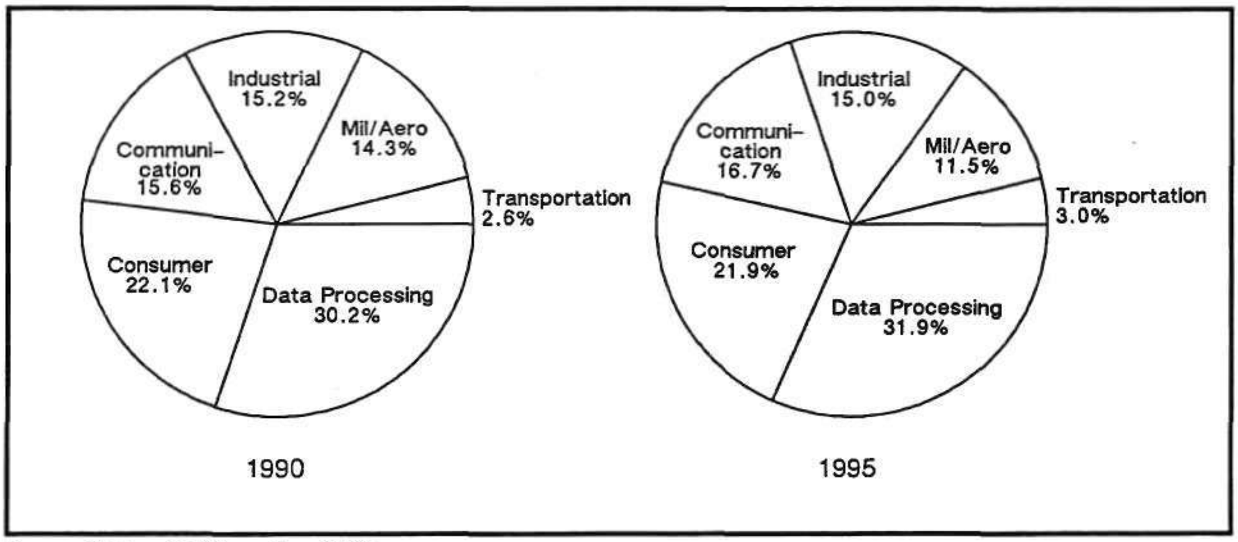
Worldwide equipment production is expected to grow from $612 billion in 1990 to $870 billion in 1995—a CAGR of 7.3 percent—reported Greg Sheppard, a Dataquest director and principal analyst. However, the growth will be fairly evenly divided among industry segments, and there will be little shift in the semiconductor distribution, he said.

Nevertheless, Mr. Sheppard does foresee some shift in where companies find their business. Traditional OEMs are beginning to provide the same value addition previously found in the distribution channels and among the value-added resellers. Also, these OEMs appear to be abandoning the bottom part of their vertical integration—making their own electronics—in favor of establishing tight relationships with electronics specialists. For semiconductor companies, this shift means learning where the customers are and where they are going to be in the future as they reposition themselves (see Figure 3).

> *"Data processing should continue to be the largest user of semiconductors."*
>
> Greg Sheppard, Dataquest

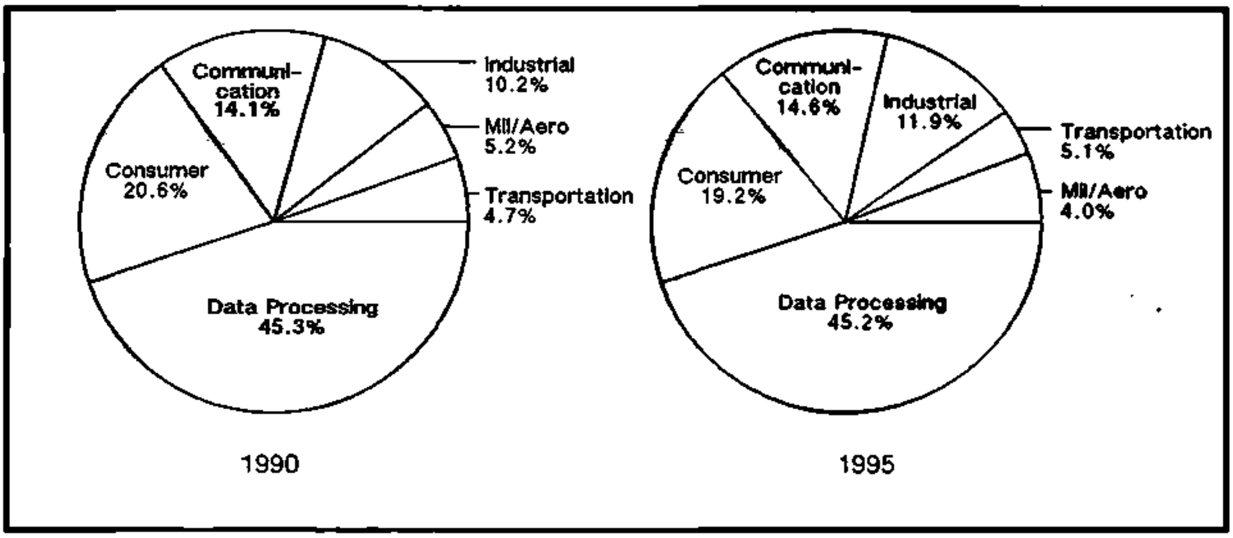
Data processing—including computers, peripherals, and office automation equipment—should continue to be the largest user of semiconductors (see Figure 4). The second-largest user of semiconductors is the consumer electronics segment. "Even though this is a maturing segment, there is a high enough level of volatility and activity to pay close attention," commented Mr. Sheppard.

Figure 3
Electronic Equipment Production by Application



Source: Dataquest (December 1991)

Figure 4
Semiconductor End Use



Source: Dataquest (December 1991)

The enabling factors and technologies that will allow the electronics industry to advance are as follows:

- The refinement of standards, which can trigger new markets and product displacement
- Power management, just now being seen in portable electronics
- Data and image compression for graphics and data storage
- PC cards for mass storage, memory addition, fax, modem, or applications
- Economical flat panel displays
- Handwriting and voice recognition

Mr. Sheppard noted that the market drivers for semiconductors are currently communication and networking, as well as portable and personal computing. He also noted that multimedia is beginning to become a factor. Digital television is beginning to become a reality, illustrated by the fact that digital signal processing (DSP)-like processing is going into current-model TVs. Moving further into the 1990s, personal communications (i.e., the cellular telephones, video pagers, and Dick Tracy-type video wrist communicator), high-definition television (HDTV), and digital photography will grow in significance. Over the horizon are parallel computing, neural computing, artificial vision, and complex speech-recognition applications.

Breakout Sessions

On both days of the conference, the general talks and lectures were followed in the afternoon by breakout sessions to cover subjects in more detail. The breakout sessions of the first day focused on semiconductor products, manufacturing, and pricing. The individual seminars covered DRAM Device and Manufacturing Trends; ASICs, Tools and Foundry; Semiconductor Pricing and Procurement Trends; and Semiconductor Manufacturing Trends.

The second day's breakout sessions targeted semiconductor application markets, trends, and issues. The individual sessions addressed Personal and Wireless Communication; PCs and Personal Workstations; Mass Storage; and Flat Panel Displays. ■

By Marc Elliot

Tentative 1992 Dataquest Conference Schedule

North America		
Forecast '92—Technology Briefing	March 19	San Jose
Ledgeway Service & Support	April 6-7	Boston
Document Management	May 6-7	San Francisco
Computer Storage	June 1-2	San Jose
SEMICON/West	June 17	San Francisco
Workstations/Networking	September	TBD
Semiconductor	October 5-6	Monterey
Europe		
Computer Storage	January 22	Munich
Computer Industry	March 31	Milan
	April 2	Munich
	April 7	London
	April 9	Paris
Semiconductor	June 3-5	Dublin
Document Management	September 16-17	Paris
Colour	September 18	Paris
Telecommunications	October 28-30	Munich
Ledgeway	November	Amsterdam
Japan and Asia		
Semiconductor	April	Tokyo
Computer & Telecommunications	June	Tokyo
Strategic Industry	September	Taipei
Technology Briefing	September	Seoul
Peripherals	October	Tokyo

TBD = To be determined

Dataquest Offers Consulting Services

Dataquest has found that there are occasions when client needs go beyond the scope of the published Dataquest service, or a client has specific needs outside the information provided by existing services. Dataquest has built a consulting group to support the information requirements of the critical or strategic decision process. We offer a wide range of custom consulting that can be grouped in three general categories: Emerging Technology, Market Opportunity Analysis, and Product Positioning.

Emerging Technology Analysis

Dataquest's Emerging Technology Analysis program is designed to assist companies in assessing the potential impact of an emerging technology on their companies, on their products, and on their markets. This analysis can help determine the timing for new product opportunities and identify potential market sizes. It can also clarify current technologies and products likely to be rendered obsolete and the characteristics of future competitive environments. The methodology is as follows:

- Identify emerging technology specification.
- Forecast competing technologies.
- Compare features.
- Assess the market penetration of the new technology.
- Identify the impact of external factors.
- Analyze risk.
- Synthesize composite information.

Market Opportunity Analysis

Dataquest's Market Opportunity Analysis program is designed to give an initial overview of a newly forming market. A multiservice team is used to ensure that all aspects of market influences are identified, not just an estimate of potential market size. The methodology is as follows:

- Assemble a multispecialty analyst team.
- Articulate the key issues.
- Refine key issues with the client.
- Gather and analyze issue-oriented data.
- Develop a recommended course of action.
- Review recommendations with the client.

Product Positioning

Dataquest's Product Positioning program is designed to assist companies in analyzing their product portfolios and to develop product/market strategies that will improve their competitive position. Dataquest works with clients to apply a disciplined procedure to analyze client products/market positions and to develop product/market strategies. The methodology is as follows:

- Work with the client to clearly define and document objectives.
- Identify the current market position and the client's strengths and weaknesses.
- Work with the client to develop strategies for the transition from existing position to defined objectives.
- Develop criteria for evaluating new products.
- When considering new products, draw on all company resources for new product ideas.
- With the client, evaluate new product ideas using criteria previously established.
- Refuse to accept the new product until all criteria are met.

Multiclient Studies

Dataquest also offers multiclient studies for a smaller set of clients than would normally support a Dataquest service. Multiclient studies are used for topics that do not require frequent updates.

If your needs go beyond the scope of your regular Dataquest service, call your Dataquest Account Manager and give us an opportunity to support your needs.

For More Information . . .

On the topics in this issue .... Semiconductors Worldwide (408) 437-8270
About on-line access .... On-Line Service (408) 437-8576
About other Dataquest publications .... Sales (408) 437-8246
About upcoming Dataquest conferences .... Conferences (408) 437-8245
About your subscription .... Customer Service (408) 437-8402
Via fax request .... Fax (408) 437-0292

0012418

Dataquest

a company of The Dun & Bradstreet Corporation

Special Edition

Dataquest Perspective

December 30, 1991

Market Analysis

0012510

Market Analysis

Preliminary 1991 Worldwide Semiconductor Market Share Estimates: Microcomponents Lead the Way

Dataquest has completed its preliminary 1991 semiconductor market share survey and analysis. We sent out a detailed survey to more than 150 semiconductor vendors in early November. The respondents then provided us with a detailed breakout of their revenue based upon a combination of their actual year-to-date revenue and a company-generated forecast for the balance of the year. These data were then processed using Dataquest's own research and analysis. The results of this process are published in this article. We will continue to refine and update the data until our final market share data documents are published on May 31, 1992.

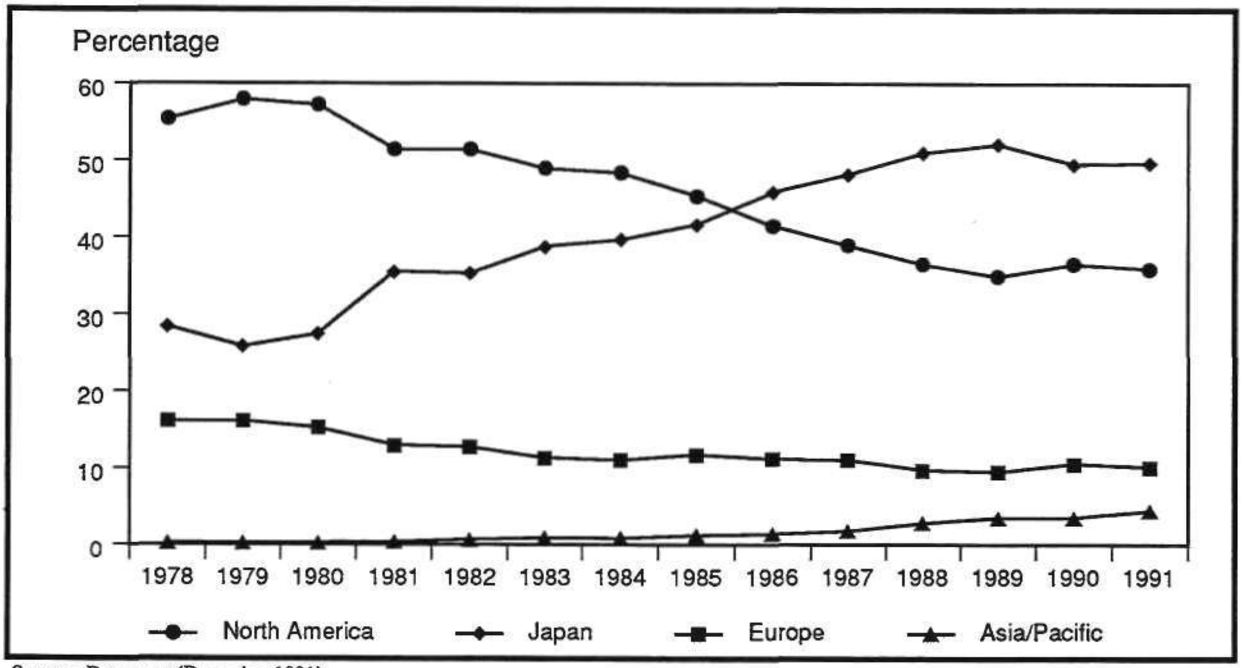
Market Share Highlights

The preliminary results indicate the following:

- Preliminary data indicate that the worldwide semiconductor market grew 11.5 percent over 1990, driven by portable, consumer, and telecommunications applications.
- Microcomponents were the primary growth contributor in the product arena and outperformed all others, growing at 22 percent.
- Bipolar digital was the big loser, dropping by 9 percent.
- North American companies' 1991 market share dropped slightly to 35.9 percent, compared with the prior year's 36.5 percent. Also, Intel Corporation surpassed Motorola Incorporated to become the No. 1 North American semiconductor vendor.
- Japanese market share grew slightly to 49.6 percent, compared with last year's 48.7 percent. NEC Corporation maintained its No. 1 position in the worldwide ranking.
- European companies' market share remained basically flat, moving from 10.7 percent in 1990 to 10.1 percent in 1991.
- Asian companies grew slightly, 4.4 percent in 1991 versus 3.6 percent in 1990.

Figure 1 shows the historical worldwide market share held by each regional company base.

Figure 1
Worldwide Semiconductor Market Share



Source: Dataquest (December 1991)

Semiconductor Rankings

Tables 1 through 9 list the top 20 suppliers for total semiconductors, total integrated circuits, total bipolar digital, and for the individual product categories: MOS microcomponents, MOS logic, analog, MOS memory, discrete, and optoelectronics.

NEC retained its No. 1 ranking, and in fact extended its lead over No. 2 Toshiba by virtue of its strong position in microcomponents. Intel, with its overwhelming strength in microprocessors, was able to overtake Motorola to claim bragging rights as the No. 1 North American semiconductor manufacturer. By virtue of its 28 percent growth in 1991, Intel outpaced the growth of every other company in the top 10. In fact, it isn't until the No. 20 position that a semiconductor vendor can be found with a higher growth rate than Intel's (see Table 1).

Product Rankings

Bipolar logic continues its precipitous slide, declining in 1991 by 9 percent. Texas Instruments Inc. (TI) suffered a 12 percent setback in this product area but was still able to regain the No. 1 position, overtaking Fujitsu, which experienced an even more severe 18 percent decline (see Table 3).

MOS microcomponents was the star performer in 1991 growing 22 percent in revenue over 1990. The top 8 vendors, led by Intel's 29.3 percent market share, remain the same as in 1990. However, a significant newcomer to the top 10 has arrived: Advanced Micro Devices Inc. (AMD). Based upon 386 microprocessor revenue, AMD jumped to the No. 9 position from last year's No. 13 (see Table 4).

MOS logic experienced strong revenue growth of 17.6 percent. The top five players, led by NEC with an 11.7 percent market share, remained the same as in 1990. Matsushita Electric Industrial Company Ltd. shot up from No. 10 last year to the No. 6 position. Sony moved up five places to No. 18 (see Table 5).

Analog grew at a 12 percent rate, which proves once again that where you find electronics you will find analog. This category experienced the greatest shakeup in regards to market share rankings. No vendor within analog's top 10 players maintained last year's position (see Table 6).

Table 1
Preliminary Estimated Market Share Ranking: Worldwide Total Semiconductor (Millions of Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	NEC	4,898	5,547	13	8.5
2	2	Toshiba	4,843	5,337	10	8.2
3	3	Hitachi	3,893	4,351	12	6.7
4	5	Intel	3,171	4,059	28	6.3
5	4	Motorola	3,694	3,915	6	6.0
6	6	Fujitsu	2,880	3,111	8	4.8
7	7	Texas Instruments	2,574	2,753	7	4.2
8	8	Mitsubishi	2,319	2,568	1	4.0
9	10	Matsushita	1,942	2,421	25	3.7
10	9	Philips	2,011	2,072	3	3.2
11	11	National Semiconductor	1,719	1,697	-1	2.6
12	13	Sanyo	1,381	1,612	17	2.5
13	15	Samsung	1,315	1,592	21	2.5
14	14	Sharp	1,325	1,562	18	2.4
15	12	SGS-Thomson	1,463	1,490	2	2.3
16	17	Sony	1,146	1,426	24	2.2
17	16	Siemens	1,224	1,250	2	1.9
18	19	Advanced Micro Devices	1,053	1,185	13	1.8
19	18	Oki	1,074	1,157	8	1.8
20	22	Rohm	774	1,029	33	1.6

Source: Dataquest (December 1991)

Table 2
Preliminary Estimated Market Share Ranking: Worldwide Total Integrated Circuit (Millions of Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	NEC	4,207	4,742	13	9.0
2	4	Intel	3,171	4,059	28	7.7
3	2	Toshiba	3,628	3,910	8	7.4
4	3	Hitachi	3,182	3,587	13	6.8
5	5	Motorola	2,860	3,096	8	5.9
6	6	Fujitsu	2,639	2,802	6	5.3
7	7	Texas Instruments	2,488	2,667	7	5.0
8	8	Mitsubishi	1,940	2,121	9	4.0
9	9	National Semiconductor	1,649	1,637	-1	3.1
10	11	Matsushita	1,243	1,585	28	3.0
11	10	Philips	1,473	1,504	2	2.8
12	12	Samsung	1,238	1,489	20	2.8
13	14	Advanced Micro Devices	1,053	1,185	13	2.2
14	13	SGS-Thomson	1,148	1,172	2	2.2
15	16	Sharp	986	1,130	15	2.1
16	15	Oki	1,031	1,109	8	2.1
17	17	Sanyo	979	1,075	10	2.0
18	19	Sony	791	984	24	1.9
19	18	Siemens	835	820	-2	1.6
20	20	AT&T	717	780	9	1.5

Source: Dataquest (December 1991)

Table 3
Preliminary Estimated Market Share Ranking: Worldwide Bipolar Digital (Millions of Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	2	Texas Instruments	663	583	-12	14.5
2	1	Fujitsu	690	564	-18	14.0
3	3	Hitachi	510	555	9	13.8
4	6	Motorola	406	391	-4	9.7
5	4	National Semiconductor	423	344	-19	8.6
6	5	Advanced Micro Devices	407	319	-22	7.9
7	7	NEC	295	311	5	7.7
8	8	Philips	280	286	2	7.1
9	9	Toshiba	113	122	8	3.0
10	10	Mitsubishi	105	113	8	2.8
11	13	Harris	60	53	-12	1.3
12	14	AT&T	59	53	-10	1.3
13	15	Raytheon	54	53	-2	1.3
14	16	Oki	47	48	2	1.2
15	12	GEC Plessey	66	41	-38	1.0
16	17	Siemens	45	38	-16	0.9
17	20	Applied Micro Circuits	24	32	33	0.8
18	18	Goldstar	26	22	-15	0.5
19	19	Chips & Technologies	25	19	-24	0.5
20	21	Matsushita	14	15	7	0.4

Source: Dataquest (December 1991)

Table 4
Preliminary Estimated Market Share Ranking: Worldwide MOS Microcomponent (Millions of Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Intel	2,726	3,590	32	29.3
2	2	NEC	1,083	1,318	22	10.7
3	3	Motorola	1,009	1,175	16	9.6
4	4	Hitachi	607	678	12	5.5
5	5	Mitsubishi	464	571	23	4.7
6	6	Toshiba	441	559	27	4.6
7	7	Texas Instruments	320	419	31	3.4
8	8	Matsushita	250	338	35	2.8
9	13	Advanced Micro Devices	178	315	77	2.6
10	9	National Semiconductor	248	293	18	2.4
11	11	Fujitsu	239	260	9	2.1
12	12	Philips	192	205	7	1.7
13	16	Oki	147	169	15	1.4
14	14	SGS-Thomson	175	166	-5	1.4
15	22	VLSI Technology	105	165	57	1.3
16	10	Chips & Technologies	240	158	-34	1.3
17	18	Sharp	138	156	13	1.3
18	19	Cirrus Logic	129	155	20	1.3
19	17	AT&T	145	134	-8	1.1
20	15	Western Digital	148	133	-10	1.1

Source: Dataquest (December 1991)

Table 5
Preliminary Estimated Market Share Ranking: Worldwide MOS Logic (Millions of Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	NEC	1,036	1,255	21	11.7
2	2	Toshiba	838	980	17	9.1
3	3	Motorola	559	645	15	6.0
4	4	Fujitsu	540	634	17	5.9
5	5	LSI Logic	503	567	13	5.3
6	10	Matsushita	285	478	68	4.4
7	8	Texas Instruments	306	469	53	4.4
8	6	Oki	410	432	5	4.0
9	7	Hitachi	352	404	15	3.8
10	1	Sharp	278	339	22	3.2
11	9	AT&T	303	333	10	3.1
12	12	Philips	252	290	15	2.7
13	13	Hewlett Packard	230	239	4	2.2
14	15	VLSI Technology	211	203	-4	1.9
15	14	National Semiconductor	216	201	-7	1.9
16	17	Sanyo	194	200	3	1.9
17	19	Samsung	153	196	28	1.8
18	23	Sony	116	187	61	1.7
19	21	Advanced Micro Devices	139	184	32	1.7
20	20	Yamaha	145	178	23	1.7

Source: Dataquest (December 1991)

Table 6
Preliminary Estimated Market Share Ranking: Worldwide Analog
(Millions of Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	3	Toshiba	610	720	18	6.1
2	5	Sanyo	541	707	31	6.0
3	2	National Semiconductor	619	680	10	5.7
4	1	Philips	653	650	0	5.5
5	4	SGS-Thomson	554	601	8	5.1
6	8	Mitsubishi	441	518	17	4.4
7	9	NEC	417	514	23	4.3
8	6	Motorola	491	496	1	4.2
9	10	Matsushita	410	485	18	4.1
10	12	Analog Devices	360	460	28	3.9
11	11	Sony	399	459	15	3.9
12	7	Texas Instruments	458	446	-3	3.8
13	13	Hitachi	347	412	19	3.5
14	14	Rohm	282	380	35	3.2
15	15	Harris	260	267	3	2.3
16	16	AT&T	197	244	24	2.1
17	21	Fujitsu	164	208	27	1.8
18	18	GEC Plessey	173	185	7	1.6
19	19	Silicon Systems	165	184	12	1.6
20	20	Sanken	164	179	9	1.5

Source: Dataquest (December 1991)

Table 7
Preliminary Estimated Market Share Ranking: Worldwide MOS Memory
(Millions of Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	3	Hitachi	1,366	1,538	13	11.0
2	1	Toshiba	1,626	1,529	-6	11.0
3	2	NEC	1,376	1,344	-2	9.7
4	4	Fujitsu	1,006	1,136	13	8.2
5	5	Samsung	971	1,135	17	8.2
6	6	Mitsubishi	853	826	-3	5.9
7	7	Texas Instruments	741	750	1	5.4
8	8	Sharp	497	557	12	4.0
9	14	Micron Technology	286	453	58	3.3
10	10	Oki	392	421	7	3.0
11	11	Intel	371	395	6	2.8
12	9	Motorola	395	389	-2	2.8
13	12	Siemens	320	301	-6	2.2
14	13	SGS-Thomson	299	280	-6	2.0
15	16	Advanced Micro Devices	253	272	8	2.0
16	15	Matsushita	284	269	-5	1.9
17	22	Hyundai	115	248	116	1.8
18	17	Sony	227	234	3	1.7
19	25	Goldstar	96	225	134	1.6
20	19	Cypress Semiconductor	166	185	11	1.3

Source: Dataquest (December 1991)

Table 8
Preliminary Estimated Market Share Ranking: Worldwide Total Discrete (Millions of Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Toshiba	904	1,070	18	12.0
2	2	Motorola	808	792	-2	8.9
3	3	Hitachi	641	688	7	7.7
4	4	NEC	567	655	16	7.4
5	5	Philips	507	531	5	6.0
6	6	Matsushita	374	438	17	4.9
7	8	Rohm	321	411	28	4.6
8	7	Mitsubishi	348	408	17	4.6
9	10	Fuji Electric	304	342	13	3.9
10	9	SGS-Thomson	315	318	1	3.6
11	12	Sanyo	232	301	30	3.4
12	13	Sanken	224	264	18	3.0
13	11	Siemens	258	243	-6	2.7
14	14	International Rectifier	224	228	2	2.6
15	15	General Instrument	214	208	-3	2.3
16	16	Shindengen Electric	176	180	2	2.0
17	20	Fujitsu	117	166	42	1.9
18	17	ITT	161	110	-32	1.2
19	23	Eupec	96	109	14	1.2
20	22	Semikron	106	108	2	1.2

Source: Dataquest (December 1991)

Table 9
Preliminary Estimated Market Share Ranking: Worldwide Total Optoelectronic (Millions of Dollars)

1991 Rank	1990 Rank		1990 Revenue	1991 Revenue	Percent Change	1991 Market Share (%)
1	1	Sharp	339	432	27	13.4
2	2	Matsushita	325	398	22	12.4
3	3	Toshiba	311	357	15	11.1
4	4	Sony	270	336	24	10.4
5	6	Sanyo	170	236	39	7.3
6	5	Hewlett Packard	223	230	3	7.1
7	7	Siemens	131	187	43	5.8
8	8	NEC	124	150	21	4.7
9	9	Fujitsu	124	143	15	4.4
10	10	Rohm	105	130	24	4.0
11	11	Telefunken Electronic	78	83	6	2.6
12	12	Hitachi	70	76	9	2.4
13	15	Texas Instruments	33	58	76	1.8
14	13	Optek	66	52	-21	1.6
15	18	Mitsubishi	31	39	26	1.2
16	17	Philips	31	37	19	1.1
17	16	Oki	33	36	9	1.1
18	14	Quality Technologies	34	35	3	1.1
19	19	Motorola	26	27	4	0.8
20	20	Honeywell	25	25	0	0.8

Source: Dataquest (December 1991)

MOS memory last year grew at a relatively moderate 6 percent versus 1990's disastrous 17 percent decline. Observed in this light, however, MOS memory has made a rather impressive recovery, especially considering the fact that the 4Mb DRAM has not taken off as quickly as some had hoped. Hitachi jumped from the No. 3 position in 1990 to No. 1 in 1991, just barely surpassing last year's leader Toshiba, which was pushed to the No. 2 position. The balance of the top 10 remained essentially the same, with the exception of Micron Technology Inc., which shot from No. 14 to No. 9 via a 58 percent growth rate (see Table 7).

Dataquest Perspective

This past year was a prime example of positioning paying off. Those companies with strong positions in consumer, communications, and portable applications had the greatest opportunities for growth in 1991. With the exception of portable applications, the segments of data processing, industrial, automotive, and mil/aero all experienced moderate growth.

However, as in every broad sweeping conclusion, there are exceptions to the rule. Intel, with its dominant position in microcomponents and its near monopoly in the X86 microprocessor family, has been able to consistently outperform the market even though its revenue is very strongly dependent upon the data processing market. Additionally, AMD has been able to piggyback upon Intel's dominance by developing its own Intel-compatible 386 microprocessor family.

This market share report reflects revenue growth but does not address the more pressing issue of profitability. Although some companies are experiencing strong revenue growth, it is rare indeed to find companies achieving satisfactory profit margins. This area requires the most focus. Weak revenue growth is more acceptable if profitability is achieved. With this in mind, the wisest course of action for companies still is to focus on value-added products that generate higher margins.

By Gerald J. Banks
Ken Dalle-Molle

For More Information . . .

On the topics in this issue .... Semiconductor Group (408) 437-8677
About on-line access .... On-Line Service (408) 437-8576
About other Dataquest publications .... Sales (408) 437-8246
About upcoming Dataquest conferences .... Conferences (408) 437-8245
About your subscription .... Customer Service (408) 437-8402
Via fax request .... Fax (408) 437-0292