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Strategic ISSUES

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Technology Transfer: Can America Learn to Move Knowledge?

By Judith K. Larsen

The United States has the largest and most creative research system in the world. Its extensive university system, which includes research as a fundamental of education, forms the basis for research leadership. Erich Bloch, director of the National Science Foundation, observes that American universities draw students and faculty from around the world and attract investment from foreign companies, which is a good indication that in a competitive educational market, U.S. institutions deliver the best product.

The United States has received more Nobel Prizes than any other country, a prime measure of research success. The number of employed U.S. scientists and engineers—more than 3.5 million—is at an all-time high. The proportion of research articles authored by U.S. scientists in core journals accounted for 35 percent of all such articles in 1982. U.S. spending for research and development (R&D) exceeded $100 billion in 1986, although more than half of that amount went for defense-related R&D. Half of the nondefense research was financed by industry.

Although the United States is ahead in research excellence, a growing chorus of critics is asking whether it has lost the knack for turning basic science into competitive products. Nearly a decade of restructuring and deregulation has forced many American companies to curtail basic research activities and focus more narrowly on immediate market needs. At the same time, other countries have learned to make devastating use of research—often U.S. research—in world markets. Japan is famous for its ability to identify promising research findings and to turn the research into commercial applications. An extensive network of R&D organizations, including corporations and government agencies such as MITI and the National Research Institutes, support Japan's achievements. Europe is developing similar institutions. As the cost of basic research in many fields escalates, the question is: How can the United States can catch up with Japan and other Asian and European countries and learn to exploit technology transfer to better economic advantage?

Technology transfer, the process through which the results from basic and applied research are commercialized, has emerged as an issue that is important to political leaders, research administrators, and industry executives. Concern about technology transfer and declining support for research led a group of 150 American corporations and universities to form the Council on Research and Technology (CORETECH) in 1987 to develop policies that encourage technology transfer. Ken Kay, CORETECH's executive director, states that until recently, the United States has not spent sufficient time studying technology transfer. "Technology transfer requires skills that are not necessarily apparent or commonly used," Mr. Kay argues.

THREE KEY PARTICIPANTS

The solution to the problems the United States faces in this critical area may be found in the three main participants in the technology transfer area: industry, universities, and government.

Industry, especially high-technology industry, knows that research information is critical to its very existence. The world's leading corporations have developed large research laboratories, some of which are the most famous research institutions in their specialties. But industry is experiencing a shift away from basic research to more product-focused activities (commentary, page 3). Companies increasingly depend on contacts with

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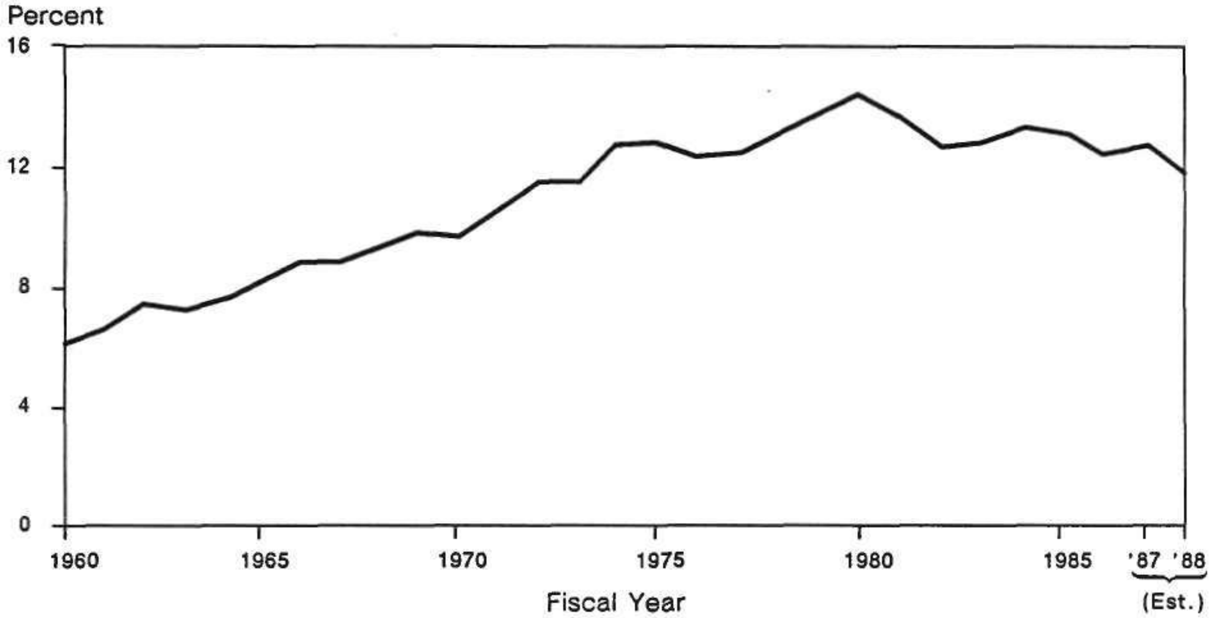
universities, federal labs, and professional societies to obtain research results and basic information about new technologies. Dozens of consortia have sprung up to help combine corporate efforts to tap these resources and to target specific research questions.

Universities are major technology transfer participants in the United States and, to a lesser degree, in Europe. In the past, industry concentrated on short-term research and product development while universities examined phenomena that had no immediate applications. Decreased federal funding to universities and colleges has limited university research activity (see Figure 1). Direct federal support of R&D physical plants in universities fell from $211 million in 1966 to $19 million in 1981, although the amount has increased in recent years. Federal research cutbacks combined with tight state budgets leave public universities unable to buy necessary research equipment or to offer salaries that can compete with industry in attracting top-level professors. As a result, university research has become more narrowly targeted and more dependent on industry funding so that now, industry and university research activities are drawing closer together.

A third technology transfer participant is government, although until recently, the U.S. government has displayed little interest in technology transfer. By contrast, government plays an active role in technology transfer in Japan and Europe. MITI-coordinated programs in Japan—such as the VLSI Project, Supercomputer Project, and Future Electron Devices Project—include highly successful technology transfer components. European governments also actively support research cooperation and technology transfer through programs such as ESPRIT (European Strategic Programme for Research in Information Technologies), EUREKA (European Research Coordination Agency), RACE (Research in Advanced Telecommunications Technology for Europe), and BRITE (Basic Research in Industrial Technologies for Europe).

Although the U.S. federal government shows little interest in technology transfer, state and local governments have no such reluctance. In recent years, the bulk of technology transfer activity in the United States has moved to the state and local levels. Nearly every state has developed technology transfer programs to encourage contacts between universities and local industry, and many can boast enviable records of success. An eminent university dean participating in a recent American Electronics Association R&D forum

Figure 1
Federal Obligations for R&D at Universities and Colleges as a Percentage of All Federal R&D



Source: Division of Science Resources Studies

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Commentary

What Is Happening to the Corporate Research Lab?

By Judith K. Larsen

AT&T Bell Laboratories in New Jersey was called a "national treasure." Philips' corporate research lab in Eindhoven, the Netherlands, was labeled "world-renowned." These two facilities still are premier research institutions, but they, along with many other research labs, are shifting their focus.

With the breakup of AT&T, Bell Labs modified its function, adopting a new approach more in keeping with its restructured corporate parent. AT&T has long been known for its basic research in areas where the applications are not known, a policy that led to the discovery of the transistor in 1947. AT&T intends to continue its basic research, noting that support of Bell Labs remains strong at $2.2 billion with total employment at 21,000 in 1987; however, Bell Labs has expanded its research agenda, devoting more attention to the near-term needs of AT&T's businesses.

Another organization, Bell Communications Research (Bellcore) was created at the time of the AT&T breakup in 1984. Bellcore's research focuses on exchange telecommunications and exchange access services, as well as communications services associated with national security and emergency preparedness. This research has direct applications to the needs of its shareholders, the seven regional Bell operating companies.

Over the years, the Dutch electronics giant Philips has earned a global reputation for research excellence. However, faced with lower profits and tough competition, earlier this year Philips announced plans to cut its basic research budget in half. Like Bellcore, Philips' research projects will increasingly focus on the businesses that the labs support. Increased attention to technology transfer is an explicit part of the new Philips strategy.

The Italian giant, Olivetti, also has announced plans to restructure its R&D division in a manner similar to that of AT&T and Philips. Olivetti will divide its research staff into more targeted groups that can provide support for specific business units.

Management guru Peter Drucker recently reviewed the place of R&D in business and concluded that the traditional corporate research lab no longer makes sense. According to Dr. Drucker, traditional corporate research labs presume that "all the technology needed by the company can be produced by its own lab, and conversely, that most everything its lab produces can be put to profitable use by the company. This is simply no longer true." As the corporate labs shift direction, links to university researchers and their basic research efforts take on new importance.

raised some eyebrows when he stated, "The action has moved from the federal level to the states. The best technology transfer in the United States today is being done by the states."

TECHNOLOGY TRANSFER—OR THE LACK OF IT—IN THE UNITED STATES

Technology transfer originally referred to the movement of a prototype product from a university or corporate research lab to manufacturing. As high-technology industry increasingly has incorporated software and information into its products, technology transfer has broadened its definition of technology to include the exchange of knowledge, including information and research findings. NSF's Erich Bloch describes knowledge as a critical national asset and observes that today's technology-based societies depend on transferring knowledge rather than natural resources. However, Mr. Bloch warns that although countries such as Japan and Korea understand present-day technology transfer, the United States "has not made the shift to the new paradigm."

The technology transfer problem involves three sectors—universities, industry, and government—that traditionally have not worked together in the United States. Cooperation was not necessary in the past when U.S. technical dominance was sufficient to guarantee success. However, growing worldwide technological competence and increased competition have changed the game so that interaction among all participants is becoming increasingly critical.

Although most people pay lip service to the importance of technology transfer, the United States has been slow to figure out what it means or how to do it. As a result, U.S. leadership has been lost or threatened in such critical fields as optoelectronics, sensors, advanced materials, and automated language translation. And the list grows, indicating that the trend continues.

Today's problems in technology transfer have an unnerving similarity to U.S. attitudes toward manufacturing in past decades. At first, U.S. companies failed to recognize the importance of manufacturing. Even when it was acknowledged, government and industry still did not study manufacturing at the detailed level needed to identify the problems and to plan the remedies. Today, technology transfer is recognized as a major weakness in the United States, but few in government or industry have developed ways to understand it and fewer still know how to do it.

INTERNATIONAL TECHNOLOGY FLOWS

The solution to the technology transfer problem will have to involve the improved global movement of technology. In the past, the assumption was that technology moved from the United States to the rest of the world. The present reality is that other countries have developed technology transfer strategies that work well within their own countries and internationally. The United States has to tap into the technology transfer expertise available abroad.

In September 1987, the Center for the Study of Intelligence sponsored a symposium comparing the flow of technology between the United States and Japan. The symposium concluded that although a few major U.S. corporations track Japanese high-technology developments, the primary information flow still is from the United States to Japan. The imbalance in information exchange places the United States in an unfavorable position compared with Japan and limits technology transfer opportunities. While newly industrialized countries in the Asia-Pacific region acknowledge U.S. leadership in scientific research, Japan offers them the best model for transferring research into products, the activity necessary for economic advancement.

Sheridan Tatsuno, senior industry analyst in Dataquest's Japanese Semiconductor Industry Service and an expert in Japanese technology transfer, states that Japan is trying to increase its lead in technology transfer. Japanese companies and government projects are developing new technology transfer methods to improve their already-formidable international competitiveness. Japanese technology transfer traditionally has been viewed as the importing of foreign technology by means of copying, licensing, and reverse engineering. However, Mr. Tatsuno warns that the stereotype of Japan as a "copycat" is simplistic and outdated because it ignores the complex transfers of technology within Japan itself.

U.S. researchers generally ignore technical information from other countries, a habit that can lead to dire consequences. In 1986, the U.S. Department of Commerce opened an Office of Japanese Technical Literature to translate Japanese research reports and conference proceedings. Since the office opened, however, requests from U.S. scientists have been far below the projected numbers. The not-invented-here syndrome, a belief that research conducted elsewhere is not of the same quality as research done at home, infects too many U.S. scientists.

SHAKING UP THE FEDERAL LABS

The technology transfer gap is also apparent to U.S. policymakers. In 1986, Congress passed the Federal Technology Transfer Act requiring federal labs to support the diffusion of research findings. More than 600 federal laboratories throughout the United States conduct research on topics ranging from agriculture to transportation. No one knows exactly how many labs there are because the smallest labs are hard to identify. An agricultural research lab may be composed of three agronomists working on a project for only six months.

Yet there are hundreds of well-established federal labs that employ hundreds of thousands of scientists and engineers. According to the Federal Laboratory Consortium, about one-sixth of all scientists and engineers in the United States—300,000 to 400,000 people—work in the federal labs. The federal government spends $16 billion to $19 billion annually supporting the labs, 85 percent of which is allocated to 300 labs.

Twelve agencies of the federal government operate research labs. The largest labs conduct research on nuclear weapons and are run by the Department of Energy (DOE) for the Department of Defense (DOD). While the DOE labs are government owned, they are operated by private contractors and are commonly called GOCOs (government-owned, contractor-operated). The private contractor can be a university, a corporation, or a nonprofit organization. Examples of GOCOs include Sandia National Laboratories, operated by AT&T Technologies; Los Alamos National Laboratories, operated by the University of California; Oak Ridge National Laboratory, operated by Martin Marietta Energy Systems; and Engineering Services at Hanford, operated by Westinghouse Hanford Co.

There are also government-owned, government-operated labs called GOGOs. All DOD labs fall into this category. Examples include the Naval Research Laboratory (Department of the Navy) and the Harry Diamond Laboratories (Department of the Army).

Dr. Richard Dorf, a technology transfer expert at the University of California at Davis, studied technology transfer in the federal laboratories and found that their traditional transfer methods are inadequate. Before the 1986 legislation, interaction with industry was not included in the charter of the federal labs. Since most federal labs have not been concerned about transfer, they do not have effective transfer strategies in place. Dr. Dorf concludes that new organizational mechanisms are required in order to obtain full commercial value from the federal labs' research.

Efforts to initiate technology transfer in the federal labs began in 1974 when several federal laboratories and research centers joined to form the Federal Laboratory Consortium for Technology Transfer. By 1988, more than 600 labs and centers had joined the Consortium. The Federal Laboratory Consortium encourages the transfer of federally developed research to industry, universities, and other users.

Since the passage of the Technology Transfer Act in 1986, the federal labs' interest in technology transfer has picked up substantially. Labs have placed increased emphasis on trying to reduce the barriers to cooperative efforts with industry. The Consortium is trying to get industry and the federal labs to work together in project development rather than waiting for over-the-fence transfer. Lee W. Rivers, the Washington, D.C., representative of the Consortium, observed that things are changing. "More companies are assigning higher-level people to provide full-time liaison with the federal labs. They are choosing people who know the company, have a knowledge base, and have enough clout to get things done. When these people are involved, the sparks fly. What you want is to get the guy from the outside and the guy from the inside looking each other in the eyeballs." Despite these actions, too few technology transfer sparks have been generated by the federal labs.

Other Federal Technology Transfer Programs

The federal labs are not the only government-sponsored labs that are concerned with transferring the results of their research. Other government agencies also conduct research, and many of these groups also encourage technology exchange. While the complete list of government research facilities is too long to report, the following examples of government-sponsored research programs are of special interest to high-technology industry.

The *National Aeronautics and Space Administration* (NASA) has conducted an active program of technology transfer since its creation in 1958. NASA's Technology Utilization Services include ten application centers located throughout the country, technology application teams, a Scientific and Technical Information Facility, and a Computer Software and Management Information Center. Robert George of Dataquest's Manufacturing Automation Service notes that NASA's Technology Utilization Services are especially suitable for small businesses.

The *National Science Foundation Engineering Research Centers* program was initiated in 1985 to provide cross-disciplinary and systems-oriented research programs. In contrast to the traditional culture of academic engineering programs that are oriented along departmental lines, the Engineering Research Centers were intended to link traditional departments and build on knowledge bases that develop across disciplines. The Engineering Research Centers are large campus-based organizations, each working on a particular area such as telecommunications, biotechnology, systems research, or semiconductor microelectronics. Fourteen Engineering Research Centers have been established thus far, and NSF plans to establish 20 to 25 Centers with an annual budget of $100 million by 1992. The NSF funding request for the Engineering Research Centers for fiscal year 1988 was $48 million.

The *National Science Foundation Industry-University Cooperative Research Centers Program* combines industry funding with NSF support to establish university-based research centers in targeted areas such as computer graphics, telecommunications, optical circuits, and electromagnetics. Each research center receives NSF funds for a five-year period with the amount of support decreasing each year. To be eligible for NSF funds, the center must line up industry support of approximately $300,000 each year. There are 41 NSF centers operating throughout the country. The oldest center, which studies polymer processing, was initiated in 1973 at Massachusetts Institute of Technology; the newest center, which conducts research in ceramics, began this year at the University of New Mexico. Total fiscal 1988 NSF funding for the Centers Program is $3.1 million.

The *Department of Defense University Research Initiatives* (URI) program provides funding to 70 universities in 29 states to support defense research programs. The DOD has requested $95 million for fiscal 1989 to fund the URI program.

Case Study

Sun Transfers Technology a Bite at a Time

By Judith K. Larsen

Technology exchange at Sun Microsystems, Inc., comes in bite-size pieces. Sun's technology exchange program is designed to meet the needs of a young company in a rapid growth phase. According to Emil Sarpa, manager in Sun's Education Products Division, university researchers work in collaboration with Sun engineers on topics of limited scope that are of interest and benefit to both the university and Sun. "We marry bite-size piece to bite-size piece, putting the pieces together and looking for new directions to emerge, rather than working with one or two huge ideas."

Founded in 1981 on the basis of university-developed technology, Sun manufactures technical workstations, servers, and software. Although Sun's technology exchange program is in its infancy, it is not ill defined. As Mr. Sarpa explained, "A technology exchange program has to be tailored to fit the objectives of the company. What would work in a semiconductor company is different from what works in a hardware or software company." The technology exchange program at Sun is relatively informal and open, an approach that Mr. Sarpa feels is consistent with Sun's corporate philosophy.

Mr. Sarpa states that three main factors determine a company's technology transfer program:

- The company's products
- The company's purpose
- Where the company is in its life cycle

If a company is young, it has not had time to define formal procedures and the technology transfer program will be loose. Older companies tend to have more standardized programs.

Technology exchange at Sun Microsystems requires "real" research efforts. Mr. Sarpa's philosophy is that "manufactured" relationships do not result in serious outcomes. While it may be important to create good relations with a university or research lab, no serious technology exchange will result from such pro forma connections. Sun's "real" technology exchange occurs when a 27-year-old scientist at Sun and a 28-year-old graduate student at a university work together on a topic of mutual concern. As Mr. Sarpa observes, "Both researchers want to solve the problem, so it's a win-win situation."

Sun's contacts with university researchers develop over time. A computer science professor in a Western university contacted Sun several months ago with an idea for a cooperative research project. The idea was close, but not quite on target, so that particular project did not work. But as Mr. Sarpa commented, "She calls every now and again with a somewhat different idea, and we are coming close. She keeps trying and soon we will have a match. Technology-exchange relationships don't happen with one contact, or even two. It takes time to get to know each other."

Sun Microsystems is a rapidly growing company, and growth creates special problems for technology exchange. Mr. Sarpa said that he constantly sells the importance of technology exchange to new employees and to departments that are expanding and developing. All companies have pockets of resistance to technology exchange. At Sun and other growing companies, resistance does not result from a lack of interest, but instead reflects the lack of time to deal with anything other than the immediate job.

The technology transfer initiatives of the many federal labs and agencies are well intended but have produced limited impact. Federal research labs have a history of responding to the research agenda identified by the funding agency. Federal labs have little experience in working in collaboration with industry to identify common research problems or in thinking about how the results of the research could be applied.

INDUSTRY-UNIVERSITY TECHNOLOGY TRANSFER

Both industry and universities conduct research, and they both transfer the results of their research to the other. In some cases, especially when federal funds are involved, the research connections between industry and universities are highly structured. In other cases, connections are very informal, perhaps based on the personal interest and the support of university faculty and alumni or of corporate friends. But really close ties are rare. As Dr. Bloch observed, "Spontaneous collaborative relationships between the two sectors have been the exception to a well-established tradition of mutual isolation."

U.S. universities produce knowledge in two forms: graduates and research results. From its inception, high-technology industry realized the importance of access to knowledge, and early companies were located near major universities in the Silicon Valley and Massachusetts. Today, three-quarters of U.S. universities have some ties with business.

Science recently observed that industry's investment in academic research "arises not from some altruistic desire, but rather from the very businesslike judgment that universities have something that corporations want: research talent and technical skill." A survey of semiconductor companies conducted by Cognos Associates found that the main reason these companies developed technology exchange programs with universities was to identify and attract students as future employees.

Universities also benefit from technology exchange with industry. They receive research funds and equipment from industry. Professors who exchange technology with industry gain useful information and experience that they can incorporate into their courses for the benefit of their students.

Technology transfer creates a synergistic effect that benefits both industry and universities. It can encourage technological innovation and speed development of new designs. Nontraditional corporate technology transfer programs, such as those at Sun Microsystems (see Case Study, page 6) and Apple Computer (see Case Study, page 9) provide indications of future corporate directions.

Increased interaction between the industry and universities also has created problems, including tension between industry's concerns with protecting its proprietary information and the universities' demands for academic freedom. High-technology companies are often reluctant to open their proprietary development programs to others, especially to students who later may be employed by competitors. Market niche companies also feel threatened. The CEO of a 100-employee company stated, "Everyone wants to arrange a technology-transfer program with us. But we have everything to lose and nothing to gain by giving outsiders even a hint of our process."

Universities feel that academic freedom requires the free flow of information to all researchers and scholars. If details of the research are not shared, others will not be able to learn from the original work. The caution of universities was expressed by The Twentieth Century Fund Task Force on the Commercialization of Scientific Research, "Universities defend their agreements with industry on the grounds of . . . technology transfer, the turning of academic knowledge to applied ends for public benefit. The goal is no doubt worthy, but . . . should be taken with a grain of salt."

RESEARCH CONSORTIA: WILL THEY HELP?

Research consortia composed of corporations that conduct joint research on basic issues are well known in Japan and Europe, but relatively new in the United States. Research consortia generally assess membership fees from sponsoring corporations and then allow member companies to have early access to research results. In the past, cooperation among U.S. companies was avoided for fear of violating antitrust laws, but the National Cooperative Research Act of 1984 provides protection for companies engaging in joint R&D ventures.

Since 1984, consortia have been formed in every part of the United States, each with its own characteristics. The following models of cooperative research consortia illustrate the range of emerging programs.

- Corporate-funded, corporate-staffed consortium—Microelectronics and Computer Technology Corporation (MCC). In 1982, ten U.S. companies pooled personnel and money to form a private joint venture to conduct research in targeted areas. The present number of member companies is 19. Located in Austin, Texas, MCC has a staff of 425 people and an annual budget of $60 million.
- Corporate-funded, university-based consortium—Semiconductor Research Cooperative (SRC). SRC is a nonprofit research foundation supported by 33 U.S. semiconductor companies. SRC's administrative offices are located in Research Triangle Park, North Carolina. However, SRC does not conduct research itself; instead, it funds research activities at universities throughout the United States.
- Corporate/federal/state-funded, corporate-staffed consortium—Sematech. In May 1988, Sematech and the Defense Advanced Research Projects Agency (DARPA) signed an agreement allowing Sematech to receive the first installments of its $100 million federal allocation for 1988. Sematech, located in Austin, Texas, will conduct research in semiconductor manufacturing. It currently has 70 staff members, but plans to expand to 700. Sematech receives support from the federal and Texas state government, as well as from 14 industry members. Its budget is estimated to be $1.6 billion over a six-year period.
- State/industry-funded, university-based consortium. In addition to national consortia, a much larger number of regional, state, and local research consortia have developed in the United States in the last decade. The Ben Franklin Partnership Program in Pennsylvania is probably the largest state development program. The Ben Franklin Program has a central board that sets policy and makes general funding allocations, but selection of specific projects and funding levels is made at the local level. The program revolves around academic institutions, but industry involvement is imperative. Research projects that lack industry participation are not funded.
- State/industry-funded, independent/not-for-profit organization. The Industrial Technology Institute (ITI) in Michigan is funded by the Michigan Strategic Fund to serve the needs of the manufacturing sector. After a decade of deteriorating competitiveness and productivity decline, Michigan realized that industrial quality had to be improved through the use of new computer-based technologies. ITI, created in 1981, includes representatives of industry, universities, government, labor unions, and private foundations.

Although research consortia are emerging at a rapid rate, not everyone is convinced that they represent the best strategy for encouraging innovation. Critics point out that the companies joining consortia are large, established companies, and large companies have the worst record for identifying new research directions. Much of technology's creativity comes from start-ups, from small- to middle-sized corporations, and from universities. Because smaller high-technology companies are not members of the research consortia, the most likely candidates for creating new technologies are ignored.

Consortia that are staffed by personnel from member organizations have been criticized as having second-rate staffs. Member corporations keep their best people at home to work on proprietary projects that are the future of the company and send their second-tier people to collaborate with the competition.

Many consortia are notorious for their weak technology transfer programs. The problem is complicated by the member corporations' fears that proprietary research information will reach competitors; consequently, consortia members are not enthusiastic about discussing strategies for transferring information. Another barrier is the confusion introduced by the emergence of so many research consortia in the United States and uncertainty regarding their status and function. Because technology transfer in each consortium is influenced by new legislation, agency policy, and relationship to state governments and member corporations, the constituencies' requirements may be contradictory.

WHAT MAKES TECHNOLOGY TRANSFER WORK

Technology transfer does not occur by chance. Programs that work have common characteristics, the most important of which is personal contact. As Barbara Bowen, manager of external research at Apple Computer, stated, "Technology transfer is a misleading term. Technology doesn't transfer by itself; it's people who transfer technology. People resources is the critical factor."

On April 27, 1988, the House Subcommittee on International Scientific Cooperation held a hearing on sharing foreign technology, including the need for translation of foreign scientific articles. While witnesses supported translation, they also advocated a much broader approach, stating that "first-hand observation and discussion of Japanese R&D by American experts is the most effective approach to remaining abreast of current developments. . . . Translation of technical material is best seen as an adjunct to personal interaction, rather than as a substitute."

Case Study

People Transfer Technology at Apple Computer

Judith K. Larsen

Apple Computer, manufacturer of personal computer systems, has long been known for its alliances with colleges, universities, and schools. Yet Apple does not encourage highly structured technology transfer programs. Dr. Barbara Bowen, manager of external research, feels that technology transfer is a misleading term, since, as she says, "Technology doesn't transfer by itself; it's people who transfer technology."

Apple's external research program has multiple components, but the engineer champion is the basis of the program. Engineer champions within Apple propose joint research projects with university researchers in areas that match Apple's directions. The engineer champion is responsible for bringing the research findings back in-house. But as Dr. Bowen explains, "The specific research results are not the only, or always the most important, outcome. We benefit from the rich set of ideas and contacts that university research brings."

University researchers work with Apple on projects that Dr. Bowen describes as "Apple-driven." Apple identifies specific research topics and then identifies the "best university people in the U.S. We look for people whose work represents a good match with Apple." Most of the contacts come on the initiative of the engineer champions and are built on previous relationships. "What works best is when people are in love with our technology and really want to participate as colleagues with the engineers. We look for the most cooperation and the least administrative overhead," she says.

The external research program is not a grants program for universities; it is an R&D program for Apple. While there are procedures and priorities that research projects must follow, the overall process is flexible and creative, allowing the researchers to respond quickly to unexpected opportunities and to shift direction if necessary. Apple does not have plans to publish guidelines for university researchers. "Occasionally we respond to an idea that comes in over the transom, but we definitely are not a mini-NSF," says Dr. Bowen.

Dr. Bowen describes Apple's fluid and non-structured research program as characteristic of Third Wave companies. She explains, "Companies of the future, like Apple, are organized around people, information, and innovation instead of large capital structures. We are a different kind of company. We may never 'grow up' and do it the way IBM and AT&T do it. We want to keep this function fluid, flexible, and innovative, and to keep people at the heart of it."

An innovative example of Apple's version of successful technology transfer comes with the formation of a third-party company. A university researcher works on research initiated by an Apple engineer champion and develops the work to a point where the university can spin it off to a new company that commercializes the research into a product. As Dr. Bowen explains, "That's good because it is based on our technology and creates a new market niche. The third-party company, a university spin-off, sells new boards or software that makes our technology more functional. Third-party companies are an excellent example of technology transfer."

A second characteristic of successful technology transfer programs is a reward structure or incentive that encourages "real" technology exchange. People will transfer technology if there is some reason to do so; rhetoric is not enough. F. Roger Tellefsen, Deputy Secretary of the Pennsylvania Department of Commerce, recently discussed U.S. and Japanese researchers, comparing the reluctance of U.S. scientists to leave their home institutions to work on joint research with the willingness of Japanese scientists to work cooperatively. Mr. Tellefsen observes that the reward systems may be different for Japanese researchers and for U.S. researchers, and that the rewards need to be studied.

A third factor that may characterize technology transfer of the future is cooperation. The research consortium may be the new form that supplements or even replaces the old corporate research lab. The consortium makes it possible for companies that do not have extensive research labs to stay abreast of basic research. The consortium can also conduct several near-term research projects, each for a different client.

If consortia are to be the model for the future, they will have to be improved. They will require better funding, better staffing, and better leadership. Questions of how to transfer research findings from the consortium to the company's manufacturing facility may determine the eventual success or failure of the model. Peter Drucker, writing in *The Wall Street Journal*, suggests that to facilitate technology transfer, each corporate client needs a "technology manager" who can determine business objectives based on the potential of the technology and who defines the necessary technical research. But Dr. Drucker concludes, "No one today . . . knows how to teach technology management, nor indeed, even where to start."

Ray Stata, CEO of Analog Devices and an expert in technology transfer, agrees that managing the complex research structure of the future is a major concern. Mr. Stata believes that corporate research labs will continue to exist, but that they may be located on a university campus as part of the university structure. On the fundamental issue, Dr. Drucker and Mr. Stata agree: "How to manage the new research paradigm is a challenge that we don't understand yet."

Ultimately, technology transfer depends on people from different organizations—industry, universities, and government—working together. This will happen when incentives that make sense replace rhetoric. Japan has proven that technology transfer works when people are committed and rewarded. U.S. scientists, corporate managers, and policy makers have yet to acknowledge that technology transfer is a critical issue and that it can be learned.

Throwing money at technology transfer will not produce results. Technology transfer depends on people. If technology transfer is to occur, incentives for exchanging information must replace rhetoric. When people see sensible reasons for cooperating, they will form the personal contacts that spawn technology transfer and that lead to growth and development.

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Strategic ISSUES

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The Bush Administration: What's in Store for Technology

By John W. Wilson with George Beckerman, Thomas D. Johnson, and Granville (Pete) Smith

The near-landslide victory won by George Bush over his Democratic rival Michael Dukakis owed much to six years of U.S. economic growth and to the expectation that prosperity will continue. But many experts believe that the economic successes of the postrecession Reagan era cannot continue unless pressing and complex issues facing the nation are effectively addressed. These include:

- A federal budget deficit that has averaged about $150 billion for the past seven years and brought the national debt to a staggering $2.6 trillion
- A trade deficit that reached $160 billion in 1987 and is proving difficult to reduce
- A negative international investment position approaching $400 billion, which gives foreign investors increasing control over American financial markets
- Long-simmering problems such as troubled savings and loans institutions, dangerous nuclear fuel plants, and deteriorating airports and bridges—any one of which could require massive federal financial intervention

With a self-confident and solidly Democratic Congress and an array of competing business and other interest groups to contend with, the Bush administration faces vigorous debate on all of these issues. The growing influence of foreign investors and trading partners and loss of leadership in semiconductors and other critical technology fields will add to the intensity of the discussion.

Editor's Note

John W. Wilson
Editor

The administration of President-elect George Bush will take office on January 20, 1989. This new team, although rooted in the Reagan administration, in which Mr. Bush has served as vice president, will bring a fresh approach that could dramatically influence the interdependent business worlds of technology-based companies in the United States and abroad.

To help sort out expectations for the next four years, this edition of *Strategic Issues* outlines the upcoming U.S. public policy environment in three areas that are critical for our readers: science and technology, international trade, and business regulation.

To assist in this project, *Strategic Issues* has called on George Beckerman, Thomas Johnson, and Pete Smith, Ph.D., all with Beckerman Associates in Washington, D.C., and Dataquest consultants. In addition, Joseph W. Duncan, corporate economist for The Dun & Bradstreet Corporation, Dataquest's corporate parent, offers his insights on "Election Results and the Economy" (see Commentary, page 2). In the coming months, *Strategic Issues* will continue to report on critical policy developments for the technology industries in Washington and other capitals around the world.

Commentary

Election Results and the Economy

By Joseph W. Duncan

One of the uncertainties about the U.S. economy in 1989 has been eliminated. We know that the president will be George Bush. But another uncertainty remains: What will be the economic policies of the new administration?

At this early date, there is no clear answer to that question. However, the issues are well known, and the political landscape has some landmarks that provide an indication of the likely initial direction that the Bush administration will take.

What Did the Electorate Say?

There has been considerable discussion about the failure of the campaign to define issues and about the resulting lack of a mandate for specific policies. In terms of economic issues, this perspective is not useful. The voters have high levels of confidence in their personal financial situations, unemployment is low by historical standards, and a long-term economic expansion continues to show strength.

Thus, there is little evidence that the election called for major changes in the economic policy of the Reagan administration. The Democrats had great difficulty gaining support for the view that the economic prosperity of the moment was hollow or that economic disorder was imminent.

The Federal Budget Deficit

Neither candidate addressed the budget issue directly. The "flexible freeze" of President-elect Bush and the idea of "collecting the uncollected taxes of the tax cheats" advanced by Democratic candidate Michael Dukakis were not credible programs for dealing with the $155 billion federal deficit.

Many observers, including this writer, assumed that the National Economic Commission would provide both proposals and an excuse for the new Congress and the new administration to make program cuts and raise revenue to narrow the budget gap. Yet, the first tangible economic action after the election was an announcement by the commission that it could not meet the early deadline of December 21. Washington became alert to the fact that President-elect Bush could delay the report until September 1989—hardly an indication of early action.

It also appears that the Bush administration will take a reactive stance toward the federal budget and fiscal policy, choosing not to participate actively in the construction of the final Reagan budget. Meanwhile, congressional leaders wait for some direction from the president-elect. On the positive side, a groundswell seems to be forming in Washington for a biannual budget process, which has the support of Mr. Bush. This long-term approach forces policymakers to consider fiscal issues more thoroughly than at present, and, depending on timing, forces an incoming administration to participate more actively in the primary stages of the budget process.

The Economic Environment

U.S. economic statistics for 1988 were adversely affected by the drought. Various estimates suggest that about $23 billion was trimmed from the gross national product as a result of poor farm production. Thus, the nonfarm economic growth for the year was particularly impressive. With real (inflation-adjusted) growth approaching 4 percent, many were concerned that the economy was overheating and that inflation was looming on the horizon.

Nevertheless, the new administration will take office with a reasonably strong economy and with little evidence of immediate weakness. In fact, the weak base in agriculture will serve to yield comparative strength in that sector during 1989. I expect GNP to grow about 2.5 percent for the year, which should allow breathing space for the new leadership to work on several key issues. Growth will slow further in 1990 (see Figure 1).

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Commentary (Continued)

Critical Issues for the New President

President-elect Bush is not going to have an easy time setting priorities. Many economic issues will be competing with foreign and social policies for the administration's attention. In addition to the fiscal deficit, the new administration will be faced with several major problems:

- The savings and loan crisis already has generated potential demands of more than $50 billion of federal funding needs. Further losses are being incurred by the system every day, and it is clear that presently funded insurance reserves (or potential reserves from higher industry-paid fees) must be augmented. Quick action is necessary to avoid even greater liabilities.
- The debt problems of the less-developed countries remain. During recent years, the folding of current interest costs into past principal obligations—a process termed restructuring—has increased the pressure on weak economies that are even less able to meet their debt burdens. Required interest payments now consume more than one-quarter of export earnings for many of these countries, making it even more difficult for them to invest in and develop their own resources. Leadership at the world level is required if surplus countries like Japan and West Germany are to help reduce this serious strain on the world trading system.
- The decaying infrastructure of bridges, sewage systems, highways and other key supports for our industrial society will bring demands for federal as well as state and local commitments. The stark challenge is now visible in the nuclear weapons industry, where the plant built shortly after World War II is now a serious safety and pollution risk. Rebuilding the base of our nuclear defense system will demand additional billions at the same time that budget pressures call for reduced spending.
- The wave of leveraged buyouts is adding risk to the business base of the economy. These deals, involving billions of dollars of private capital, assume that prosperity will continue and allow debt service requirements to be met from growing cash flow and the sale of assets. In an economic slowdown, cash flow will fall and asset sales will be difficult, except at fire-sale prices. The risk of bankruptcy will increase, and there will be calls for governmental intervention to save jobs and to avoid further economic decline. The new administration must move swiftly to keep leveraged buyouts from creating long-term problems and to ensure that an economic slowdown does not occur.

The Economic Policy Challenge

Government's traditional tools for dealing with economic slowdowns or recessions are increased government spending and lower taxes or a loose monetary policy. The Bush administration will have little room to expand spending or reduce taxes with the deficit at such high levels. The Federal Reserve system is not going to reduce interest rates or flood the market with dollars, since such an action would most likely weaken the dollar and frighten off foreign investors. Withdrawal of foreign funds would place pressure on capital markets, resulting in higher interest rates, less consumer and business spending, and grave problems for the less-developed countries and highly leveraged U.S. companies.

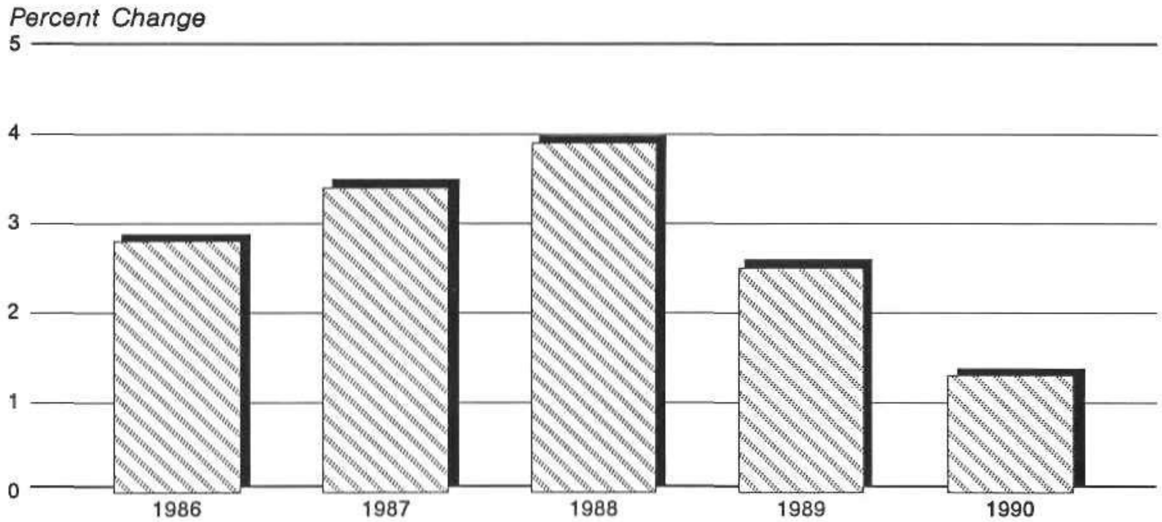
The Bush administration must act swiftly to gain the confidence of the markets, consumers, and business decision makers. In my view, Mr. Bush is likely to bring in a strong team of experienced moderates and to set forth a reasonable economic policy. If this does not happen, many clouds are looming on the horizon for the world economic system.

Dr. Duncan is corporate economist and chief statistician of The Dun & Bradstreet Corporation.

TECHNOLOGY'S NEW ROLE

The search for a new policy direction will consume much of the administration's time and energy during 1989. The debates will be of acute interest to U.S. technology companies and to their competitors around the world. Not only are technology markets increasingly influenced by fiscal and monetary policies and other macroeconomic factors, but governments are playing an increasing role in determining the competitive positions of all technology industries.

Figure 1
U.S. Economic Growth
Inflation-Adjusted GNP Increase



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Source: Dun & Bradstreet

This worldwide trend has found expression even in Ronald Reagan's Washington, despite Mr. Reagan's preference for private market solutions. An emerging consensus throughout government, industry, and academia has escalated the importance of science and technology matters in economic decision making. That George Bush concurs in this consensus was shown during the campaign by his commitment to appoint an assistant to the president for science and technology. The appointee, he said, will have a broad charge to participate widely in White House economic and national security policy initiatives.

Mr. Bush's decision followed the timely release of an influential report by the Council on Competitiveness, chaired by John A. Young, president of Hewlett-Packard Co. The broad-based council has succeeded in building congressional support for giving greater weight to science and technology issues. And the Reagan administration has already moved to create a new position of under secretary of commerce for science and technology, who will be on an equal footing with the under secretaries for economic affairs, international trade, and export administration.

Most controversial of these moves has been the attempt to position the U.S. Department of Defense (DOD) as an active player in general economic policy affairs affecting both defense industries and so-called "dual-use" industries, such as semiconductors, which are important in both defense and commercial markets. Despite Mr. Reagan's reluctance to use government funds to solve industry's problems, the DOD has been given a leading role in the creation of Sematech, the semiconductor manufacturing research consortium. The Defense Science Board, composed of leading defense industry representatives who advise the Pentagon on technology matters, now is urging it to take a leadership position in making American industry more competitive.

CONGRESS FLEXES ITS MUSCLE

The new focus on science and technology will influence and in turn be influenced by developments in trade policy and regulatory matters. In both of these fields, the Bush administration enters a playing field where a fired-up congressional team has taken the ball and is attempting to control the action. In trade policy, the Omnibus Trade and Competitiveness Act that was approved in August requires strong bilateral actions from an administration whose bias is toward multilateral solutions to trade problems. In regulation of everything from federal procurement to acquisitions, Congress will be urging a retreat from the great experiments in deregulation presided over by the Reagan administration.

Although the stage might be set for confrontation, George Bush and his close advisors are known as pragmatists who are capable of negotiation and compromise. Thus, it seems likely that the Bush administration and Congress can work out creative solutions to the policy problems they face. If so, the American government will move past political confrontations that could block progress on many issues crucial to the technology industries.

SCIENCE AND TECHNOLOGY POLICY

Science and technology issues during the Reagan Administration were largely defined by the U.S. defense buildup, which required a substantial investment in military research and development. At the same time, budget constraints and a strong preference for nonintervention in marketplace decisions led to a decline in the share of government R&D spending for civilian purposes (see Figure 2). As the Council on Competitiveness noted, U.S. nondefense R&D has been stagnating at about 1.8 percent of GNP while that of Japan and West Germany has grown to 2.8 and 2.6 percent, respectively, over the past two decades.

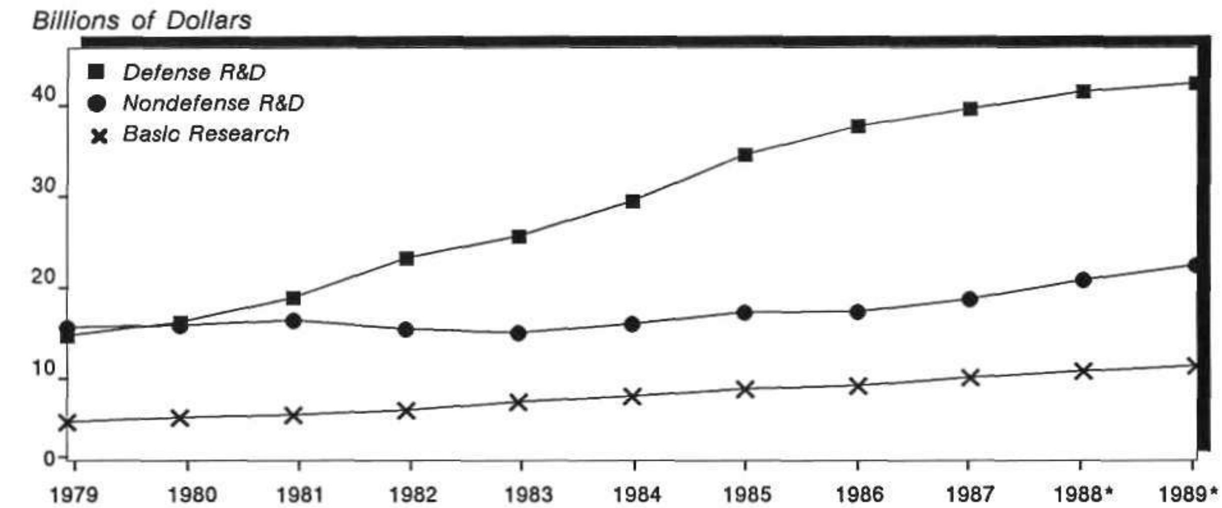
Nondefense R&D funds have been focused primarily on basic research, whereas 90 percent of defense R&D spending goes for development of military systems with little transferability to commercial applications. As a result, the government's role in the commercial development of technology has declined. At the same time, American industry has been losing market share and technology leadership in several critical high-technology fields. This situation has resulted in a growing clamor for increased funding and stronger government leadership in industrial technology.

President-elect Bush, although he clearly shares Ronald Reagan's preference for private-sector solutions to industry's problems, has taken a strong position favoring steps to improve American education and technology. "Technology is America's economic fountain of youth," he said during the campaign. For Mr. Bush, the proper role for government in science and technology is to support basic research. It is up to the private sector, he added, "to decide which technologies will have the most potential in the marketplace."

The Policy Agenda

Congress and the Bush administration will be wrestling with one overriding problem: how to invest wisely in science and technology at a time when budget constraints are tightening. Major trade-offs are likely as Congress and President-elect Bush choose between such big-ticket projects as the $4.5 billion superconducting supercollider, the $15.0 billion to $20.0 billion space station program, and the $3.0 billion human genome mapping project. Broader questions, especially those dealing with the role of government in support of U.S. technology competitiveness, must also be addressed.

Figure 2
Trends in U.S. Government Research and Development



*Estimated

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Source: Office of Management and Budget

A number of new approaches to setting technology policy will be tested in the coming months. Responding to industry recommendations and substantial evidence that American leadership in science and technology is eroding, Mr. Bush has committed to upgrading the science and technology policy function in the White House. He intends to name an assistant to the president for science and technology policy and to create a president's council of science and technology advisors. The council would be composed of "leading scientists, engineers, and distinguished executives from the private sector."

Given the expected charter of the new presidential assistant and the enormous range of science and technology issues that need to be addressed by the new council, President-elect Bush's appointees will have more than a full plate. In addition to presenting the interests of U.S. technology companies in economic policy affairs, the advisor will help fashion a Bush administration position on federal R&D budgets, chart a course for government-industry cooperation in science and technology matters, and focus attention on science and engineering education programs. The selection of an advisor with credibility in both the technical and political communities will be crucial to establishing an orderly process for setting science and technology priorities.

Private Sector Involvement

Contributing to these efforts will be two new committees authorized by Congress in the Omnibus Trade and Competitiveness Act and supported by the White House Office of Science and Technology Policy:

- The National Advisory Committee on Semiconductors, composed of five government officials, four representatives of the semiconductor industry, and four private-sector experts in technology, defense, and economic development
- The National Commission on Superconductivity, whose members will represent government, scientists and engineers, and the private sector

These committees will report to Congress for the purpose of assisting legislators with the formulation of national policies and strategies. This should help improve the agenda-setting efforts of a Congress that has taken a much more assertive position on technology policy in recent years. Dozens of congressional committees are involved in technology-related legislation, and political considerations often outweigh technical merit in decisions on scientific projects.

Another important player in the policy-making process will be Richard Darman, the director-designate of the Office of Management and Budget (OMB). This agency, often the final arbiter on budget priorities, will be deeply involved in a key report required by the new Trade Act on the president's policies and budget proposals on federal research in semiconductors, fiber optics and optical-electronic technologies, superconducting materials, and advanced manufacturing technologies. This report is due in January 1989.

Congressional Foundations

President-elect Bush and his advisors will face a well-informed and action-oriented Congress in January—a Congress that has passed almost a dozen major laws effecting science and technology policy during the past eight years. Although many committees and subcommittees are involved in technology-related legislation, the focal point has often been the senate Committee on Commerce, Science, and Transportation and its Subcommittee on Science, Technology, and Space—both chaired by Democratic Senator Ernest F. Hollings of South Carolina. Hollings' counterpart in the House is Representative Robert A. Roe of New Jersey, chairman of the House Committee on Science, Space, and Technology.

Perhaps the number one concern within these committees is the problem of sorting out conflicting arguments for multi-billion-dollar science projects. Sources on the Hollings committee indicate considerable unhappiness over recent decisions such as the supercollider, which received intensive lobbying support until a siting decision was made. Now there seems to be little backing in Congress for pursuing the supercollider, unless it can be done as a cooperative venture with other nations.

Opening Up the Labs

The Stevenson-Wydler Act of 1980 heads the list of technology-related laws passed this decade and reflects a congressional interest in leveraging the government's science and technology assets for the benefit of the private sector and the economy. It directed the 700 laboratories in the federal government, funded at about $20 billion per year, to disseminate information about the products, processes, and services they have developed. This was Congress' first attack on transferring federal resources and know-how into the private sector and was only partly successful. Lab directors have often been slow to open up their domains, and business in turn has been reluctant to share secrets with government researchers.

The Federal Technology Transfer Act of 1986 enlarged the scope of the Stevenson-Wydler Act to permit government-operated laboratories to collaborate on R&D with universities and the private sector. Under this act, a collaborator can receive title or an exclusive (or partially exclusive) license to any invention resulting from an R&D cooperative agreement. In April 1987, President Reagan pressed the implementation of the act by issuing Executive Order 12591, Facilitating Access to Science and Technology. But the industrial technology centers authorized by Congress under the Stevenson-Wydler Act have not been funded, and the R&D budgets for major nondefense agencies have not been significantly increased.

Further Congressional efforts to improve U.S. technology performance were rolled into the Omnibus Trade and Competitiveness Act. The act changes the name of the National Bureau of Standards to the National Institute of Standards and Technology (NIST) and expands its role as the government's lead laboratory in support of U.S. industrial competitiveness.

Cooperation Is the Name of the Game

Congressional staffers from both houses emphasize that the policy foundations to form beneficial partnerships between the federal and private sectors are already in place and that the new authority given to NIST is viewed by the members as a continuation of this effort. A key senate aide on this legislation noted that "in 1989, cooperation will be the name of the game."

Extensive cooperation may, however, be elusive. Companies often view these programs negatively because the red tape required to collaborate is massive and proprietary research is generally not allowed by the labs. If Sematech is successful, however, the reluctant courtship of the labs and industry may warm up. Congress clearly will be watching the performance of the semiconductor manufacturing research consortium closely as it looks at new proposals for government assistance to such projects as developing a domestic consortium for high-definition television.

Sematech could also be a prototype for the stronger DOD role in commercial technology envisioned in the Defense Science Board recommendations. There is widespread reluctance both in Congress and in civilian agencies to admit Defense to nonmilitary policy matters. And DOD participation might well be a double-edged sword if it subjected the Pentagon to reviews and controls that it now avoids. Still, the Bush administration must find a way to deal with the fact that national security interests are at stake in the lagging competitiveness of American technology.

THE INTERNATIONAL TRADE ENVIRONMENT

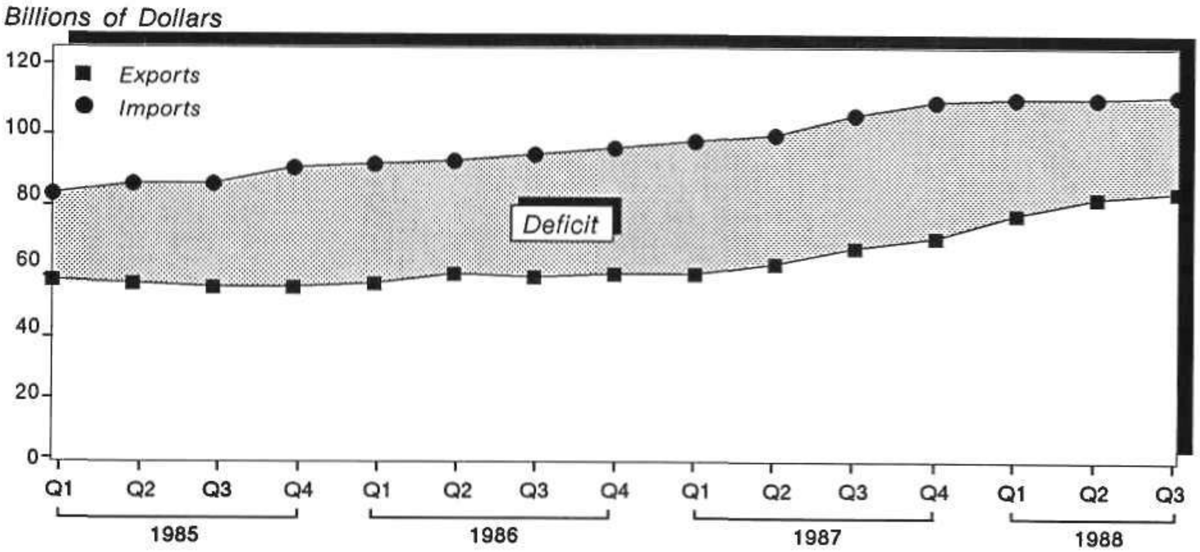
At a recent trade and investment forum, New York Congressman Charles E. Schumer, chairman of the House Budget Subcommittee on Economic and Trade Policy, noted that politics must catch up with the economic interdependencies that characterize key industries around the world. Perhaps he had the needs of U.S. technology companies in mind.

U.S. trade and economic policies during this decade have brought huge rewards to America's trading partners—newly industrializing countries as well as industrialized nations—and extremely troubling trade and current account deficits to the United States. The export performance of American companies has improved, but serious imbalances remain (see Figure 3). Responding to the political pressures created by continuing trade deficits, Congress passed the multifaceted Omnibus Trade and Competitiveness Act of 1988, requiring the president to take aggressive action against countries deemed to practice "unfair" trade. The Reagan administration, abandoning its early hands-off policy, launched an activist trade policy that included winning international support for a lower dollar and stepping up bilateral pressure on selected surplus countries.

Along with the federal budget deficits, trade problems are likely to stay at the top of the policy agenda. In working to correct the imbalances, President-elect Bush and his advisors will focus on broad economic and policy measures. They strongly favor multilateral agreements over bilateral deals as an approach to reducing U.S. deficits while increasing world trade flows. But the Trade Act requires the administration to pay close attention to bilateral problems, and congressional agreement will be critical to developing a new trade agenda.

In this environment, U.S. technology companies may find it easier than in the past to find a sympathetic ear in Washington when they feel they have been injured by unfair trading practices. But they must anticipate policy trade-offs because trade policy will continue to be based on complex issues of domestic economic and fiscal policy, foreign policy, national security concerns, and the often-conflicting demands of suppliers and users of technology products.

Figure 3
U.S. Merchandise Trade Performance



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Source: U.S. Department of Commerce

The Trade Policy Agenda

The president-elect's position on trade suggests that his administration will emphasize increasing U.S. exports to and moderating imports from major trading partners to achieve a balance in merchandise trade while resisting new protectionist measures. Managed by experienced policy players, including Secretary of State-designate James Baker and Treasury Secretary Nicholas Brady, further efforts on these related legislative, diplomatic, and negotiating fronts are certain:

- Implementation of the new Trade and Competitiveness Act
- Reinvigoration of multilateral and multi-issue trade negotiations and of international economic policy coordination on such matters as the debt burdens of less-developed countries
- Preparation for responding to plans of the European Economic Community for achieving a single market by 1992

Senate Finance Committee Chairman Lloyd Bentsen and House Ways and Means Committee Chairman Dan Rostenkowski will play key roles in shaping these policies from Capitol Hill. Both men were instrumental in pushing the huge Trade Act through Congress, and Senator Bentsen has said that the 1988 act "was only a beginning."

Putting the Trade Act to Work

In a decision issued just before election day, departing U.S. Trade Representative Clayton Yeutter denied a petition from politically influential Texas and California rice interests to investigate Japan's exclusion of imported rice from its $35 billion domestic market. Instead, Mr. Yeutter referred this matter to negotiation in a multilateral framework. Although Mr. Yeutter will not stay on as U.S. trade representative (USTR), the decision on rice reflects an important element in both Reagan and Bush trade policy: there will be judicious rather than aggressive application of strong Trade Act provisions for relief from unfair trade practices (and perhaps also for import relief).

Thus, although it may be true that "computer chips are the rice of the technology age," U.S. technology companies should not expect quick results from the Trade Act. The act permits considerable latitude for the administration in implementing its provisions and strongly encourages alternative and multilateral resolution of trade disputes.

Cooperation by Congress and the willingness of key U.S. industries to accept this policy direction will affect how well the administration is able to sustain it. Tom Campbell, a newly elected Republican congressman from the Silicon Valley area in California and a professor at Stanford Law School, warns that Democrats in Congress could use the Trade Act to embarrass a Republican president. "The president is obliged to give reasons if he fails to impose sanctions in the presence of unfair trading practices or the breaching of a trade agreement," Mr. Campbell said. "With a Democratic Congress, Bush could get ripped up."

Trade Act provisions of interest to U.S. technology companies include:

- Unfair trade—The act expands the definition of "unfair" trade practices and calls for mandatory retaliation against violators. Under the act, the United States must crack down on such practices as export targeting and denial of worker rights, although the president retains many options for avoiding retaliation.
- Enemies list—The act requires the USTR to identify countries with large U.S. trade surpluses associated with trade barriers. The USTR would then be expected to initiate investigations and open negotiations with countries on this "enemies list," as some Washington observers call it.
- Government procurement—The act calls for the identification of countries whose government procurement policies discriminate against U.S. companies and requires the president to seek elimination of those policies. It permits a ban on U.S. government purchases from firms in offending countries.
- Telecommunications—The act counters protectionist procurement policies and restrictive import practices affecting U.S. telecommunications equipment companies. The USTR is required to conduct an investigation of foreign telecommunications trade barriers and to seek remedies, preferably through negotiations, although harsher measures are also available.

The Multilateral Approach

The Bush administration will place great stress on multilateral coordination to resolve trade and global economic problems and avoid destructive trade wars. Bush advisors believe that only multilateral agreements can deal with the new interdependencies of the global economy and effectively resolve the overwhelming numbers of trade and related issues that would otherwise drag on in bilateral, single-issue negotiations.

The principal vehicle for international trade coordination is GATT, the 96-member-nation General Agreement on Tariffs and Trade. At the midterm review of the Uruguay round of GATT negotiations, held in Montreal in December, the U.S. agenda included strengthening trade dispute settlement procedures and extending the coverage of GATT in agriculture (the venue for the Japanese rice dispute), services and investment, and intellectual property.

The Trade Act provides the U.S. trade representative with new tools to obtain successful outcomes in this GATT round, which is scheduled to conclude in late 1990. The free trade agreement with Canada, strongly supported in the Canadian election, should also strengthen the U.S. hand in these talks, since it demonstrates that bilateral trade agreements would be an alternative to freer trade on the global level. Aggressive moves to protect U.S. intellectual property, also authorized by the Trade Act, would be another result should the Montreal negotiations fail to accommodate U.S. interests.

The principal vehicle for international economic policy coordination is the Group of Seven (G-7), composed of senior financial and political officials from the United States, Japan, Germany, France, the United Kingdom, Canada, and Italy. G-7 was established in 1986 under the leadership of then-Treasury Secretary Baker with the objective to develop a process for coordinating economic policies.

The Trade Act recognizes the importance of the G-7 process and requires the treasury secretary to submit periodic reports assessing "the impact of exchange rates and international economic policies on the domestic economy." The first report was issued on October 15, 1988. It was well received in Congress and will reinforce the international economic policy coordination direction of the new administration.

It will take time for multilateral and multi-issue coordination to achieve favorable outcomes for specific U.S. industries. Pressure to speed the process comes from many sources, including affected industries demanding relief. It is too early to anticipate how the administration will manage these pressures, but at least initially Mr. Bush can be expected to resist them while he seeks to improve the U.S. trade position through international economic coordination.

The European Single Market

A major test of the Bush administration's trade policies will be Europe's drive to create a single market, "an area without internal frontiers in which the free movement of goods, persons, services, and capital is ensured." In 1987, the population of this area was 244 million people, and the combined GNP of the countries in it was $4.5 trillion. Imports from the United States totaled $61 billion.

The emergence of a unified European economy has long been a foreign policy goal of the United States, but it is now also seen by U.S. policy makers as a potential "Fortress Europe," threatening U.S. trade and economic policy relations. Japan perceives the same threat, and some Europeans share this view. Washington is encouraging U.S. industries to prepare for the opportunities that are expected from the removal of physical, technical, and fiscal barriers to internal trade. The U.S. government is also negotiating with European Community officials to prevent creation of new external barriers and to assure fair treatment of U.S. companies with European operations.

THE BUSINESS REGULATORY ENVIRONMENT

After almost a decade of deregulation, supervised by Vice President Bush, business has come to expect a minimum of government intervention in the free market. The elimination of some regulatory agencies and steep cuts in resources for others have left the impression that the watchdog days are past. Only a few business mergers and acquisitions have been questioned by the Justice Department and Federal Trade Commission, and takeovers have increased rapidly (see Figure 4).

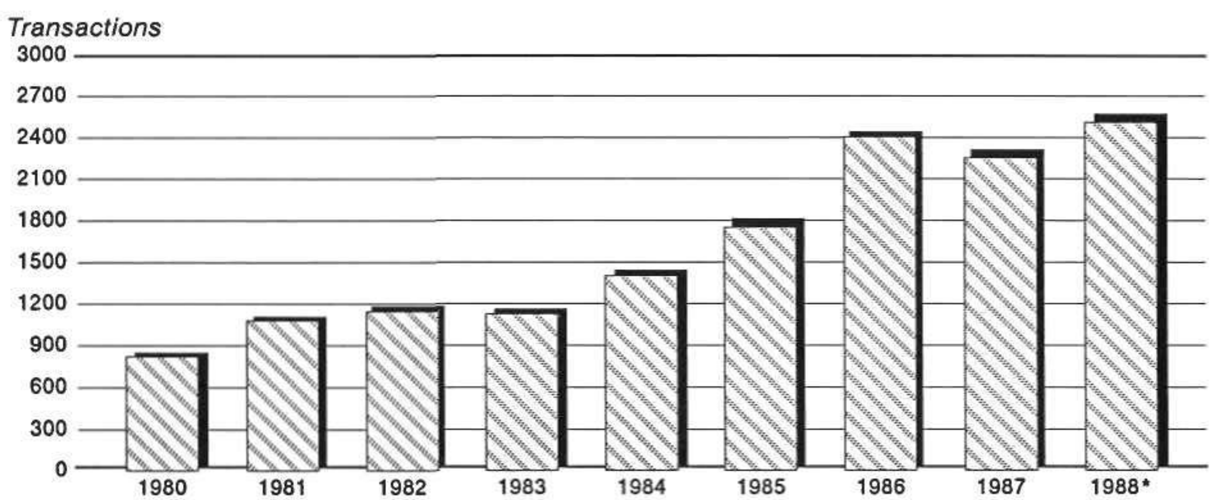
Although Mr. Bush clearly favors minimal government regulation of business, pressures are building for reregulation in several fields important to the technology industries. These pressures stem from such problems as:

- Procurement scandals and a widespread perception of inefficiency and mismanagement in the contracting activities of the Department of Defense and other agencies
- Highly publicized threats to clean air and water supplies, along with global warming and other long-term environmental concerns
- Insider trading and other illegalities that have accompanied the merger and acquisition boom, as well as political opposition to foreign investment in the United States
- Health care cost increases that continue to outrun inflation at a time when budget restrictions are tightening

The stage for resolution of these regulatory issues was set during the Reagan years. Despite its early emphasis on deregulation, the Reagan administration has initiated responses to many of these problems. Now, in most cases, it will be up to the Bush administration to implement reforms.

Except in the area of defense procurement regulations, the Office of Management and Budget (OMB) strongly influenced the deregulation movement, both through its control of the spending cycle and its implementation of the 1980 Paperwork Reduction Act. OMB is now preparing a proposed revision of the executive order that initiated deregulation, updating it and perhaps extending its reach to new areas. Under Mr. Darman, OMB can be expected to continue its leading role in the deregulation effort.

Figure 4
Business Combinations in the United States



Note: Transactions valued at $15+ million
**Estimated*

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Source: U.S. Federal Trade Commission

The Bush administration inherits a tangle of government procurement problems and a host of proposals for solving them. No fewer than 40 new bills addressing the issue were introduced in the last session of Congress. Many of these bills, which are likely to be reintroduced, presume that the problems are caused and perpetuated by industry and would place further, expensive burdens on contractors.

The Reagan administration responded to criticism of DOD procurement practices by creating the President's Blue-Ribbon Commission on Defense Management (known as the Packard Commission for its chairman, Hewlett-Packard founder David Packard). Some recommendations of the Packard Commission's far-reaching 1986 report are in the process of being implemented. The Pentagon's "procurement czar," a post now held by Dr. Robert Costello, fulfills one recommendation: to introduce unity to management of the competing weapons systems and production of the military services. Other recommendations that could strengthen the defense industrial base and benefit technology-based industries remain to be addressed during the Bush administration. These include:

- Making multiyear commitments to approval and funding of long-range programs
- Using commercially available products and components in lieu of custom specifications
- Sharing government rights to proprietary technical drawings and data
- Reducing regulations by as much as 40 percent

Solutions in these areas, especially multiyear funds, have previously been rejected by a Congress that is motivated to keep short reins on programs. It is highly likely that these and other related matters, such as reimbursement for independent research and development costs, will be vigorously debated, as new efforts are made to restrain growth in the defense budget.

"There will be a defense procurement reform effort, which will have the Packard Commission report as its philosophic blueprint," said Bob Bedell, former head of the Office of Federal Procurement Policy. Mr. Bedell, now an attorney in private practice, believes that the Bush team will make steady progress to complete the commission's recommendations. But he adds that "selection of people is critical—people who believe in the reform philosophy."

The Environment

After years of enjoying a "clean" image, the electronics-based manufacturing industries are among those being studied as sources of groundwater pollution and toxic air emissions. The use of solvents, etching compounds, arsenides, and other potentially damaging materials makes the industry subject to the problems and pressures of environmental regulations and responsibilities.

Recent environmental initiatives have come not from the administration, but from Congress. Air and water pollution are close-to-home issues and bring quick congressional reaction. Recognizing the strong public interest in these issues, Mr. Bush frequently voiced his concern for the environment during the campaign, advocating three key principles:

- Better coordination among environmental, energy, and agricultural policies
- Harnessing technological innovation and incentives to work for improved air and water quality
- Strong cooperation between the public and private sectors to protect national resources

Mr. Bush has already met with key environmentalists, who presented a set of 700 recommendations for national action. The group emerged from the meeting with high spirits, encouraged by Mr. Bush's measured interest and his willingness to discuss environmental concerns. Larry Buc, a vice president for ICF, a Washington-based environmental policy analysis firm, expects Congress to emphasize waste minimization, perhaps including requirements for reducing solid and hazardous waste products by a flat figure, perhaps 25 percent. The best way for companies to prepare for the future, Mr. Buc says, is to start inventorying and analyzing their own waste outputs, as well as lobbying to impact legislative efforts for new regulations.

The Antitrust Agenda

With the reduction of regulatory activity in the Reagan administration has come minimal antitrust enforcement. Mergers and acquisitions have proceeded at a rapid pace, fueled by a huge increase in corporate debt. The Federal Trade Commission staff has been cut dramatically and has insufficient resources to do much more than monitor current activity. The Antitrust Division of Justice focuses on only the most important targets—illegal price fixing, bid rigging, and criminal conspiracies—according to Assistant Attorney General Charles Rule. Last year, only a few dozen mergers were challenged by the two agencies.

Robert Pitofsky, dean of Georgetown University School of Law and a former FTC commissioner, feels sure that the pendulum will swing back under the new team. How far depends on whom Mr. Bush appoints to the critical posts and the resources committed to staff the effort. Richard Thornburgh, reappointed to the post of attorney general, is said to be a manager and a moderate. Budget constraints will limit increased antitrust efforts, but ideological stands against federal intervention may give way to reasoned action to establish orderly controls if they become necessary.

Employer/Employee Issues

Congress will move strongly in 1989 on measures that could add substantially to business costs for American-based companies. A bill increasing the minimum wage did not finish its journey through Congress before adjournment in 1988, but such a measure will be introduced early in the next session. Expectations are that the increase, if approved, will move the minimum wage to $4.55 per hour. Inflationary effects on U.S. technology industries at this time are thought to be minimal.

Another employee-related bill could have significant cost and benefit impacts on industry and its workers. Mandatory, minimum care health insurance initiatives are being aggressively pursued at both state and federal levels. Democratic proposals, expected to be introduced early in the next Congress, may include elimination of the $48,000 cap on the Medicare part of the Social Security payroll tax: 1.45 percent of salary from both the employer and the higher-salaried employee.

In contrast, Mr. Bush's policy appears to focus on covering the costs of long-term care for the elderly and disabled rather than current medical and health coverage. His approach leaves the cost charged to the employee's side of the ledger. Congress is likely to be aggressive in putting the tab on the corporate world and highly paid professionals. The likeliest outcome of any negotiations on this issue would probably be a larger burden for both employers and employees.

THE FINAL WORD—FOR NOW

The primary economic goal for the Bush administration is to sustain and broaden the economic growth that characterized the last six years of the Reagan administration while dealing effectively with the huge deficits that threaten U.S. and international prosperity.

To accomplish this, Mr. Bush's plan for his first 100 days in office will focus on the federal budget deficit. Cutting the budget deficit should have a favorable impact on both economic growth and the trade deficit as interest rates decline, consumption of imports moderates, and favorable economic activity, including export growth, continues. But deficit reduction will also increase the funding squeeze for many programs, including those important to the technology industries.

Trade and international economic coordination policy will continue on the course established in the Reagan administration. The preference for deregulation of business will continue, although pressing issues will require new regulations. Science and technology policy and related investments will be significantly affected by the overall economic program of the Bush administration, including deficit reduction and improved international competitiveness of U.S. industry. More explicit policies and strategies will emerge as the new mechanisms for technology policy development begin to operate.

The actions of Congress, affected industries and other interest groups pursuing remedies under the Omnibus Trade and Competitiveness Act, and foreign business and governmental interests will be critical to the design and execution of these policy directions. The president-elect's early pledges of cooperation with Congress and commitment to international coordination have been well received. However, the outcomes of debates on fiscal policy, as well as trade, industry regulation, and science and technology matters, are far from certain.

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Strategic ISSUES

January 1989

U.S. Semiconductors: How to Stop the Slide

By John W. Wilson and Michael Boss

Once again American technology is in the news, and once again the news is bad. Press headlines recently reflect broad national concern about the fate of a critical industry: "Battle for the Future," suggested *Time*; "A High-Tech Lead in Danger," warned *The New York Times*; "U.S. Fights for Its High-Tech Life," blared *The San Francisco Examiner*.

The situation is indeed serious—but not yet desperate. Based on market share trends in electronic equipment, semiconductors, and semiconductor equipment and materials, the U.S. technology industry is clearly in a state of decline. To some extent, the American decline represents the inevitable outcome of historic patterns of industrial development: Rapid growth in Japan and then in Asia has enlarged the world market for technology-related products while reducing U.S. and European shares of that market. But the decline is becoming self-perpetuating. That is, the loss of market position among American makers of end equipment is hurting semiconductor device makers; their pain in turn damages American makers of semiconductor process equipment and materials; and loss of competitiveness at the process and device level is threatening U.S. competitiveness in end equipment.

On the other hand, it is much too early to be writing obituaries on American technology. And in some ways the strategic problems facing Japanese, European, and Asian companies are just as serious as those confronting the Americans. This newsletter sums up Dataquest's analysis of this situation, with special attention to the semiconductor industry and the materials and equipment industries that serve it, and our suggestions for bolstering American competitiveness. While Dataquest is an American company, we serve many clients in the technology industries of Japan, Europe, and Asia. In advocating steps to shore up the American position, we believe that we are serving the best interests of all our clients. We make three critical assumptions:

- The decline of the American industry has been caused by trends and events that are global in scope and include economic and trade policies, capital formation and industry structures, management and accounting strategies, and the actions of individuals. Any solution must involve participation at the government, industry, and firm level—both in the United States and in its major trading partners, especially Japan.
- The decline in U.S. competitiveness is an issue of concern to Japan and other trading partners. The United States has been the primary source of semiconductor and computer-related innovation since the beginnings of the industry. Further competitive erosion could dry up that innovation and threaten increased government/military interference in the market. It also threatens to damage trade and political relations on a broad range of issues.
- The health of the semiconductor and related industries is a factor of growing importance in U.S. electronics equipment leadership. At the same time, the fate of the U.S. semiconductor industry cannot be separated from U.S. success in equipment markets ranging from data processing and telecommunications to consumer electronics. Any solution must involve recognition of this interdependence and actions to strengthen it.

John W. Wilson is vice president for business and technology analysis at Dataquest and editor of Strategic Issues. *Michael Boss is an industry analyst in Dataquest's Semiconductor Industry Service and editor of* IC USA.

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Commentary

The Erosion of a Keystone Industry

By Joe Grenier

World leadership in electronics requires leadership not only in semiconductor devices but also in the equipment used to manufacture those devices. It is process technology that drives semiconductor manufacturing, which in turn provides the device performance and cost advantages that result in superior electronics equipment. Thus, leadership in the relatively small $4.2 billion wafer fabrication equipment market is the gateway to leadership in the $53 billion (merchant and captive) semiconductor market and ultimately the $674 billion worldwide electronic equipment market.

The United States has long held the reins of the world semiconductor wafer fabrication equipment market. But just as U.S. leadership in semiconductor devices has slipped away, so too has the U.S. role diminished in the strategically important wafer fab equipment market. In the last five years, U.S. companies have seen their share of the world market decline from 62 percent to 45 percent. At the same time, Japanese companies, which held only a 29 percent share of the world market in 1982, increased their share to 44 percent in 1987, or essentially the same as U.S. companies. Preliminary indications are that the Japanese moved ahead of their U.S. rivals in 1988.

The increasing strength of the Japanese manufacturers of wafer fab equipment is led by their growing dominance of their own home market. In 1982, Japanese suppliers provided 67 percent and U.S. companies provided 31 percent of the Japanese equipment market. By 1987, Japanese suppliers had increased their share to 83 percent, while the U.S. companies' share fell to 14 percent. Japanese companies are also increasing their penetration of fab equipment markets in the United States, Europe, and Asia.

When we look at key segments of the overall wafer fabrication equipment market, the situation becomes even more alarming for U.S. vendors. Many experts agree that lithography equipment, especially advanced wafer steppers, is the key to the submicron era in device geometries. Next-generation devices cannot be built without next-generation steppers. But stepper technology, which was invented and dominated by U.S. companies, is being lost to Japanese companies. In 1988, Japanese stepper manufacturers provided 70 percent of the world stepper market, while United States-manufactured equipment had only a 23 percent share. In other equipment segments, the situation is similar if not quite so bleak as in steppers. A recent report published by the Defense Science Board concluded that the United States has lost its leadership position in 7 of the 14 critical areas necessary for a viable semiconductor manufacturing industry.

Sematech, the research consortium aimed at improving semiconductor manufacturing technology, should help to regain at least some of the vanquished U.S. leadership. Otherwise, there is nothing on the horizon to reverse the trends discussed above, and even the effects of Sematech may not be felt for some time. The Japanese wafer fab equipment industry, meanwhile, is getting stronger and more international.

The result is likely to be a severe shakeout as the effects of competition begin to take their toll on marginal equipment companies. Certainly, strong U.S. equipment companies are emerging from the industry upheaval, but the question remains: Will they collectively be able to carry the United States forward in the race for leadership in advanced manufacturing equipment, and, hence, leadership in the world electronics market?

Joe Grenier is senior industry analyst in Dataquest's Semiconductor Equipment and Materials Service.

MEASURING THE DECLINE

The deteriorating U.S. position in semiconductors can be measured fairly precisely both in terms of declining or stagnant regional market penetration and of eroding competitiveness in individual product segments. With less precision but with considerable anecdotal evidence, it can be shown that the U.S. position is also at risk in semiconductor capital spending, in manufacturing

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efficiency, and in the equipment and materials that are the cornerstone of semiconductor process technology. Furthermore, the loss of market position is in danger of becoming a "death spiral" in which lower sales and profits damage the industry's ability to make the investments required to recover, leading to further declines.

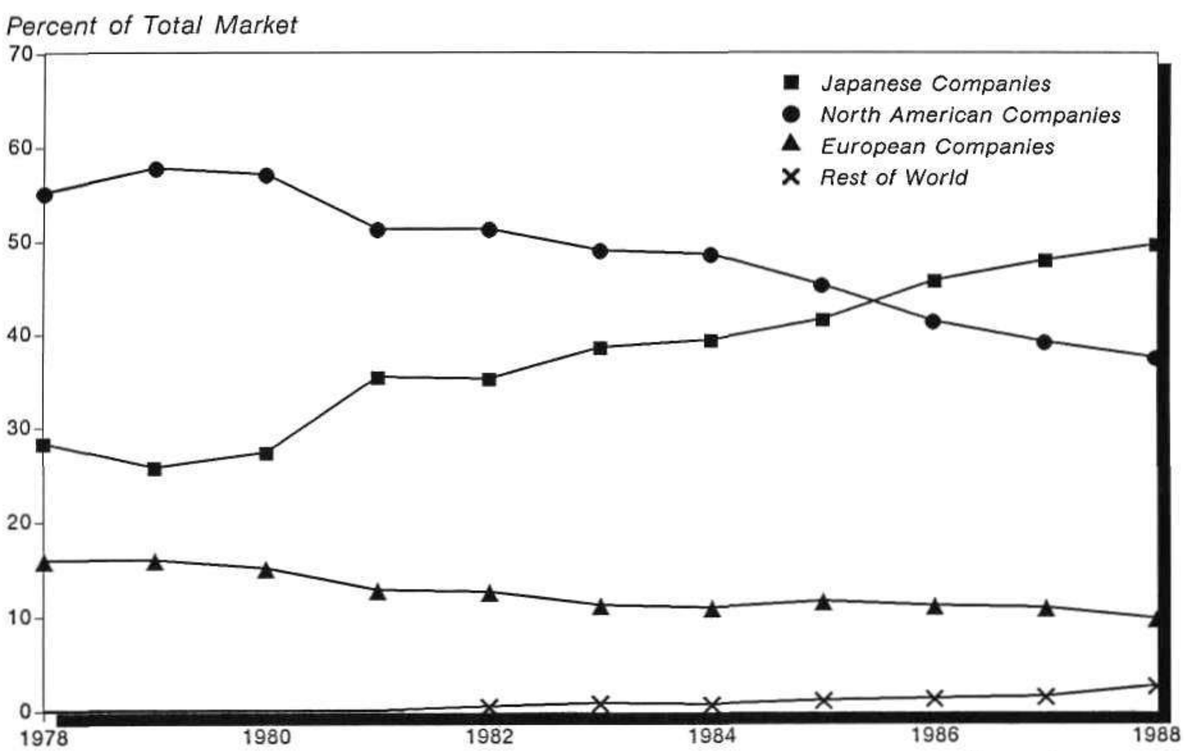
Losing on All Fronts

Dataquest's preliminary 1988 semiconductor market share survey indicates that Japanese and Asian producers gained sharply on virtually all fronts while U.S. and European companies continued a decline that has persisted through most of the decade. As shown in Figure 1, Japanese vendors took half of the $50 billion world market last year, while the U.S. share declined to 37 percent and that of European companies dropped to 10 percent. This reverses the standings in 1983, when U.S. companies held 49.1 percent of the world market and the Japanese only 38.7 percent (see Figure 2).

A similar pattern of Japanese strength and American weakness is evident in semiconductor trade statistics. While U.S. exports of semiconductor products grew by about 30 percent in 1988, imports were up some 40 percent and the trade deficit grew to nearly $3 billion. The gap was largest with Japan, which imported only an estimated $325 million worth of U.S. chips, according to Department of Commerce statistics, while increasing exports 70 percent to $2.2 billion (see Figure 3).

The unusual situation in dynamic random access memories (DRAMs) accounted for much—but by no means all—of the gains in Japanese market share and exports last year. Shipments of memory devices using the metal-oxide semiconductor (MOS) process, of which DRAMs account for more than half, grew 91.1 percent in 1988 as prices stayed well above their expected levels. Japanese producers held 64 percent of that market and U.S. companies only 25 percent. But United States-based producers lost market share in all but one of the five primary semiconductor market segments last year (see Table 1), suggesting that the problem is much broader than a DRAM issue.

Figure 1
Worldwide Semiconductor Market Shares by Market Base



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Source: Dataquest
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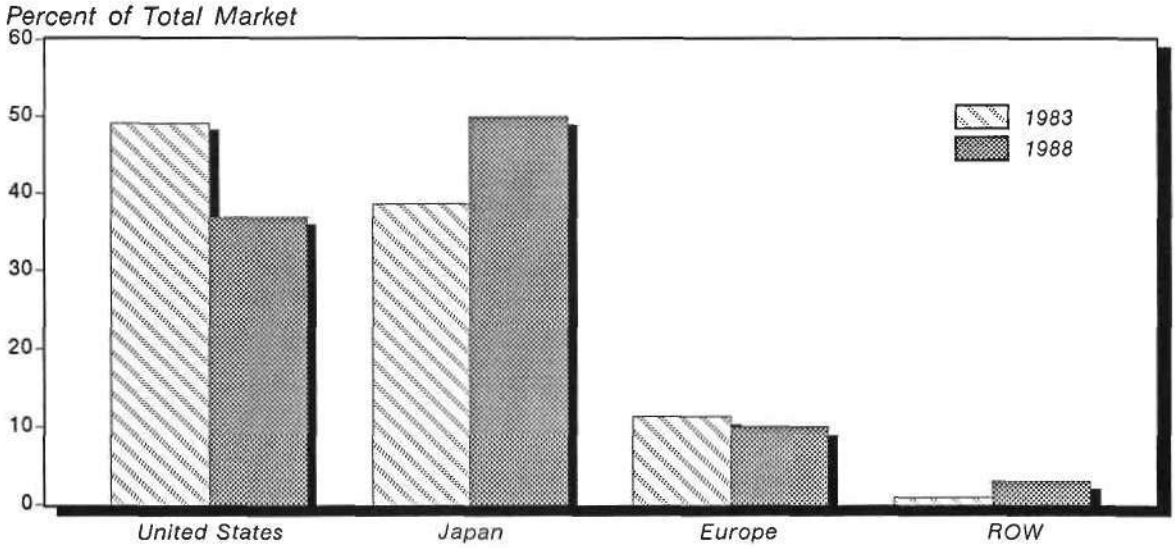
Figure 2
Regional Shifts in Market Share



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Source: Dataquest
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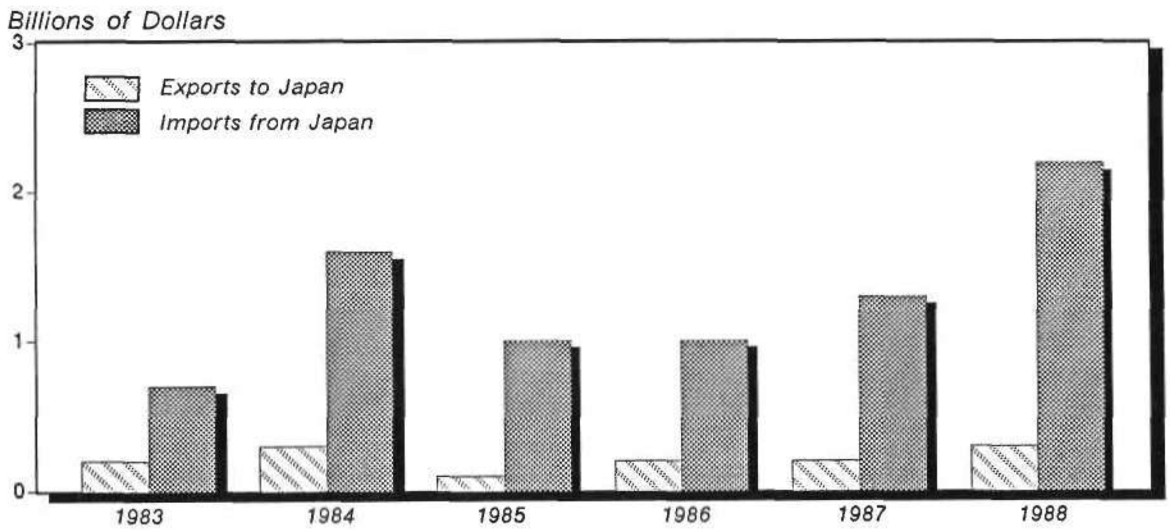
Figure 3
U.S. Semiconductor Trade with Japan



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Source: Department of Commerce
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Table 1

World Market Share of
Semiconductor Product Segments

Company Base	Bipolar Digital 1987	Bipolar Digital 1988	MOS Digital 1987	MOS Digital 1988	Analog 1987	Analog 1988	Discrete 1987	Discrete 1988	Opto-electronic 1987	Opto-electronic 1988
United States	55%	54%	40%	37%	40%	40%	31%	29%	23%	17%
Japan	33%	33%	51%	52%	45%	45%	51%	53%	64%	71%
Europe	12%	12%	7%	6%	14%	13%	17%	17%	13%	12%
ROW	0	1%	2%	4%	1%	2%	1%	1%	0	0

Source: Dataquest
January 1989

Changing World Markets

The crisis in U.S. semiconductors has been caused in part by the declining role of the United States in the production of electronic equipment. According to estimates of Dataquest's Semiconductor User and Applications Group, North American production of electronic equipment accounted for almost 46 percent of world output as recently as 1986, but stands at only 40 percent this year (see Table 2). Although the numbers vary slightly, these troubling statistics were confirmed recently by the American Electronics Association (AEA), which used data compiled by the Electronic Industries Association of Japan to conclude that the U.S. share of world electronic production fell from 50.4 percent in 1984 to 39.7 percent in 1987.

The decline of U.S. market share in equipment almost exactly parallels the drop in U.S. semiconductor market share, and the two trends are obviously connected. But this does not tell the whole story. Not only are its domestic customers becoming a smaller factor in world markets, but the U.S. semiconductor industry also is losing market share with those same customers. At the same time, it is failing to significantly increase its penetration of the equipment markets that have experienced the fastest growth—those of Japan and Asia.

While political pressure and industry attention are focused largely on U.S. efforts to increase semiconductor sales in Japan, Dataquest's analysis indicates that the key area for concern is Asia. The Rest of World (ROW) category, largely comprising Korea, Taiwan, and other industrializing economies of Asia, grew from 12.6 percent of electronic production in 1986 to 17.5 percent in 1988. During the same period, U.S. semiconductor companies saw their share of this fast-growing regional market increase slightly to 33 percent, still well behind Japan's 44 percent share. U.S. vendors did manage to hold onto their 44 percent share of the European semiconductor market in 1988, but Asian and Japanese competitors grew rapidly in that market at the expense of European companies.

These regional trends in equipment production are an important key to any effort by U.S. semiconductor producers to halt their decline in world market share. In particular, the ability of American companies to increase market penetration in Asia may spell the difference between success and failure in this effort. Over the next four years, while growth slows or declines in North America, Europe, and Japan, Asia's production of electronic equipment will almost double. By 1992, Asia will surpass both Europe and Japan in output of data processing and consumer electronics equipment and account for 21.9 percent of all electronics equipment production. It is here that the battle for world market leadership will be won or lost.

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Table 2

Electronic Equipment Production and Market Share

	1986 Production ($ Billion)	1986 Worldwide Market Share	1987 Production ($ Billion)	1987 Worldwide Market Share
North America	$231	45.5%	$250	42.7%
Europe	113	22.2%	124	21.2%
Japan	100	19.7%	117	20.0%
Rest of World	64	12.6%	94	16.1%
Total	$508		$585	

	1988 Production ($ Billion)	1988 Worldwide Market Share	1989 Production ($ Billion)	1989 Worldwide Market Share
North America	$271	40.2%	$292	39.9%
Europe	138	20.5%	149	20.4%
Japan	147	21.8%	153	20.9%
Rest of World	118	17.5%	137	18.7%
Total	$674		$731	

	1990 Production ($ Billion)	1990 Worldwide Market Share	1991 Production ($ Billion)	1991 Worldwide Market Share
North America	$314	40.1%	$339	39.8%
Europe	160	20.4%	173	20.3%
Japan	157	20.1%	167	19.6%
Rest of World	152	19.4%	172	20.2%
Total	$783		$851	

	1992 Production ($ Billion)	1992 Worldwide Market Share
North America	$361	38.5%
Europe	186	19.9%
Japan	185	19.7%
Rest of World	205	21.9%
Total	$937	

Source: Dataquest
January 1989

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Commentary

Is Silicon a Strategic Material?

By Peggy Marie Wood

As 1988 drew to a close, two announcements were made that will fundamentally reshape the merchant silicon wafer industry in the 1990s. On November 9, Monsanto Co. announced that it had signed a letter of intent to sell its Monsanto Electronic Materials Co. (MEMC) subsidiary to Huels AG of West Germany. Less than four weeks later, Osaka Titanium Company Ltd. (OTC) of Japan announced that it was negotiating to purchase the semiconductor materials division of Cincinnati Milacron, one of the largest suppliers of epitaxial wafers in the United States.

The Monsanto acquisition would place the last major U.S. silicon wafer company under European ownership, while the Cincinnati Milacron deal would represent the latest in a series of U.S. silicon acquisitions by Japanese interests. If these proposed acquisitions go through, the U.S.-owned silicon supplier base will be reduced to an inconsequential position in the world merchant silicon wafer industry (see Table 3).

Based on 1987 market data, the sale of MEMC would cut the world market share of U.S.-owned silicon companies from 14 percent to 4 percent. The divestiture by Cincinnati Milacron would further reduce this percentage to a mere 2 percent. The impact on market share in the United States is particularly significant. The share of U.S.-owned merchant silicon companies in their home market will drop from 45 percent to 8 percent if both acquisitions are approved. This is in contrast with the early 1970s, when virtually all the silicon used by U.S. semiconductor companies came from U.S.-owned suppliers.

A handful of niche-oriented merchant wafer suppliers will still remain under U.S. ownership if the Monsanto and Cincinnati Milacron acquisitions are approved. In addition, four U.S. semiconductor manufacturers—AT&T, IBM, Motorola, and Texas Instruments—have captive silicon operations, typically maintained for manufacturing wafers with custom specifications as well as providing familiarity with silicon technology. However, no captive semiconductor producer relies solely on internal production to meet all its silicon requirements.

Table 3

Shifts in Market Share of Merchant Silicon and Epitaxial Wafer Companies

	1987 Actual Share	With Monsanto Acquisition	With Cincinnati Milacron Acquisition
World Market Share			
Japanese Companies	70%	70%	72%
European Companies	16%	26%	26%
U.S. Companies	14%	4%	2%
U.S. Market Share			
Japanese Companies	32%	32%	40%
European Companies	23%	52%	52%
U.S. Companies	45%	16%	8%

Source: Dataquest January 1989

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Commentary (Continued)

Because Monsanto is a publicly traded company, it has disclosed the poor financial performance of its silicon operations back to the early 1980s. But the company has not been alone in its financial problems. Several factors are significantly influencing the profitability of many silicon wafer companies around the world. Most important, silicon consumption (in square inches) is growing far more slowly than the growth of semiconductor device revenue would suggest. As device manufacturers improve yields and as high-priced devices become a larger part of the product mix, less silicon is required. At the same time, competition is becoming more intense as several new silicon companies enter the marketplace. Finally, cost-conscious semiconductor manufacturers have applied strong downward pricing pressure on wafers.

Only in 1988 did silicon wafer producers return to profitability as long-awaited price increases went into effect. It is not clear, however, if wafer pricing stability is strong enough to survive the industry slowdown expected during 1989 and 1990 or if merchant silicon companies will once again have to buckle under to demands for lower prices.

With the announcement of the proposed Monsanto acquisition, many industry watchers and participants are bemoaning the potential demise of the domestically owned merchant silicon supplier base in the United States, and with it, access to a key electronic technology. Some have suggested that silicon should be considered a strategic material and that the U.S. government should block the sale to Huels to keep MEMC in domestic hands. The federal interagency Committee on Foreign Investment was expected to present a recommendation to the president on that issue in mid-January.

[Editor's note: It was recently announced that the Committee will recommend to President Bush that the sale of Monsanto not be blocked.]

Dataquest believes that there are several key issues of concern. If the United States loses all control over the production of merchant silicon wafers, will its semiconductor manufacturers be at a disadvantage in the development of next-generation integrated circuits? Will silicon operations under foreign ownership be fully responsive to the needs of U.S. semiconductor manufacturers? Will Sematech, the research consortium intended to revitalize U.S. semiconductor manufacturing, end up buying wafer material and technology from foreign sources?

In the end, only the customers—the semiconductor and end equipment manufacturers for whom silicon is a raw material—can answer those questions. If U.S. electronics companies succeed in convincing their government that silicon indeed is a critical material that must stay in domestic hands, they will have to bear some of the costs of keeping these operations viable—through higher prices or shared research costs. Without that kind of help, it is doubtful that any standalone U.S. commercial venture in silicon can survive.

Clearly, other countries have already decided that silicon is a crucial strategic material. Most of the new entrants in the merchant silicon wafer market over the last several years have come from outside the United States—notably from Japan, Europe, and the Pacific Rim. In these countries, the short-term rigors of the silicon wafer market are endured as part of a long-term strategy for survival in the electronics industry.

Peggy Marie Wood, Ph.D., is an industry analyst in Dataquest's Semiconductor Equipment and Materials Service.

The Product Picture

The other essential for recapturing market share in semiconductors is to strengthen the U.S. position in the fastest-growing product segments. Here again, recent developments are not encouraging. Sales of bipolar digital integrated circuits, the only major category in which U.S. companies hold a commanding position, are expected to grow at an annual rate of only 8.8 percent between 1988 and 1993. Meanwhile, the MOS segment of the market, which increasingly is dominated by Japanese companies, will grow at nearly a 15 percent rate. Obviously, increased

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market share for U.S. companies requires far greater success in the MOS segment. Four other segments with strong growth potential—analog, application-specific, and gallium arsenide integrated circuits, and microcomponents—merit closer examination:

- *Analog ICs.* While fast-growing niche areas such as "smart power" devices helped U.S. companies to grow slightly faster than than their Japanese and European competitors in 1988, this trend may be short-lived. Analysts in Dataquest's Semiconductor Industry Service point out that the consumer equipment market accounts for more and more of analog device sales, and that United States-based equipment companies now are all but out of that market. American semiconductor companies have been notably unsuccessful in selling to Japanese consumer electronics makers. In addition, Japanese companies that had stayed away from standard analog products now are coming into this market and are well-positioned to succeed.
- *ASICs.* Although still relatively small, the ASIC market is expected to grow at a rate of nearly 18 percent through 1992, when it should reach sales of $13.5 billion. Application-specific devices are no longer a U.S. stronghold. A scant five years ago, only one Japanese company ranked among the top five suppliers worldwide. Today, the top three positions are held by Japanese semiconductor companies (see Table 4). Granted, the Japanese strength is due in large measure to the size of internal sales—markets that often are not open to outside competitors but are included in Dataquest's market estimates. But this vertical integration, as in other product segments, is propelling Japanese companies into merchant market dominance.
- *Gallium arsenide ICs.* U.S dominance of the $100 million merchant market for digital GaAs devices is due in part to the importance of supercomputer applications for this technology. Dataquest believes that the requirements of Cray Research alone made up 25 percent of the market in 1988. On the other hand, Japanese companies and universities are investing heavily in GaAs and other III-V compound semiconductors. And future growth in the GaAs market is likely to be spurred by high-definition TV(HDTV), a technology where Japanese and European companies have taken a commanding lead.
- *Microcomponents.* Although the high-end microcomponent segments such as 32-bit microprocessors, advanced microcontrollers, and digital signal processing chips are dominated by U.S. companies, the lower end of this $7.4 billion market has been claimed by Japan. Now there are signs that Japanese companies are migrating toward the higher end of the microcomponent spectrum. For example, the 8-bit microcontroller market, now dominated by the United States, will move to Japanese suppliers because of their CMOS expertise and their ability to develop a broad portfolio of specialized products. Japanese companies have also been much more active in the development of 32-bit microprocessors than they were in 16-bit microprocessors, in part because they have been unsuccessful in obtaining multisource licensing from 32-bit MPU suppliers in the United States.

Table 4

Top Five Worldwide ASIC Suppliers
1983 versus 1988
(Millions of Dollars)

1983 Ranking	1983 Company	1983 Revenue	1988 Ranking	1988 Company	1988 Revenue
1	Fujitsu	$101	1	Fujitsu	$442
2	AT&T Technologies	$ 82	2	NEC	$432
3	MMI/AMD	$ 65	3	Toshiba	$360
4	Philips-Signetics	$ 43	4	LSI Logic	$343
5	Ferrani	$ 35	5	AMD	$330

Source: Dataquest
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The U.S.-Japanese Conundrum

In terms of political impact alone, one market penetration issue overshadows all others: The Japanese share of American markets now is twice the American participation in Japan's markets, and the gap is growing. Strong demand and higher prices for DRAMs last year propelled Japanese companies to a record 20 percent share of the U.S. semiconductor market, up from 15 percent in 1987. Meanwhile, with a concerted effort to step up investments in Japan and aided by the steep rise in the value of the yen, U.S. vendors managed to improve their penetration of the Japanese market from 8.3 percent to 10.0 percent. This was the first gain in Japan for American companies since 1984, but it leaves the U.S. Semiconductor Industry Association (SIA) far short of its goal of achieving a 20 percent share for foreign participants in the Japanese market by 1991.

Because the United States insists that Japan is not making sufficient progress on its commitment to expand foreign access under the U.S.-Japan Semiconductor Trade Arrangement of 1986, a portion of the trade sanctions imposed for non-compliance are still in place. Thus, failure to win improvement in Japanese market share has the double disadvantage of limiting sales and earnings gains for beleaguered American companies while also exacerbating a major source of trade friction between two countries and industries that are increasingly interdependent.

JAPAN'S DILEMMA

It is not only the U.S. semiconductor industry that faces a strategic dilemma. Since 1986, the Japanese market has been the largest consumer of semiconductor components in the world. Now, however, Dataquest's equipment forecasts indicate that the Japanese share of worldwide semiconductor consumption has peaked—and since we expect that the correlation between Japanese consumption and the world market share of Japanese companies will continue, it follows that the Japanese market share has peaked as well. While this may be a temporary phenomenon, important developments in end-use related markets are running against Japan:

- Japan will face increasing competition in equipment production from the Asia-Pacific region and Europe in the wake of 1992.
- The rising value of the yen is causing end-use production to move offshore from Japan.
- Many consumer electronic products that have been large consumers of Japanese semiconductors, such as VCRs, are entering a mature phase of their product development life cycle, while replacement products such as HDTV are not yet ready to go to market.

Meanwhile, Japan's share of the worldwide installed base of semiconductor manufacturing capacity has grown steadily over the years, and it will continue to increase. In 1988, capital spending in Japan was approximately 1.4 times that of spending in the United States, as measured in dollars. If this trend in capital spending continues, as our capital spending forecast indicates it will, then Japan's share of world manufacturing capacity will grow from 44 percent in 1988 to 48 percent in 1992.

Given the possibility of limited growth in domestic consumption, what will Japan do with this added production capability? The obvious answer is to attempt to increase market share in other world regions. This may, however, be more difficult than it has been in the past, given rising political resistance to further inroads in the United States and Europe, the emergence of strong competition in Asia, and limits to the patience of Japanese investors with the losses piled up in the name of long-term objectives. Nevertheless, Japan's possession of a very large share of production capacity and some of the world's best manufacturing science to operate this capacity make it highly unlikely that Japan will lose market share in the very near future. As a result, the stage could be set for a stalemate in which neither the Japanese nor the Americans are able to alter their competitive alignment.

MARKET SHARE: WHY IT MATTERS

The battle for market share is more than a struggle to carve a bigger portion of the revenue pie. For semiconductor companies, especially those in the United States that must operate in an unforgiving financial environment, market share is the fountainhead of reinvestment. Ultimately, reinvestment in capital equipment and research and development matter more to a semiconductor company than its quarterly or annual profits, for these investments assure its future viability.

The Capital Spending Gap

A key question regarding the future of the U.S. semiconductor industry is whether it can stay the course in capital spending. At first glance, it might appear that the loss of worldwide market

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share to Japan has been accompanied by a widening gap in the ability to match Japanese capital investment. Measured in dollars, this is certainly the case, as shown in Figure 4.

Indexed on the basis of local currencies, however, the levels of capital investment between U.S. and Japanese companies since 1983 have remained in relative parity. In other words, the decline of the dollar exaggerates the investment gap. If anything, Japan has been slower than the United States in regaining the level of capital spending it reached during the orgiastic spree of 1984. Still, the fact remains that Japan has more manufacturing capacity, and is adding to it at a *faster rate*, than the United States.

Closely related to the declining share of manufacturing capacity and equipment spending is a precipitous loss of market share for U.S. makers of wafer fabrication equipment (See Commentary, page 2). Production of silicon and other raw materials of the semiconductor industry is also passing from American hands (See Commentary, page 7). Without some kind of structural change, the erosion of world market share would eventually cripple the entire food chain of technology-related industries.

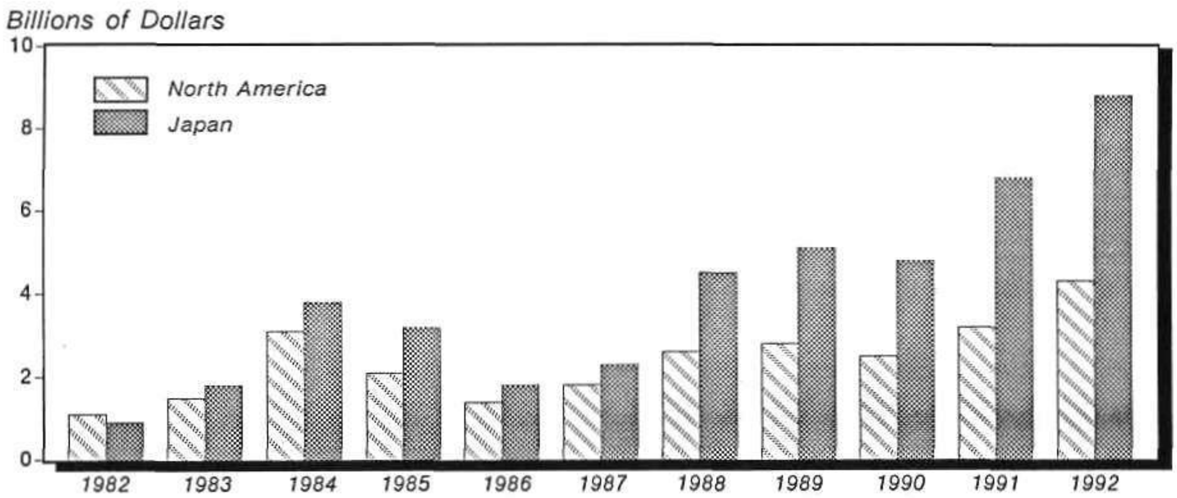
The Efficiency Gap

Complicating the problem still further is the fact that the Japanese have won a substantial manufacturing cost advantage over their U.S. rivals in many advanced products. In a recent study published by Dataquest *(The Drive for Dominance: Strategic Options for Japan's Semiconductor Industry)*, the consulting firm Quick, Finan & Associates shows that the Japanese industry has moved from about a 30 percent cost disadvantage in 1980 to nearly a 70 percent relative advantage in 1988 (see Figure 5). The cost advantage, according to Quick, Finan, has two primary sources: the learning-curve headstart that the Japanese derive from getting new products into the market faster than the Americans and—most important—a decisive lead in manufacturing yields. In mature devices, however, U.S. companies have not lost their cost advantage.

At the heart of the efficiency issue is the need for leading-edge, high-volume products that can serve as "technology drivers" that improve yields for all products. Thus, the highly publicized loss of U.S. market share in high-density memories is more than a matter of lost revenue opportunity. As lucrative as it has been during the latest market upturn, the DRAM business has never been characterized as a profit margin haven. Below the market share tip of the DRAM iceberg, however, is the more crucial issue of manufacturing technology.

Although much debate occurs in industry circles as to the merits of ASICs versus DRAMs as the manufacturing driver of choice, analysts in Dataquest's Semiconductor Equipment and

Figure 4
Semiconductor Capital Spending



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Source: Dataquest
January 1989

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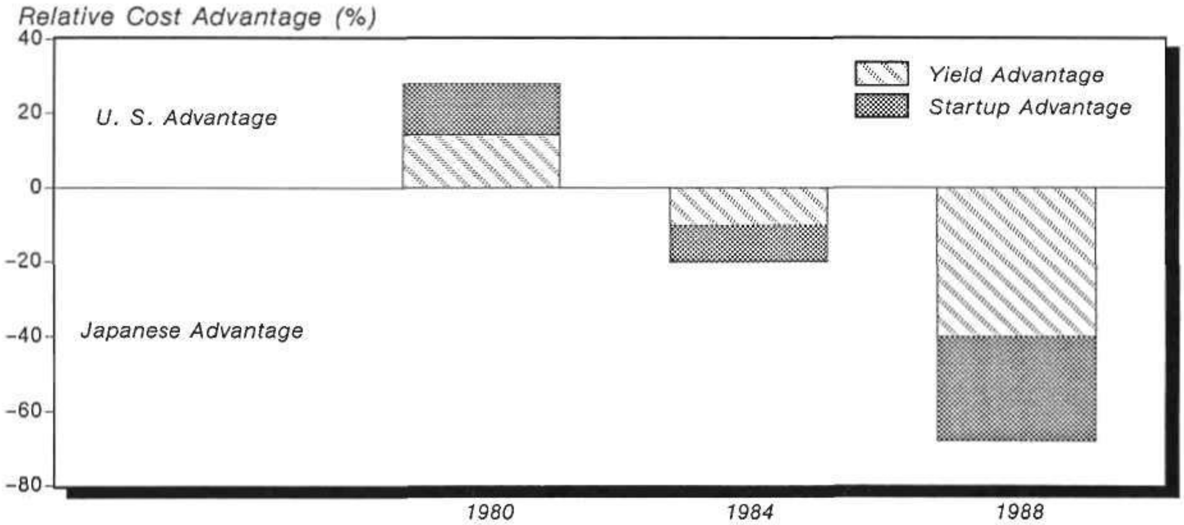
Figure 5
The Swing in Manufacturing Costs



0002950-5

Source: Quick, Finan & Associates

Materials Service believe that DRAMs are the ideal vehicle for pushing the absolute limits of line geometry. Memory production provides a "test pattern" that ensures the highest levels of productivity and reliability in equipment. This relationship among memories, process manufacturability, and semiconductor equipment is paramount in the development of semiconductor technologies. Because of this relationship, it is easy to understand the importance that semiconductor producers and consumers alike place on recovering some of the dwindling U.S. presence in high-volume memories.

THE CUSTOMERS TAKE NOTICE

If the DRAM availability crisis of 1988 accomplished anything positive for the American electronics industry, it was to push the issue of interdependence between semiconductor vendors and users to the front burner. As *Strategic Issues* argued last April, alliances and other forms of cooperation "are an inevitable outcome not only of competition but of the changes in technology and economics that have swept the industry in the last decade." In January, a joint steering committee of the American Electronics Association and the Semiconductor Industry Association finally authorized initiatives to improve the collection of information on demand for semiconductors and to develop concrete proposals for consortia or alliances that could expand DRAM production in the United States.

If steps like these are successful in reversing the U.S. decline in semiconductors, American end-equipment producers may escape with minimal damage. Although the higher prices and availability problems of DRAMs and other devices created severe headaches for procurement managers throughout the electronics industry last year, little evidence exists that they caused lasting competitive problems for major U.S. systems companies. "In times of shortage," points out Hal Feeney, general manager of Dataquest's Components Division, "the Japanese vendors have tended to take care of their established customers."

Survival of the Integrated

On the other hand, it is clear that newcomers to the industry, especially the host of IBM PC clonemakers that sprang up both in the United States and Asia in the last few years, have had to scramble for components. In some cases, this has resulted in missed deliveries or reduced production. And in the brutal world of computer retailing, inability to supply product to the market can mean a death sentence. According to Bill Lempesis, industry analyst in Dataquest's Personal Computer Industry Service, the vendors benefiting most from the supply disruptions were

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vertically integrated producers of both semiconductors and computers. Japan's NEC, for example, about doubled its sales of personal computers to 224,000 units in 1988. And Hyundai of South Korea went from sales of 20,000 units worldwide in 1987 to 115,000 last year.

The biggest threat to computer vendors and other systems companies dependent on U.S. semiconductor technology may not be the availability of DRAMs and other memory devices. The growth of new producers in Asia and Europe, along with joint venture or consortium activity in the United States, should ensure that these commodity markets eventually will be adequately served. What should be of most concern to semiconductor users is the prospect that U.S. vendors are losing leadership in high-speed logic, application-specific devices, and other technologies that have a direct bearing on performance, features, and time-to-market of leading-edge products. Because the Japanese, Korean, and European producers of these strategic semiconductor devices are for the most part also producers of end equipment, they cannot avoid customer concerns that internal needs will take precedence over merchant market requirements.

Amdahl's Advantage

To date, there is little evidence that integrated companies abroad have been able to use their semiconductor prowess to gain an advantage over the largely nonintegrated U.S. systems companies. However, one clear example of the leverage provided by advanced semiconductor technology is the rapid growth of Amdahl Corp. as a mainframe alternative to IBM. Amdahl, which is partly owned by Japan's Fujitsu Ltd., introduced two new processors last year that are based on Fujitsu's emitter-coupled logic (ECL) technology and that give the company at least a short-term edge over IBM in raw machine horsepower.

This is only part of the advantage that Amdahl derives from Fujitsu technology. According to Jeffry Beeler, industry analyst in Dataquest's Business Computer Industry Service, Amdahl has used this technology to provide major improvements in floor space, power consumption, and the functionality of its hardware. "Price/performance is important in the plug-compatible mainframe market," Mr. Beeler notes, "but not as important as it once was." Still, Amdahl gained a 33 percent improvement in machine cycle time, in part by using ECL logic chips with switching speed of 180 picoseconds.

Where such pure performance advantages might pay off best for Fujitsu is in supercomputers. Christopher Willard, senior industry analyst in Dataquest's Technical Computer Systems Industry Service, points out that the powerful supercomputer announced by Fujitsu in December is based on 80-picosecond ECL technology that is not available in the United States. It is not yet clear exactly how fast the Fujitsu machine really is or whether semiconductor technology can override the architectural and software advantages held by American producers. Nevertheless, the announcement clearly concerns U.S. competitors who rely on Fujitsu as a merchant vendor of advanced ECL devices.

Toward Collective Solutions

The issue of "strategic silicon"—the close linkage between semiconductor technology and the competitiveness of electronic systems—has come most sharply into focus in the defense industry. The Defense Science Board, which advises the Department of Defense on technology matters, has viewed the decline of the U.S. semiconductor industry with mounting alarm for several years. In a report on the issue last October, the board warned that lagging competitiveness in semiconductors could allow foreign computers to surpass U.S. technology "in the immediate future." The board added that computer technologies "are the foundation of every defense system, either as a part of the system itself or in its design and development." To prevent further declines, the board has urged the Pentagon "to act in a new and unfamiliar role" by involving itself in economic policies that affect U.S. industry and technology.

Despite the growing perception that a strong domestic semiconductor industry is vital to leadership in both commercial and defense systems, it has not been easy for America's entrepreneurial managers to find collective solutions to their problem. Until the breakthrough meeting of AEA and SIA representatives in January, proposals for alliances to expand DRAM production had gone nowhere. Victor de Dios, director of Dataquest's North American Semiconductor Market Service, explains that semiconductor users shrink from investing in captive production in part because of the danger that the captive will not be competitive in price or quality with merchant sources. Another concern has to do with the issues surrounding allocation of production and confidentiality in a consortium that includes competitors.

All of these issues will be addressed in detail as semiconductor users and vendors develop specific alliance proposals over the coming

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months. While the urgency of the DRAM crisis may well have faded by the time decisions are to be made, we expect one or more alliances to go forward. Not only are equipment companies fearful of another DRAM shortage, but high semiconductor prices appear to have improved the economics of such investments. "The environment (for DRAM expansion) is right because pricing has made it economically viable," said Wilfred J. Corrigan, chairman of LSI Logic Corp.

WHAT MUST BE DONE

Any recommendations for action to rescue the U.S. semiconductor industry from further decline must start with the question: What happens if the recovery effort fails? This is a legitimate question, given the fact that losses and layoffs are mounting again, barely two years after the industry emerged from a crushing recession. Dataquest's forecasts do not suggest a repeat of the 1985-1986 debacle, and the U.S. industry is in better shape financially than it has been in many years. According to Semiconductor Industry Association figures, mean pretax income bounced back to 7 percent of sales in 1987 after two years of losses and reached 11 percent of sales in the first nine months of 1988. "By almost any financial measure," said Rick Whittington, semiconductor analyst for Prudential-Bache Securities, "the industry is tremendously improved over where it stood a few years ago."

But these companies are entering a period of slower growth and intensified competition at a time when cash requirements for research and capital investment have never been higher. The logical forecast is for continued erosion of market positions around the world and increasing inroads on product markets that provide above-average growth and revenue opportunities. Would this matter to the broader electronics industry? To the nation? To U.S. trading partners?

We believe that the answer is yes to all three questions. Semiconductor technology and production is a strategic resource that must be preserved in the United States. There is, in fact, no doubt that at least some of this resource will be preserved because systems companies and defense planners will not risk dependence on foreign competitors. The question becomes how this resource is to be preserved.

The likeliest outcome of a continuation of present trends, it appears, is a much larger government—mainly military—role in financing semiconductor research and even manufacturing operations. As the Defense Science Board has made clear, the nation charged with defense of the free world cannot afford to lose its technological edge. Recent DOD initiatives to support Sematech, superconductor research, and high-definition television suggest that the Pentagon has already lost its reluctance to cross into the civilian domain. These efforts could be just the start to a powerful military role in the U.S. semiconductor industry. At the same time, systems companies interested in commercial technology would have to build up internal chipmaking activities and find ways to support key suppliers of materials and equipment.

In the short run, foreign competitors all across the electronics industries might profit from the problems of America's merchant semiconductor device and equipment companies. But as more and more of this technology disappears behind military or corporate walls, the global flow of ideas that has characterized the semiconductor industry from its inception might slow to a trickle. Domestic markets for many electronics products might have to be protected to ensure satisfactory volumes and pricing for strategically important devices—leading to similar barriers elsewhere in the world. Technology would take on many of the characteristics of agriculture, with government support leading to government control of pricing and international trade.

What are the steps that can alter this scenario in favor of a healthy and independent domestic industry, open markets, and continued global movement of technology? Without reciting the considerable evidence that has been compiled by such groups as the Council on Competitiveness, it is safe to state that the problems in semiconductors are part and parcel of a broad malaise affecting many aspects of American society. At the same time, it is at the industry and corporate level where these national problems are played out. Thus, any real solution must involve actions at the government, industry association, and company level.

Recommendations for Government Action

Economic and Fiscal Policy

Agreeing with the Council on Competitiveness and many economists, we urge the Bush administration and Congress to cut the budget deficit and adopt policies to encourage savings in order to lower the cost of capital in the United States. Beyond this, we urge specific steps to encourage capital investment and spending on R&D and to reward companies and investors for focusing on long-term results. For example, close attention should be paid to the recommendations of the Ad Hoc Electronics Tax Group, formed by 21 companies concerned about the impact of tax policy on capital costs and investment incentives. These issues have been virtually ignored in the push to cut individual tax rates, but they now must be given serious attention.

Science and Technology Policy

We urge the Bush administration to move quickly to elevate the scientific and technological field to a leading position in policy debates, to develop a coherent long-term strategy to guide government actions that affect industries in this area, and to increase government investment in technology-related infrastructure. New techniques to encourage targeted private investment in critical technologies should be explored. Planned government investments in science and technology should be reviewed to ensure that they benefit commercial competitiveness. Leadership in this area should come from civilian agencies, rather than the Department of Defense.

Education Policy

We support proposals to improve math, science, and engineering education from grade school through university and postgraduate levels. Tax policy should support company efforts to educate and train employees.

Trade Policy

We agree with Clyde Prestowitz, the former counselor on Japan Affairs to the Secretary of Commerce, that technology trade with Japan, Korea, and other emerging industrial powers is unlikely to be truly open. These nations have made technology a cornerstone of their development policies, and so will Europe as it moves toward true integration by 1992. This does not mean that trade must suffer. We urge the Bush administration to negotiate more openly for results, seeking reciprocity rather than just procedural improvements. Consultations should cover direct investment and technology transfer as well as trade, seeking "win-win" policies for both foreign and domestic industries.

We support the price monitoring system of the Semiconductor Trade Agreement as necessary to encourage investment, and we urge Japan to work for acceptance of the market penetration goals envisioned by the agreement. We oppose limits on foreign investment in U.S. technology companies except in cases where national security is truly at risk. We believe that any investment that will enhance U.S. technology should be encouraged.

Recommendations for Industry Action

"Virtual" Vertical Integration

We applaud efforts to promote manufacturing consortia or joint ventures of domestic electronics equipment and device makers as a means of encouraging an increase in U.S. DRAM capacity. Only by sharing risks and costs can nonintegrated companies overcome the advantages of vertically integrated competitors in capital-intensive commodities. We suggest that foreign manufacturers be given an opportunity to participate in these ventures, both to ensure access to critical technology and to encourage similar treatment for U.S. vendors abroad.

Role of Trade Associations

Industry associations will be the primary intermediaries and facilitators for the expanded cooperation that we foresee. In his book *Competing for Control: America's Stake in Microelectronics*, Michael Borrus suggests as a model the cooperative planning, research, and production done by West Germany's highly competitive machine tool industry—all organized by a powerful trade association. We urge industry groups to enlarge their presence in Washington, Tokyo, Brussels, and other decision centers and to enhance their ability to analyze and interpret the industry's needs as government policies increasingly affect their industries. They should do more to support their members' efforts to export and invest abroad. They should support rigorous investigations of industry economics, intellectual property standards, management and manufacturing practices, and financing and accounting policies to ensure that policy makers, investors, and corporate managers understand the true nature of competition in this industry.

Sematech and Other Research Consortia

Companies must support these industry efforts with resources and top people or work to change them. They cannot be viewed as retirement waystations. Only if good young engineers are involved and then return to parent firms will backers get a full measure of technology transfer. Special attention must be paid to the needs of the process equipment industry, the most vulnerable link in the technology chain. Additional consortia in such areas as materials, X-ray lithography, and packaging may be required to offset declining U.S. market positions.

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Consumer Electronics/HDTV

We support efforts to rebuild a consumer electronics industry in the United States by drawing computer and electronics companies into a high-definition television consortium. Alliances with foreign producers may be necessary to develop the manufacturing/distribution infrastructure required. The intent should not be to drive foreign brands out of the market but to ensure a strong role for domestic technology in the coming revolution in consumer electronics.

Recommendations for Company Actions

International Alliances

We support technology and manufacturing ventures with Japanese and other foreign competitors. They are needed to gain technology, share development costs, and provide market access. In light of the difficulties that both American and Japanese companies will face in gaining market share at the expense of the other, it is likely that growth prospects will depend on the quality and nature of the "spheres of influence" that international alliances provide. Management must ensure that both parties gain equally from the deals and that they do not undercut Sematech or other domestic R&D projects.

Domestic Alliances

We urge U.S. companies to seek opportunities to support domestic suppliers of critical components and equipment. Investments in manufacturing or research consortia should be analyzed in terms of long-term benefits and risks, not just short-term returns.

Manufacturing Efficiency

We urge U.S. companies to continue efforts to improve yields and other measures of factory productivity by emphasizing manufacturing in hiring and promotion, shifting resources toward manufacturing, and adjusting investment criteria to recognize long-term payoffs.

Market Penetration Abroad

We urge U.S. companies to step up investments in manufacturing and test/assembly facilities, as well as in language training and other human resources investments, that will integrate them more tightly into key foreign markets. New mechanisms such as joint ventures or export consortia should be explored to share expenses and risks. U.S. companies must take full advantage of the decline of the dollar in their pricing strategy abroad.

CONCLUSIONS

We think that the American semiconductor industry can be saved. But none of these recommendations will help if the makers of silicon, wafer fab equipment, devices, and electronic systems cannot agree on one fundamental assumption: that they need each other. Manny Fernandez, Dataquest's president, puts it this way: "If the customer doesn't care, you won't succeed." The challenge for managers at all levels of this industry is to make sure that the customer cares about them and about their survival.

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Strategic ISSUES

February 1989

South Korea: Following the Leader?

By John W. Wilson and Sheridan Tatsuno

In terms of economic development, Japan and South Korea have followed strikingly similar paths. Starting from the rubble of devastating wars, both countries achieved twentyfold growth in per capita gross national product—from $100 a head to $2,000—in just 20 years. Japan accomplished this feat between 1950 and 1970 and went on to build a successful high-technology industry and a highly advanced economy with the help of licensed technology and wide-open export markets. Korea's growth sprint took place between 1965 and 1985, and it too is now poised to become a fully developed country.

But times have changed. Foreign markets that once were open are closing their doors. Technology that was weakly protected or licensed inexpensively now is tightly guarded. In many other ways, the global environment for industrial development is radically different than it was for Japan two decades ago. If the Koreans hope to continue their rapid economic growth, they will have to write a new script. And that is exactly what they are doing. Knowing that they cannot rely on others for all the elements that are needed to meet their ambitious development goals, Korean managers and policymakers are reshaping their industries and their society to provide these elements internally.

What the Koreans are attempting dwarfs even Japan's amazing progress for sheer boldness of the plan and the magnitude of the challenge. In the next dozen years, Korea proposes to convert itself from an exporter of labor-intensive commodities to a leader in high-technology research and development. The number of scientists and engineers in the country is to triple, from 54,000 to 150,000. Spending for research and development is to jump from 2 percent of GNP to 5 percent or more. The overwhelming business dominance of a handful of *chaebol*, or industrial conglomerates, will give way to a balanced mix of small, medium-size, and large companies. Venture capital will flourish, and entrepreneurs will recreate Silicon Valley all over the Korean Peninsula. Rather than depend on foreign technology and imported parts, Korea will develop its own; rather than depend on export markets, Korea will build a strong and self-sufficient domestic economy.

The odds are against the Koreans. The structural and social changes this development path requires are formidable, and South Korea is a country with limited resources and a political system not noted for its stability. Nevertheless, technology managers in other countries would do well to watch closely the events in South Korea. This accelerated drive for the top will present many opportunities for alliances and investments that further the Korean endeavor. At the same time, the Koreans' energy and ambition will make them dangerous competitors in a host of advanced-product markets. It would be foolish to underestimate them.

The title of a new book, *Is Korea the Next Japan?*, by T. W. Kang, reflects a growing concern in the United States and Europe. As Korea takes a bigger share of world markets, will it take over Japan's image of the ruthless exporter piling up huge trade surpluses? That does not seem likely. Not only are Korea's economy, culture, and political structure very different from Japan's, but the world conditions that allowed an export-oriented development strategy to work have changed drastically (see Figure 1). If it is to succeed, Korea's future development strategy must depart from the Japanese model in several important respects.

(John W. Wilson is vice president for business and technology analysis at Dataquest and editor of Strategic Issues. *Sheridan Tatsuno is a senior industry analyst for Dataquest's Asian and Japanese Components Groups.)*

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Commentary

Venture Capital Takes Root in Korea

By John W. Wilson and J. H. Son

Venture capital in Korea, which began as a government-backed program to finance technology development, is beginning to look more like the free-wheeling investment vehicle that launched Apple Computer, Digital Equipment, and Intel. It will be some time before Korean Silicon Valleys arise to challenge the American original. But the private risk investors and entrepreneurial technical talent needed to create them are now becoming available.

Until about two years ago, Korea boasted only four venture capital firms, all but one government-supported and engaged primarily in lending to small companies for technology-related projects. The first private venture capital company, Korea Development Investment Corp. (KDIC), was set up in 1982 by seven investment finance firms with the goal of providing equity financing for promising companies; however, until last year, it had raised only about $15 million and invested in only 45 companies.

The venture field began to heat up in 1987, when new legislation providing financial incentives both to private venture capitalists and to entrepreneurs went into effect and an unlisted stock market opened. Since then, some 20 new venture capital funds have been formed and the established firms have moved to create new, equity-oriented funds. Korea Technology Development Corp. (KTDC), the largest of the Big Four with $50 million in disbursements since 1981, led the way. Its Korea Technology Investment Corp. (KTIC) subsidiary has raised a $6.6 million fund and taken equity positions in 39 start-up companies.

The investment focus of Korea's new venture capitalists is not technology development but profits. KDIC, in fact, turned down government support because of a potential for conflicting goals. "It is easy money," explained Yeo Gyeong Yun, KDIC's executive vice president, "but later on it becomes very complicated because the government's objective is not to maximize gains." Nevertheless, both KDIC and KTIC have put about a third of their funds into electronics-related deals and another third into industrial machinery because growth prospects are strong in Korean technology.

Venture capital in Korea faces many obstacles, including inexperience on the part of both investors and entrepreneurs. Korean entrepreneurs, like their counterparts in Europe and Japan, are often reluctant to give up ownership. Investors have no smooth way to exit from a deal, since trading on the new over-the-counter securities market is still negligible and the government discourages local acquisitions by the chaebol companies. In addition, Korea's domestic market for technology products is small enough that investment strategies are limited. Software start-ups, says Kap-Soo Suh, chief executive of KTIC, only became possible when Korea passed legislation protecting intellectual property and began training a cadre of programmers.

The best thing that could happen to Korean venture capitalists would be to get some solid success stories in their portfolios. And they are starting to emerge. The biggest winner so far is probably Tri-Gem Computer, a maker of personal computers and word processing equipment. KDIC first invested in 1983, when Tri-Gem had sales of only about $1.5 million. Last year, Tri-Gem recorded sales of $190 million and ranked as the leading personal computer brand in the Korean market. Tae Il Media Co. (heads and media for hard disk drives) and Qnix Co. (software) are other venture-backed companies with strong growth records. These companies say that their flexibility, intensive service levels, and fast decision making give them big advantages in their competition with Korea's giants.

As Korean Apples grow, foreign investors will try to share in the action. Most government restrictions on foreign venture investments have been removed, but attempts by Korean firms to raise foreign funds last year were stalled by the Ministry of Finance, which is worried about excessive capital inflows. This seems shortsighted, since foreign venture capital investors could play a vital role in promoting technology transfer and in enhancing the sophistication of Korean entrepreneurs. Without doubt, Korea needs a strong venture process to complete its leap to full equality in global technology markets.

John W. Wilson is editor of Strategic Issues *and author of* The New Venturers: Inside the High-Stakes World of Venture Capital. *J. H. Son is a senior industry analyst and manager of Korean research for Dataquest's Asian Components Group.*

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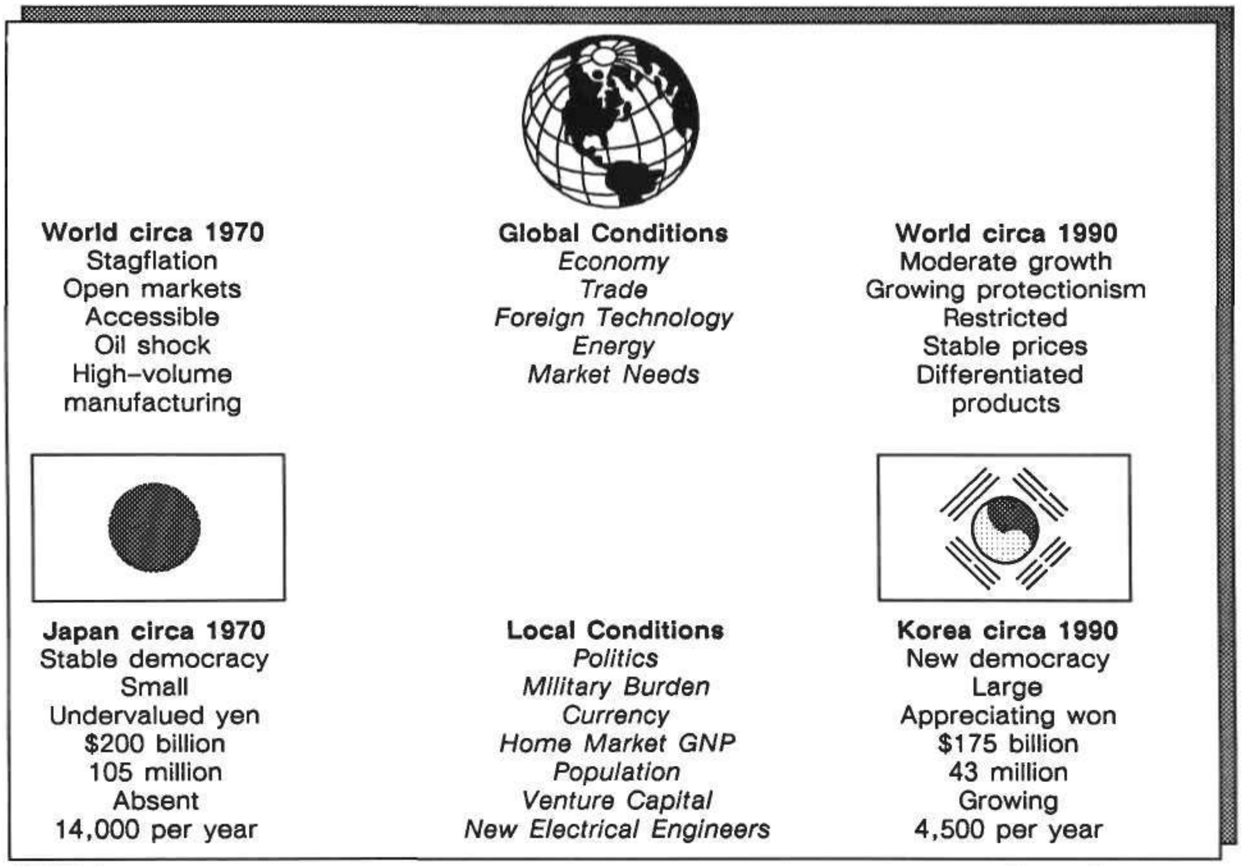
Figure 1
Comparing Japan and Korea



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Source: Dataquest
February 1989

BEHIND THE KOREAN MIRACLE

The biggest reason for taking seriously the Koreans' prospects is their proven ability to accomplish a great deal with very little to work with. The Republic of Korea began its life at a severe disadvantage. The division of Korea into Soviet and American zones at the end of World War II, followed by the creation of rival governments in 1948, left the North with most of the industry and mineral and energy resources. The South, which had been largely agricultural, lost what little industrial infrastructure it had developed in the Korean War of 1950 to 1953. Seoul, its capital, was in ruins.

Partly because of Japan's success at stimulating rapid growth without the help of natural resources, Korea modeled its early development strategy on the Japanese example. Government agencies picked out industries with export or import substitution potential, encouraged industry to pursue them with subsidies and protection, and developed an infrastructure of transportation, energy, research, and education. As in Japan, large companies were the main vehicles for carrying out the export drive; the 10 largest Korean chaebol still account for a third of all manufacturing activity in the country. The four largest—Hyundai, Samsung, Lucky-Goldstar, and Daewoo—had revenue totaling more than $40 billion in 1987 (see Table 1).

The chaebol proved to be highly successful exporters. First in labor-intensive light industries such as plywood, textiles, and shoes, then in steel, shipbuilding, and other heavy industries, and most recently in autos and consumer electronics, Korea's aggressive giants conquered foreign markets. As shown in Table 2, electrical and electronics products accounted for almost 15 percent of Korea's GNP last year and fully 25 percent of the country's exports.

In most cases, the focus has been on mass production of low-cost products—often assembled from imported components. Product design and

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Table 1

Performance of Korea's Chaebol in 1987
(Billions of U.S. Dollars)

Group	Sales	Liabilities	Assets
Hyundai	16.1	9.4	1.7
Samsung	14.6	7.5	1.1
Lucky-Goldstar	11.9	6.9	1.5
Daewoo	8.9	9.8	1.5
Sunkyong	5.9	3.0	0.6
Ssangyong	3.9	2.9	0.5
Hanjin	3.0	4.6	0.3
Korea Explosives	2.3	1.8	0.7
Hyosung	2.3	1.3	0.4
Dongkuk Steel	1.8	0.9	0.2

Source: Business Korea

marketing was often left to third parties, because the Koreans found that the quickest way to penetrate a new market was through retailers or original equipment manufacturers (OEMs) seeking low-cost manufacturing. In the last few years, U.S. and Japanese companies have stepped up their direct investments in Korean manufacturing operations and have added their output to the export boom.

The strategy worked amazingly well. Korea's economy accelerated through the 1960s and 1970s, and the oil shocks and world recession of the early 1980s presented only temporary setbacks. Growth in the last few years hit double digits as production and exports of consumer electronics, electrical appliances, and computer equipment went into high gear. Table 3 shows that some of Korea's reliance on consumer electronics is declining as production of industrial products such as computers, peripherals, and telecommunications equipment has increased.

FACING A CHANGED WORLD

Despite Korea's obvious success in export markets, some critical weaknesses exist in the Korean economy and business structure that were hidden during the days of rapid growth. Now Koreans are asking themselves if their powerful export engine can propel them to the new heights they hope to achieve in the next decade. Their concerns about these developments at home and abroad are as follows:

- Rising protectionism. Japan was able to take large market positions in autos, consumer electronics, semiconductors, and other products before triggering a protectionist response from the U.S. government. Korea will apparently not have that luxury. Its balance of trade had barely turned positive (in 1985) when the Reagan Administration started pressing for currency adjustments and market-opening measures. As a result, the Korean won has climbed about 25 percent against the dollar since 1984, and quota restrictions have been eliminated on all but 5 percent of manufactured imports.

Table 2

Korean Electronics Industry
(Billions of U.S. dollars)

	Production					
	1983	1984	1985	1986	1987	1988*
GNP	$ 75	$ 81	$ 83	$ 95	$ 119	$ 145
Electronics/Electrical	$6.7	$8.4	$8.5	$12.1	$17.4	$21.0
Share of GNP	8.9%	10.3%	10.2%	12.7%	14.7%	14.5%
	Exports					
	1983	1984	1985	1986	1987	1988*
All merchandise	$ 24	$ 29	$ 30	$ 35	$ 47	$ 52
Electronics/Electrical	$3.3	$4.6	$4.6	$7.4	$11.2	$13.0
Share of Exports	7.3%	15.9%	15.2%	21.3%	23.6%	25.0%

*Estimated

Source: Dataquest
February 1989

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Table 3

Growth of Korea's Electronics Industry
(Billions of U.S. Dollars)

				Electronics Production			
	1983	1984	1985	1986	1987	1988	CAGR 1983-1988
Consumer	$2.2	$2.4	$2.4	$ 3.3	$ 4.9	$ 5.8	21.4%
Industrial	0.9	1.2	1.5	2.1	3.1	3.8	33.4%
Parts and Components	2.4	3.5	3.4	5.2	7.3	8.9	30.0%
Total	$5.5	$7.1	$7.3	$10.6	$15.3	$18.5	27.5%
				Electronics Exports			
	1983	1984	1985	1986	1987	1988	CAGR 1983-1988
Consumer	$1.2	$1.5	$1.5	$2.4	$ 3.8	$ 4.3	29.1%
Industrial	0.4	0.6	0.8	1.3	2.0	2.5	44.3%
Parts and Components	1.4	2.1	2.0	3.0	4.2	5.0	29.0%
Total	$3.0	$4.2	$4.3	$6.7	$10.0	$11.8	31.5%

Source: Electronic Industries Association of Korea

- Technology constraints. The cost of entry into high-technology industries has escalated sharply since the Japanese made their move. Around the world, governments and industry are putting together well-funded consortia for research and manufacturing. Even the largest companies are joining in alliances with competitors to reduce the cost burden of pushing the state of the art. Not surprisingly, U.S., Japanese, and European companies have started placing a higher value on their technology and limiting its availability. The Koreans cannot buy their way into the market; they know they must develop their own technology. "Intellectual property can be our great weapon," said Young-Soo Kim, executive vice president of Samsung Electronics.
- New competition. Korea is not the only emerging export power in Asia. Whereas Japan had no serious competition as a low-cost, high-quality exporter during its early growth phase, the Koreans are facing serious challengers both in labor-intensive manufacturing and in the higher-value products they must now emphasize. And, Korea is especially vulnerable because it has not developed Japan's self-sufficiency in components and materials and thus cannot control its own destiny in costs or product development.
- Economic outlook. By changing the ground rules for industrial success, economic upheaval can provide opportunities for new market participants. Japan was helped by the global energy crisis, which created new markets for energy-efficient autos and other innovative products. Japanese companies responded faster than most Western companies, many of which were paralyzed by the "stagflation" crisis that gripped the world economy. Korea is coming onto the global stage at a time of economic tranquility.
- Changing market needs. Fierce global competition and new technology are altering the rules of the game in every industry important to Korea. Efficient manufacturing of commodity products, the basis for Korea's early successes, is now less important in many industries than the ability to bring new products to market quickly and to shift production among many highly differentiated products. To succeed in this environment, companies must be close to end markets, have access to new technology, and achieve high levels of corporate creativity. In high technology, this means coupling advanced and efficient production processes with creative product design and manufacturing flexibility.

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- Democratization. To some extent, Korea's success has depended on a close coupling between authoritarian military governments and a few large industrial organizations that are run along military lines, with strong direction from the top. This structure is under attack in the wake of political changes that have swept the country in the last two years. Public concern over the concentration of economic power has led to efforts to limit the growth of the chaebol and to help small business. At the same time, workers have taken advantage of their new-found freedom to press for wage increases, further threatening the competitive position of big companies.

TARGETING TECHNOLOGY

All of these pressures are converging on Korea's young technology industry, forcing it to mature at an accelerated pace and to reevaluate its structure and strategy. Korea has chosen to meet the challenge head-on. In the latest long-range plan promulgated by the Korean Ministry of Science and Technology, the target is to catch up with the most advanced countries in microelectronics, information technology, automation, and fine chemicals by the year 2001. This ambitious plan will require major changes in both industry and Korean society.

The Entrepreneurial Bent

In several ways, the Koreans are well suited to compete in a high-technology world that rewards both size and agility. Their heritage of Confucianism—a code of conduct stressing consideration for others, respect for education, and loyalty to the hierarchy of family and clan—ensures a well-educated, disciplined work force. In fact, Koreans work even harder than the industrious Japanese—an average of more than 2,500 hours per year, compared with about 2,000 hours in Japan.

Koreans are also entrepreneurs. Unlike Japanese employees, who are usually reluctant to strike out on their own, many Koreans are eager to change jobs or start a new business. "We are not as drastically entrepreneurial as the Chinese," said Korean venture capitalist Yeo Gyeong Yun, "but we are more entrepreneurial than the Japanese." This cultural tendency shows up clearly in the accomplishments of Korean immigrants to the United States. In their book *The Third Century*, Joel Kotkin and Yoriko Kishimoto report that Koreans have the highest rate of self-employment of any immigrant group—far above the national average.

In the large companies that dominate Korean industry, this unique culture results in what Tom Peters and Robert H. Waterman, in their management classic *In Search of Excellence*, called "a bias for action"—a willingness to move ahead even though plans may be incomplete. This tendency is in part, suggests Mr. Kang, because Koreans are conditioned by their history of coping with hardship and rapid change to accept less than perfection. A typical Korean company, he writes, "*tends to combine willpower with fatalistic optimism.*"

A striking example of this approach is provided by the account of Samsung's entry into the microwave oven business in *The Silent War: Inside the Global Business Battles Shaping America's Future*, a new book by Ira C. Magaziner and Mark Patinkin. Samsung pressed ahead with manufacturing facilities, even though its first oven prototypes were crude failures, no local market existed, and export orders were slow to materialize. Just eight years after Samsung began experimenting with the product, it was producing more than a million ovens a year.

High-Tech Handicaps

Despite the obvious successes that Samsung and the other chaebol have achieved, Korea has many handicaps as it enters the high-technology race. For one thing, catching up in semiconductors and other capital-intensive fields will require huge investment outlays for research and capital equipment. As Table 1 indicates, Korea's industrial giants already are highly leveraged, with liabilities outweighing assets by 5 to 1 or more. Bank loans to the 30 biggest chaebol typically account for a third of all lending by Korean banks, and political pressures are building to reduce that dominance of the credit market. Clearly, Korean companies will have to find new sources of capital if they are to meet their new commitments. Korean government resources, too, are limited by a huge defense budget that consumes about 5 percent of GNP. Even if relations with the North suddenly warm up, it will not be easy to scale down military spending overnight.

Another problem Korea must solve is filling the gaps in manpower and technical infrastructure that have been ignored during the country's rapid growth phase. Despite heavy stress on technical education, Korea still is producing only about 4,500 electrical engineers annually, or about 110 per million population. By comparison, Japan in the early 1970s—a comparable point in its development—was graduating 15,000 engineers, or 140 per million, every year.

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Because many Korean graduates go abroad for further training or employment, the recruiting prospects for fast-growing companies are grim.

Personnel shortages are especially acute in semiconductor design, computer systems, and software. Writing in *Business Korea*, Seon-Hyung Cho, president of Wang Computer Korea, warned that Korea lacks the infrastructure to achieve its ambitious goals for the information industry. "The most important element," Mr. Cho noted, "is having a specialized institution which produces high-quality software engineers." One expatriate Korean engineer notes that rigid hierarchies and inexperienced technical management make it difficult for Korean companies to attract top designers who are in demand all over the world.

Furthermore, the rapid development of large companies has come at the expense of the small and medium-size business sector, which, in most of the developed world, is an important source of design and innovation. Japanese companies, for example, rely on networks of small suppliers for many components and services. The one-dimensional nature of Korea's industrial structure has left the country heavily dependent on foreign suppliers of parts and materials. Japanese imports alone make up a third of the value of Korean exports, and in products such as video tape recorders, the foreign content is much higher.

One result of this import dependency has been to raise costs. K. O. Park, senior vice president of Hyundai Electronics Industries, pointed out that semiconductor fabrication equipment costing $100 in the United States carries an effective purchase price in Korea of $124 after commissions, insurance, freight charges, customs duties, and taxes are added. "To be competitive," said Dr. Park, "we need a balanced industry."

RESTRUCTURING FOR THE 2000s

Although the problems are formidable, Korea is pressing ahead with typically ambitious plans to confront them. In the next decade, the Koreans hope to upgrade their technical infrastructure to world-class status, reorient their biggest companies, and create almost from scratch a thriving small-business and venture capital sector. Considering the difficulties that the United States and Europe face in matching Japan's manufacturing prowess, and the possibly greater test confronting Japan in developing U.S.-style innovation, Korea at least is not alone in taking on a challenge. But its task seems larger and its resources thinner than those of its rivals.

Improving Technical Resources

Korea has done a remarkable job of bootstrapping the development of technical and scientific education, building public and private research facilities, and putting to good use the technology it borrows from abroad. As a nation, Korea now spends about 2 percent of its GNP on research and development, with three quarters of that burden carried by the private sector. This represents an impressive increase from the level of 0.86 percent in 1980 but is still well behind Japan, West Germany, and the United States, which spend nearly 3 percent of GNP on research. In electronics, however, Korean companies are investing in R&D at highly competitive levels (see Table 4).

Now the science ministry proposes to kick Korean research spending to much higher levels—to 3 percent of GNP by 1991 and to a startling 5 percent by 2001 (see Figure 2). To support this all-out national effort, the ministry intends to triple the number of scientists and engineers working in Korea, recruit some 2,000 expatriates now working abroad, and develop a series of "science towns" patterned after Japan's Technopolis concept, where research institutes, universities, and innovative companies can rub shoulders. The big Korean companies also have ambitious plans for expanding their R&D efforts. The number of private research institutes has grown from 124 in 1983 to more than 600, and some of them are quite ambitious. Goldstar, for example, plans to employ some 2,000 scientists and engineers at its new research center by 1990. Research consortia have proliferated, led by a $100-million-plus project to develop 4-megabit DRAM technology.

Reshaping the Chaebol

The success of Korea's technology drive will depend greatly on the ability of the country's biggest companies both to pay for advanced research and to use its fruits to good effect in

Table 4

Comparison of R&D Investment

	Korea	United States	Japan
All R&D/GNP (1987)	2.0%	2.8%	2.9%
Electronics/ Sales (1986)	4.1%	6.0%	5.5%
Semiconductor/ Sales (1987)	18.0%	16.0%	18.0%

Source: Korea Industrial Research Institute

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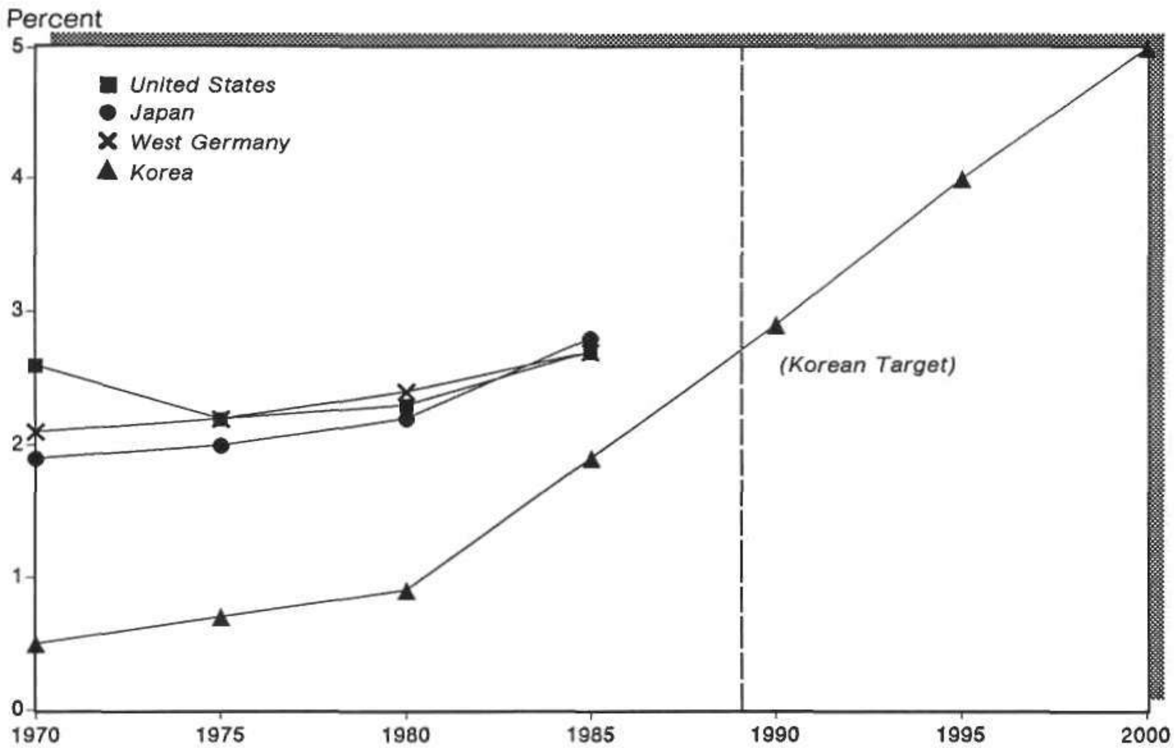
Figure 2
R&D Spending as a Percentage of GNP



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Source: National Science Board, Korean Ministry of Science and Technology

world markets. This requirement may conflict with the government's effort to reduce support for the chaebol and open the Korean credit markets to smaller companies. Like Japanese companies, the Korean giants depend heavily on bank lending at favorable terms and are not highly profitable. If they must now turn to the public capital markets, they will have to increase their profits at the same time that they are trying to match U.S., Japanese, and European technology spending.

A new breeze appears to be blowing through the boardrooms of Seoul. Led by Samsung and Hyundai, the two biggest of the chaebol groups, Korean companies are improving their ability to develop new products, raising quality levels, establishing closer links with the markets that they serve, and creating worldwide brand awareness for their products. Hyundai, for example, is leveraging the North American promotion efforts of its automotive group to build awareness of its name in personal computer products. And, going direct to the consumer, rather than through OEM intermediaries, carries extra benefits for Hyundai. "Now that we are closer to the customer base we get comments and complaints that used to be buffered by the distributors," said C. S. Park, chief executive officer of Hyundai Electronics America.

As the chaebol increase their presence in foreign markets, they will have to find ways to adapt their inbred management structures to the needs of a global enterprise. The Korean management system relies heavily on family, school, and regional networks. Not only do family members of the chaebol founders usually take key jobs in the organization, reports Chan Sup Chang, a business professor at Lander College in South Carolina, but other top executives often are recruited from the same university and even the same region as the founders. The new challenges of moving to higher-value products and participating fully in foreign markets may require fundamental changes in this parochial management style. One pressing requirement is to become much more adept at finding and managing foreign acquisitions that will give the Koreans access to markets and technology. And, the rigors of international competition will force the chaebol to select and promote managers on the basis of ability, rather than family or school connections.

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Making Room for Small Business

The third crucial element in Korea's bold leap to full equality among the world's high-technology powers is to recognize the importance of the entrepreneur and the small company. A healthy small-business sector could provide many of the components and services that now must be imported, and a venture capital mechanism would stimulate innovation and product development. The Koreans are being nudged in this direction by political pressures unleashed in the process of democratization. Already, the share of value added in manufacturing by smaller companies has increased from less than 30 percent to almost 40 percent. The government of President Roh Tae-Woo, responding to opposition demands in the National Assembly, has started pushing the chaebol out of some lines of business, restricting their bank credit, and dropping barriers to local competition.

At the same time, a Korean venture capital industry is emerging to supplement banking resources in the small-business sector. With some $700 million under management, Korea's 22 venture capital companies provided more than $200 million in financing for small and medium-size companies during 1987, an increase of 44 percent over 1986, and they apparently grew substantially again last year. The venture boom stems in part from a 1986 law giving increased financial incentives to venture capitalists and to the opening in 1987 of a market for unlisted securities.

Venture capital in Korea has a long way to go before it creates a robust business development process similar to that in the United States and Europe. Most of the funding still consists of loans, often to support specific development projects, rather than equity investment. But the focus is shifting gradually toward equity investing, resulting in the birth of several fast-growing start-up companies (see Commentary, page 2). Meanwhile, small companies are finding it easier to arrange technology licensing deals with foreign partners under a law relaxing the reporting requirements for royalty payments. Limitations imposed on technology transfer by foreign companies do not affect smaller ventures as much as they do the chaebol. Kap-Soo Suh, chief executive of Korea Technology Investment Corp. (KTIC), estimates that one-third of the 40-odd projects KTIC has backed in the last two years involved a joint venture or technology transfer from abroad.

CONCLUSIONS

Korea is climbing a mountain that gets steeper with every step. Although Japan has shown that the mountain can be conquered, Korea must find its own path because both the climber and the conditions are very different. The major elements in Korea's strategy—improving its level of science and technology, revitalizing its biggest companies, and encouraging its entrepreneurs—are interrelated. Without world-class technology, Korean companies have nothing to contribute to the alliances that shape high-technology competition. Without successful large companies, Korean technology will starve. Without the support of a strong small-business sector, technology will stagnate and large companies will depend on their competitors for critical components.

Technology companies around the world should find many opportunities to participate in the Korean adventure. In particular, Korea's emergence as a force to be reckoned with in high technology might present an opportunity to defuse the bilateral tensions between Japan and the United States with three-way alliances that provide benefits to all the partners. In his book, Mr. Kang argues that Korea can provide an alternative to Japanese dependence on U.S. markets and U.S. dependence on Japanese suppliers while diversifying its own unbalanced trade pattern. Without doubt, the unique Korean mixture of Confucian values and entrepreneurial instincts will also provide useful models for managing technology transitions anywhere in the world.

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Strategic ISSUES

March 1989

Soviet Union: What Perestroika Means for Technology

By John W. Wilson and Clifford M. Lindsey

In land area, it is the largest country in the world; its population of nearly 300 million and its $2 trillion economy rank third; its military power, aerospace achievements, and vast empire of satellite governments make it a superpower. But as a producer and user of high-technology products, the Union of Soviet Socialist Republics is an underdeveloped country. Only a quarter of the country's urban families have telephones, and no more than 100,000 personal computers are in use. The Soviet Union is so far behind in microelectronics, some analysts believe, that it can no longer even copy advanced circuits made in the West. Yet the combination of Soviet paranoia about controlling information, a perennial shortage of hard currency, and Western security concerns has prevented U.S., European, and Asian companies from rushing in to fill this huge technology market gap.

Now the outlook for technology trade with the Soviet Union is being changed dramatically by the reformist policies of General Secretary Mikhail Gorbachev and the warming of East-West relations. Both *perestroika*, Mr. Gorbachev's strategy for restructuring the Soviet economy, and *glasnost*, his campaign for openness in Soviet society, carry major implications for high technology. Indeed, it is unlikely that Mr. Gorbachev will succeed in improving the lot of the Soviet consumer and modernizing Soviet industry without significantly upgrading his country's use of computer technology. This change can only come about with the help of the West.

Recognizing their need for outside assistance, Soviet leaders have launched an unprecedented campaign to court trade and investment from Western businesses. Legislation legalizing joint ventures between Western companies and Soviet organizations has been followed by steps toward convertibility of the ruble, plans for a law protecting intellectual property, and other concessions to capitalistic needs. Speaking at a Silicon Valley forum cosponsored by Dataquest and ICD Austria, Soviet scientist Yuri Levine stressed that the Soviet Union is seeking long-term relationships with Western technology companies. Joint ventures, he said, should be considered "long-standing companies operating in the Soviet market with no limitations."

This newsletter examines the emerging Soviet market opportunity from three perspectives: the state of electronics technology in the Soviet Union; the influence of perestroika and glasnost on demand for computer-related technology; and the new mechanisms that are emerging to allow Western companies to participate in satisfying this pent-up demand. Selecting the right Soviet business partner, a critical factor for success in this unpredictable environment, is discussed in a commentary by trade consultant Gordon Feller (see page 2). Also crucial for any business relationship with an Eastern bloc country, points out Washington attorney Mark D. Herlach, is an understanding of the export control laws and the limitations they impose (see commentary, page 6).

MR. GORBACHEV'S DILEMMA

The leaders of the Soviet Union are finally acknowledging something that Western observers have known for some time: Their economic system does not work. The centralized control of production, prices, and profits imposed by Joseph Stalin in the 1930s functioned well enough when the challenge was to build up heavy industry and to achieve carefully chosen objectives in aerospace and atomic science. But it has failed

John W. Wilson is editor of Strategic Issues. *Clifford M. Lindsey, vice president and director of Dataquest's Strategic Executive Service, visited the Soviet Union in 1988.*

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Commentary

Exploring the Joint Venture Option

By Gordon Feller

Most companies would prefer to do business abroad through straightforward sales for hard currency. But given the conditions that prevail in the Soviet Union, the joint venture (JV) option should be explored. The first task is determining who to do business with. A primary goal must be to find partners that are sufficiently committed to the venture and to the product line that they have a vested interest in protecting the proprietary nature of the technology. It is also important to look for a partner that can be a nationwide distribution entity. Potential partners for technology companies include the following:

- Academy of Sciences. Mikhail Gorbachev's reforms have led to the creation of new forms of R&D organizations that are important vehicles for technology-related joint ventures. These organizations include Science-Production Associations, or NPOs, which bridge the gap between basic research and industrial applications, and Interbranch Scientific-Technical Complexes, MNTKs, which promote industrial innovation and partnership between R&D and manufacturing.
- State Committee on Science and Technology (GKNT). Established in 1965 after a number of failed attempts, GKNT serves in theory as coordinator for science and technology policy. In practice, it coordinates industrial research—not too successfully—and acquires foreign technology.
- The ministries. Minradioprom, Minpribor, and Minelectron-Prom are among the most prominent of the nine ministries that are involved in computer design or manufacturing in one way or another. The government is still the major participant in the computer business, but its influence is limited by orders from the top not to import (in order to force the evolution of an indigenous industry) and by a shortage of hard currency.
- State Committee for Computers and Informatics (GKVTI). Established in early 1986, GKVTI's ostensible purpose is to serve as the main policy-making body for computer use. Key government institutions involved in computers are represented on the committee. GKVTI joins a Council of Ministers-level *buro* for machine building, which is focused on improving service and maintenance.
- Other joint ventures. JVs are, by their nature, formal legal entities that have the right to enter into new JVs without many of the prior approvals needed by others that are not yet formally registered as JVs.
- Cooperatives. Government agencies are often too rigid to be real business partners. By contrast, the cooperatives that were legalized in 1987 for manufacturing and service industries are far more flexible. The only problem in dealing with the Soviet co-ops is that they suffer from a hard-currency scarcity, which is more severe than the scarcity that predominates in the government. In addition, the potential of a strong public or government backlash to these co-ops' new-found freedom could make it less than desirable to do business with them.

THE PARTNERS' CONTRIBUTIONS

The Soviet contribution will often come in the form of buildings, land or water rights, equipment, and rubles. The Western partner's contributions will include licenses, know-how, equipment, and hard currency. The catch is that both sets of contributions are to be valued in rubles according to an agreement between the partners that is reached "with due regard for world market prices" and at the official exchange rate established by Gosbank (the State Bank). That rate, fixed on a certain date agreed to by the JV partners, will serve as the rate for all subsequent contributions.

There are two related areas in which negotiations will be intense: the value to be assigned Soviet contributions "with due regard for world market prices" and the official Soviet exchange rate for convertible currencies, which is not realistic. I recommend that the exchange rate issue be raised forcefully in the negotiation and, if the Soviets show inflexibility on the official rate (which is likely), that the Western partner

Commentary (Continued)

overvalue its noncurrency contributions accordingly. One ploy to beware of is the local agency charging in hard currency for rent and social services. The agreement should stipulate that the Soviet partners can pay through the JV in rubles for office space and services.

Exchange rate distortions may affect the JV later when it generates hard-currency earnings from exports. These funds will be deposited in the JV's hard-currency account. As one expert said, "If the venture's expenses in rubles are not offset by revenues in rubles, then the hard currency will presumably be applied, at the official exchange rate, to make up the difference in the ruble account maintained with Gosbank. Because of ruble overvaluation, this procedure would draw down the hard-currency account at a rate that unfairly prejudices the foreign partner's ability to preserve hard currency for repatriation." This element should be factored into the early negotiations and reflected in the foundation document.

GETTING MONEY OUT OF THE JOINT VENTURES

In the best of possible worlds, the Western partner would be paid for all sales in hard currency. Assuming that this will not happen, the following are strategies to be explored:

- Maximize ruble expenses. If the JV can minimize non-Soviet labor and supplies, ruble earnings can be applied toward the full range of costs. Soviet programmers are paid a fraction of what programmers are paid in the West, and their skills are often equivalent. The firm should therefore review the full range of R&D efforts that are under way in the company and consider the advantages (weighed against the disadvantages) of moving some of these R&D projects inside the JV to benefit from the ruble inconvertibility problem.
- Sell to Soviet enterprises for hard currency. If the JV's product is desired by government enterprises, then the JV could emphasize marketing to those Soviet entities that have hard currency and can pay with that currency. This activity is possible in part because the law now allows the partners to agree on the currency for their internal exchange.
- Move-hard currency profits from the Soviet partner to the Western partner. The JV proposal should stipulate that the Western partner can retain all (or a disproportionate share) of hard-currency profits. The Soviet partner will get an equivalent share of the profits earned in rubles. Normally, of course, the Soviets participate in a JV for the hard-currency earnings, but some partners have other motives that outweigh this one.
- Emphasize hard-currency sales to Soviet citizens and Soviet-based foreigners. Remember that many foreigners are based in the Soviet Union. Likewise, many Soviet individuals and cooperatives have access to hard currency. However, the viability of this market depends upon the success of the JV's strategy for dealing with piracy.
- Insist on hard-currency sales to the JV by the Western partner. The Soviet partner could pay for goods or services supplied by the Western firm in three ways: in commodities that are convertible to dollars on the international market, especially likely when the partner is in that business (such as oil); with countertrade, barter, or buy-back agreements; and in cash. The current practice is tending toward buy-back agreements, under which the Soviets buy manufacturing equipment or technology in return for an agreement that the trading partner will purchase some amount of the products involved.

None of these steps represents a perfect solution to the problem of repatriating profits from a Soviet venture. But the significance of recent reforms should not be understated. The new policy should provide far more realistic ruble exchange rates for those cooperatives and ministries that conduct foreign trade. This means that it will be a little easier to profit from a joint venture in the Soviet Union.

Gordon Feller is president of Integrated Strategies, a consultancy specializing in East-West trade and publisher of the monthly periodical The East/West Report: Strategic Business News for the Perestroika Era. *Readers are invited to call (800) 333-0877 for a sample copy of the report.*

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miserably in agriculture, in consumer goods, and in the transition to new technologies. When Mr. Gorbachev took over in 1985, he found himself in charge of an economy in deep trouble. Grain harvests were declining, production of steel and machine tools were down, and housing starts—despite a critical shortage of housing—were stagnating. Corruption, alcoholism, inefficiency, and red tape were deeply embedded in the society. Resistance to change and an incentive system based on production quantities rather than price or quality had frustrated all efforts at piecemeal reform over the years.

Perhaps most serious of all the problems confronting Mr. Gorbachev, reports Alan B. Sherr, director of the Project on Soviet Foreign Economic Policy and International Security at Brown University, was the Soviet Union's embarrassing failure to keep up in technology. A common theme running through the flood of reformist critiques and decrees emanating from Moscow is the need to use technology to improve efficiency and quality and to break away from dependence on basic industries. Writes Abel Aganbegyan, a top economic advisor to Mr. Gorbachev, in *Perestroika 1989*, a book of essays on the reform process by Soviet experts: "We must press for speedy, revolutionary changes in techniques and technology; switch over to the manufacture of a new generation of machinery and to large-scale application of fundamentally new technologies, and move on to the economy of the scientific-technical revolution, the economy of technological breakthrough, the economy of renewal."

The Soviets realize they cannot achieve this kind of change on their own. Indeed, Marshall I. Goldman, associate director of the Russian Research Center at Harvard University, argues that they may not be able to carry it off at all without all-but-unthinkable changes in their economic and political system. In his book, *Gorbachev's Challenge: Economic Reform in the Age of High Technology*, Mr. Goldman suggests that the Soviets have fallen into a "systems trap" of backwardness in computers, communications, microelectronics, and related disciplines so severe that they cannot catch up in any field without overhauling all of them.

THE TECHNOLOGY GAP

The sorry state of Soviet technology is detailed in *The Soviet Personal Computer Marketplace 1988*, a report by Finnish trade consultant Heikki K. Auvinen to be published shortly by Dataquest. According to this study, Soviet experts complain that production quotas for computers, insufficient in the first place, are not met; that reliability is poor; that personal computers made by different ministries are incompatible; and that data banks are not accessible. The impact is pervasive. The Ministry of Energy complains that its automated control systems are rapidly becoming obsolete, yet computers needed to upgrade them are not available. In another example, the Ministry of Machine Tools needs 400 design workstations in order to develop 800 flexible manufacturing systems. So far, it has received only 46 workstations. And the mean time between failure (MTBF) of Soviet equipment, the ministry finds, is 170 hours instead of the thousands of hours expected in the West.

Another recent study of Soviet technology, carried out by the National Research Council's Committee to Study International Developments in Computer Science and Technology, found that the Soviet Union and its allies are 5 to 10 years behind the West in most areas of computer technology. The committee's findings include the following:

- In microelectronics, the Soviets admit to lagging by two generations. Eastern bloc semiconductor design and processing equipment is inadequate for producing today's high-density circuits. Unable to produce exact copies of Western chips through reverse engineering, the Soviets and their East German allies generally require five years or more to produce functional duplicates of a Western device (see Table 1).
- In technical computers, the Soviets have installed only a few supercomputers, and even these have little more power than the original CRAY-1 machine. Efforts by the Soviet Academy of Scientists and other organizations to develop advanced machines based on reduced instruction set computing (RISC) and multiple microprocessor architectures are still in the prototype stage.
- In mainframes and minicomputers, the Soviets have abandoned attempts to develop machines based on their own designs and have concentrated on duplicating IBM mainframes and Digital Equipment and Hewlett-Packard minis. These copycat machines, handicapped by outdated components and peripherals, are far slower than the originals. However, compatibility with important Western products allows the Soviets to use existing software for many applications.

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Table 1

The East-West Chip Race

Western Chip		Soviet/East German Equivalent	
Name	Year of Appearance	Name	Year of Appearance
Intel 4004	1971-1972	U 808 (GDR)	1978
Intel 8080	1973-1974	K 580	1978-1979
AM 2900 Series	1975	K 1804	1982-1983
Zilog Z8000	1978-1979	U 8000 (GDR)	1983-1984
Intel 8086/88	1978-1979	K 1810	1983-1984
Intel 80286	1982-1983	No equivalent yet seen	
Intel 80386	1985-1986	No equivalent yet seen	

Source: National Research Council

- In microcomputers, the Soviets are barely getting started. The NRC committee cites evidence that only 50,000 personal computers, mostly based on Western designs, have been installed in the Soviet Union. Mr. Auvinen estimates the installed base at between 80,000 and 100,000. And although the latest five-year plan contains an objective of producing 1.1 million personal computers by 1990, Mr. Auvinen believes that this goal is more likely to be met through assembly of imported components than through domestic production.
- In software, progress has been slowed in part by the shortcomings of Soviet hardware, by a shortage of programmers, and also by the nature of the Soviet economy. With little incentive to modernize operations or improve their ability to analyze market data, Soviet enterprises have no need for productivity-enhancing software applications.

PERESTROIKA AND THE COMPUTER

The rise to power of Mikhail Gorbachev and his support for fundamental economic and social changes place the shortcomings of Soviet technology in a merciless spotlight. Widespread application of computer technology is essential to carrying out the management and manufacturing reforms that are at the heart of perestroika. Vast improvements in telecommunications are needed, not only to help decentralize the Soviet economy but to allow Soviet citizens to take full advantage of glasnost. Eventually, a rejuvenated electronics industry will be expected to play a major part in expanding trade, commercializing research, and accelerating the growth of the Soviet economy.

In leaning heavily on technology solutions, which in turn require substantial Western cooperation, Mr. Gorbachev is going far beyond previous efforts to reform the Soviet economy. Before 1960, reform usually consisted of mild reorganizations and entreaties aimed at persuading workers to work harder. Nikita Khrushchev went farther with experimental incentive plans, but until Mr. Gorbachev, no Soviet leader had seriously tampered with the Stalinist system of state ownership and central control. In fact, this system is now so deeply ingrained that even Mr. Gorbachev has refrained from attacking it directly. Writes Mr. Goldman: "There are strong indications that the majority of the population has come to oppose anything more than a marginal adjustment in the economy."

The great problem with the Soviet system of central planning is its failure to provide any incentive for improved performance, higher quality, lower prices, or innovation. This fundamental shortcoming alone explains the Soviet failure to keep up in technology, but it has been compounded by ideological fears that prevented Western companies from participating in the economy and effectively transferring their know-how. Barred since the 1920s from holding any equity interest in the Soviet Union, Western companies often saw their products and technologies misapplied and neglected. Marshall Goldman surveyed 50 Western and Japanese businessmen about their experiences selling equipment to the Soviets and found that the large majority felt their equipment was poorly utilized and badly maintained.

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Commentary

Soviet Trade and Export Controls

By Mark D. Herlach

Even though trade between the superpowers is once more a real possibility, Western businessmen still must negotiate the complex system of export controls imposed by the United States and its allies. The U.S. export licensing regime is based on the proposition that exports of all U.S.-origin commodities and technical data are prohibited unless licensed. The burden rests on the exporter to establish that the export is authorized either by a general license or a validated license.

U.S. controls are administered by numerous agencies, with the Department of Commerce having primary responsibility for civilian exports and the State Department's Office of Munitions Control having authority over military exports. In addition, applications are often referred to other agencies, such as the Department of Defense, for detailed review. A comprehensive review of U.S. export controls would fill a volume, but the following are a few basic rules worth remembering when dealing with exports to the Soviet Union:

- U.S. law requires a license. One of the first steps in any proposed deal should be to determine whether the necessary exports can be authorized under existing regulations. For exports of nonmilitary commodities and technical data, there are broad general licenses that permit exports without the need to obtain specific authorization from the U.S. government. For advanced technology, however, exports require the submission of a license application, detailed review, and specific approval by U.S. authorities.
- Levels of technology and destinations are critical. Both the level of technology to be shipped and the destination affect whether an export can be authorized. Goods that may be shipped to a NATO country are not necessarily available to customers in the Soviet Union. However, even for shipments involving relatively sensitive products and countries, it is sometimes possible to negotiate with U.S. authorities over ways to safeguard basic technology or to downgrade performance so that an export will be allowed.
- U.S. export controls extend beyond the water's edge. Simply because a commodity or technology is outside the territorial boundaries of the United States does not mean that its exportation is uncontrolled. Even the use of U.S. technology in an overseas manufacturing plant may subject the final product to U.S. export controls. This is the case even though the goods themselves would be considered products of the country in which the overseas factory is located.
- Exports take many forms. An export can take place in a variety of contexts. A visit by a Soviet delegation to a U.S. manufacturing facility could result in the exportation of technical data to the Soviet Union. Carrying a floppy disk containing a proprietary computer program on a business trip to the Soviet Union may also be a prohibited export.
- Controls are multilateral. The United States is not the only country with export controls. An organization called the Coordinating Committee for Multilateral Export Control (CoCom) has responsibility for administering export controls for all of the NATO countries (except Iceland) plus Japan. Although U.S. regulations historically have been more restrictive than those agreed to by the CoCom countries, the trend has been toward the multilateral approach. In February, the United States eliminated unilateral controls on a variety of commodities, but the fundamental restrictions remain largely unchanged.
- Violations can be costly. The law includes stringent criminal and civil sanctions for violations. Criminal convictions for violating the Export Administration Act or for submitting false or misleading information can result in large fines and long prison terms. Even civil penalties can have drastic effects on a company's business. Under its denial order authority, the Commerce Department can suspend or revoke a license, deny a company its export privileges, and pursue civil penalties up to $100,000 for each illegal export to the Soviet Union.

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Commentary (Continued)

Companies dealing with the Soviet Union are well advised to consult an expert prior to engaging in any substantive discussion with or shipment to Soviet entities. There is some flexibility under the existing regulations, but the rules are confusing and sometimes appear contradictory. The U.S. government views export controls as necessary to protect national security, but with proper planning, these controls need not interfere with the legitimate activities of U.S. businesses seeking to expand their international marketing activities to the Soviet Union.

Mark D. Herlach is a partner in the Washington office of Coudert Brothers, an international law firm. He works in the field of international trade and serves as an advisor on export controls and related matters.

Mr. Gorbachev, after an initial period of caution, has attacked both the issue of incentives and the problem of technology transfer with a series of bold reforms. According to academician Aganbegyan, who also spoke at the Dataquest-ICD Austria forum, these reforms include:

- Shifting the focus of Soviet economic development from volume of output to efficiency and quality, and from basic industry to consumer products and technology-related industries
- Reducing the authority of central planners over output and prices, with corresponding increases in the autonomy of individual enterprises and cooperatives
- Expanding foreign economic relations, including trade with nonsocialist countries and joint venture investments by Western companies
- Reforming the Soviet financial structure by decentralizing the banking system, bringing prices into line with world levels, and moving the ruble toward full convertibility

These changes are so far-reaching and interrelated that it will be many years before they have the effect that Mr. Gorbachev's advisors hope to see. For example, it is unlikely that the ruble will be fully convertible before the end of the century. Until that happens, trade with the West will lag. Nevertheless, the reforms have already created an opportunity for Western companies to play a meaningful role in the Soviet economy. U.S. trade with the Soviet Union, after languishing for several years, turned up sharply last year (see Figure 1). The WEFA Group forecasts that Soviet trade with all nonsocialist countries will reach $86 billion in 1991, an increase of 28 percent from the 1988 volume of $67 billion (see Figure 2).

Mr. Gorbachev and his colleagues have placed heavy stress on attracting Western investment, primarily through the vehicle of joint ventures with Soviet organizations. By giving Western companies a long-term stake in their economy, the Soviet leaders hope to acquire technology more effectively than in the past, introduce modern techniques of management and production, and develop new industries that are competitive in world markets.

Despite serious limitations in the first laws allowing joint ventures between Soviet enterprises and Western companies, more than 500 proposals for such ventures have been filed and more than 100 approved and registered. Although most of these deals are small, larger companies are testing the water. A group including Chevron, Ford, Eastman Kodak, Johnson & Johnson, and RJR Nabisco is close to signing a blanket trade agreement with an association of 13 different Soviet agencies. Under this arrangement, members of the American Trade Consortium will be able to work out individual joint ventures with a uniform set of guidelines. In another major effort, Alcatel of France is reportedly negotiating a $1 billion sale of telecommunications equipment that would also involve a manufacturing joint venture.

Several joint ventures involving assembly and sales of computer equipment have been put together in the last year. In one of these, called Kompan, a West German company is working with the Science and Technology Corporation (STC) of the Soviet Academy of Sciences not only to improve STC's manufacturing capacity but also to develop the basis for other joint ventures. Dialog, one of the first U.S.-Soviet joint ventures, involves a Chicago trading company and several Soviet organizations, including Moscow State University, the Space Science Research Institute, and the Kamaz Truck Plant. Gerald Y. Genn, president of ICD Austria, the Austrian development agency, estimates that the Soviet Union will need 20 million to 30 million personal computers in the next several years.

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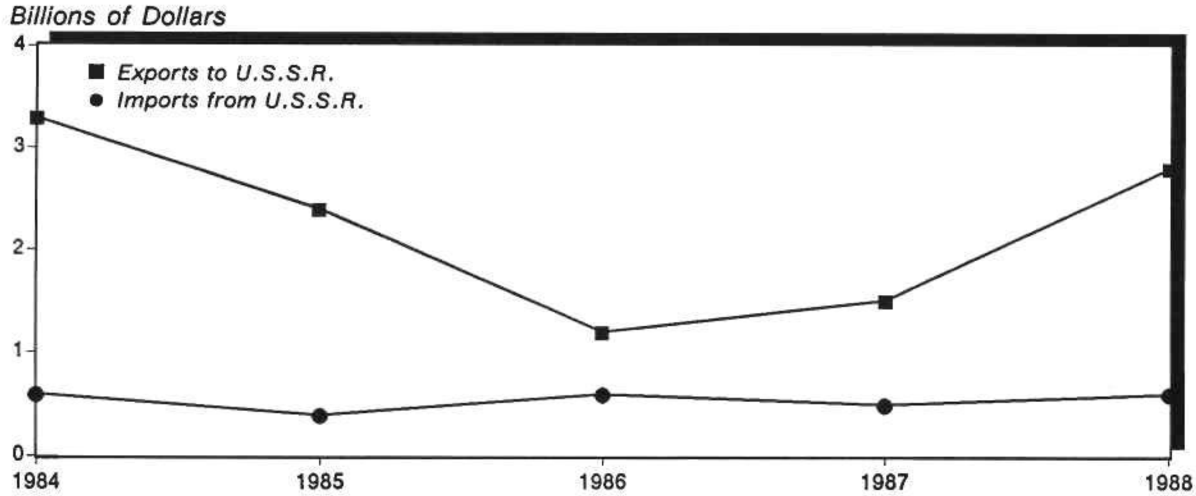
Figure 1

U.S. Trade with the Soviet Union

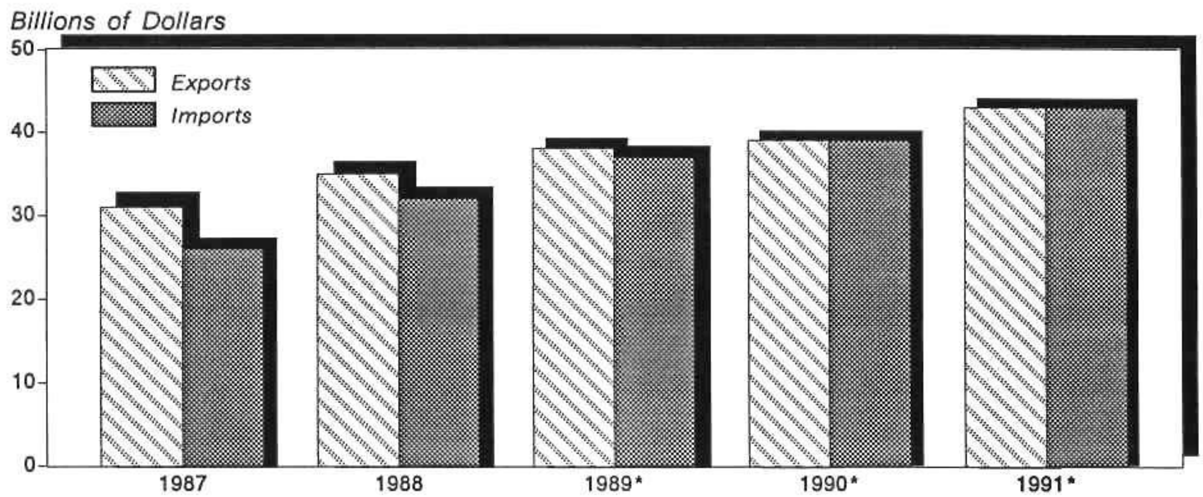


0003464-1

Source: Bureau of the Census

Figure 2

Nonsocialist Trade of the Soviet Union



*Forecast

0003464-2

Source: WEFA Group

DEVELOPING A SOVIET STRATEGY

Despite the publicity surrounding Mr. Gorbachev's dramatic reforms, many technology companies are understandably reluctant to jump in. Their hesitation stems from concerns about their ability to run viable business operations in a communist society and to repatriate their earnings, about the willingness of the U.S. government and its allies to allow exports of up-to-date technology to the Soviet bloc, and about the political risks that investments in the Soviet Union would entail.

Although these issues are far from being fully resolved, enough progress has been made on all three fronts to suggest that many companies

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should begin developing a Soviet market strategy. For their part, the Soviets clearly have no alternative to expanding relations with the capitalist world if they seriously expect to escape their economic dilemma. And the closer these relations become, the less likely it will be that the Soviet Union could again retreat to isolation.

DOING BUSINESS IN THE SOVIET UNION

A flurry of new legislation in the last two years has transformed business conditions for Westerners in the Soviet Union from impossible to very difficult. Richard N. Dean, a Moscow-based attorney for Coudert Brothers, calls the signing of more than 100 joint ventures "an extraordinary accomplishment," considering the economic and political turmoil that has occurred in the Soviet Union recently. But he notes that many points of business law remain unclear and that the infrastructure of communications, housing, and transportation—not to mention markets—is still undeveloped by Western standards. Thus, most Western companies are looking at the Soviet Union less for quick profits than for the chance to build an early position in an emerging market.

One way to do that, thanks to recent legislation, is through a joint venture with a Soviet organization. The original joint venture decree, enacted by the USSR Council of Ministers in January 1987, contained several restrictions that limited the appeal of a Soviet investment. The Western partner could have no more than a 49 percent share of the venture, top management jobs were reserved for Soviet citizens, and sales and purchases in the local market had to go through a Soviet foreign trade organization (FTO). The application of Soviet commercial laws and labor codes to joint ventures was cloudy, and intellectual property was inadequately protected. Most important of all, the problem of repatriating profits remained a difficult issue unless the joint venture could generate hard currency through exports from the Soviet Union or by selling to tourists and other foreigners.

Some of these problems can be alleviated by setting up the joint venture through an affiliate in Austria, where trade with the Eastern bloc is well understood. But many of the issues, including the requirement for buying and selling through FTOs, have been resolved through changes and clarifications of Soviet laws. More reforms are imminent. At the Dataquest-ICD Austria forum, Soviet officials described the sweeping changes envisioned in a December decree as a "radical restructuring of foreign economic activity" in the Soviet Union. The decree abolished the 49 percent equity limitation for foreign partners, opened all joint venture management positions to foreign nationals, liberalized a venture's ability to set its own hiring and wage policies, and extended the tax holiday given to joint ventures. A new law covering intellectual property rights should be completed by the end of 1989, Dr. Levine stated in response to a question.

The Soviets are also opening up their financial system to an unprecedented degree, with the intent of making the ruble a freely convertible currency with its value set by world markets. As it stands, the official rate of 1.66 rubles to the dollar is far above the black market rate of five or more rubles to the dollar. Similarly, official prices often have little relationship to costs of production. According to Eric Stubbs, staff economist of the Brown University Center for Foreign Policy Development, the Soviet system requires calculating some 2,000 different currency coefficients for several types of rubles—most of them noninterchangeable.

In this situation, negotiating equitable values for Soviet and Western partners' contributions to a joint venture, setting prices in rubles of imported goods, and dividing hard-currency earnings have presented serious problems. "Hard currency is a valuable asset in the Soviet Union," observes Mark Vecchio, a Coudert Brothers attorney specializing in Soviet transactions. "Nobody wants to give it up unless there is a more realistic exchange rate." As a result of the hard-currency shortage, most joint ventures have involved some form of "countertrade," in which the foreign partner earns hard currency by selling Soviet goods abroad.

A resolution adopted by the Soviet Council of Ministers in December 1988 appears to start the ruble on the path to convertibility. As a first step, the official value of the ruble will be cut in half in January 1990, and a single exchange rate will go into effect a year later. Another step, which Mr. Aganbegyan said will be taken next year, is a national "auction," through which Soviet enterprises will be able to buy and sell hard currencies. Mr. Stubbs points out that the resolution is vague on how such an auction would work and how it would coexist with present methods of allocating hard-currency reserves.

Nevertheless, the prospect of more realistic handling of foreign exchange matters, coupled with rapid improvements in the climate for foreign investment, make the Soviet market potentially interesting for many Western companies. Joint ventures there, once unthinkable, now deserve serious investigation (see commentary, page 2).

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SHEDDING THE COLD WAR HERITAGE

For many technology companies, however, the Soviet market opportunity still is severely limited by multinational export controls aimed at keeping advanced technologies with military applications out of Soviet hands. Despite the obvious easing of East-West tensions recently, these controls are likely to remain in force for many years—at least until the United States and its allies are persuaded that the Soviet bloc no longer presents a military threat. Said Michael W. Liikala, director of the western region for the U.S. Commerce Department's Bureau of Export Administration: "The fundamental U.S. policy has not changed in regard to export controls. We prohibit trade in strategic goods that would enhance the military position of the Soviet Union and other adversaries."

However, advanced technology is spreading rapidly to countries that are not members of CoCom, the multinational coordinating committee that sets policy for the controls. In addition, CoCom members do not follow the U.S. lead in all cases. As a result of complaints from U.S. companies that they were losing export business unnecessarily, last year's Omnibus Trade Act contained provisions streamlining the administration of export controls. The Commerce Department moved in February to eliminate controls on most products that the United States had restricted unilaterally. And Washington is known to be considering the possibility of decontrolling computers based on technology equivalent to the Intel 80286 microprocessor, a step that would sharply boost personal computer sales to the Soviet Union. Further relaxation of the controls can be expected if the Cold War continues to wind down.

Even within the limits imposed by export controls, many technologies are candidates for joint venture activities or for export to the Soviet Union. For example, exports of most data base software are controlled because the software uses the data encryption-algorithm standard (DES) developed by the National Bureau of Standards in the 1970s, even though the standard has been widely copied. But DataEase International, a Connecticut-based software company, was able to negotiate a distribution contract in the Soviet Union because its relational data base program for the IBM PC does not use DES.
Bo Denysyk, formerly head of the Export Administration and now senior vice president of Global USA, Inc., a Washington-based consulting firm, suggests six other computer-related projects that would be possible under the export control laws:

- Assembly and limited manufacturing of electronic components specifically designed for automotive or home electronics, personal communications up to 150 MHz, certain cameras, and medical prostheses or equipment
- Assembly and limited manufacture of semiconductors with line widths exceeding 5 microns
- Assembly only of personal computers with clock speeds of less than 3 MHz
- Software development concentrating on business and administrative applications such as word processing or accounting
- Assembly and limited manufacture of older computer peripherals such as dot matrix printers, floppy disk drives, and non-Winchester hard disk drives
- Manufacture and assembly of single-layer printed circuit boards

Because the export control laws are so complex, any company contemplating a business relationship with the Soviets should consult the Commerce Department or an outside expert early in the planning process (see commentary, page 6). Even with the best advice, delays should be expected, especially for a joint venture that contemplates ongoing sales of technology and transfers of technical data. Dr. Denysyk and others believe that much could be done to simplify and speed up the processing of export controls. For example, since 1983, the Department of Defense has reviewed all technology exports to the Soviet Union, including low-level computers. Although the DOD seldom rejects an application, says Dr. Denysyk, the review adds 30 to 60 days to the process and sometimes results in costly changes in the product.

AN EVOLVING POLITICAL CLIMATE

No business decisions regarding the Soviet Union can be made without assessing the political risks involved in trading with a country that has been perceived for more than 40 years as the principal adversary of the United States and its allies and investing in an economy that is going through wrenching changes. Events like the recent arrest of West German computer hackers who allegedly tried to tap U.S. computer networks in search of secrets for the KGB can undermine fragile public support for increased Soviet trade—especially in technology. Conservative voices already are questioning whether it is in the interest of the West to help Mr. Gorbachev. In this view, any assistance in the form of credit or technology only postpones the day of reckoning for the communist system and allows the Soviets to maintain their huge military budget.

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Equally grave questions have been raised in regard to Mr. Gorbachev's chances of succeeding in his effort to reform and revitalize the Soviet economy. Zbigniew Brzezinski, former national security advisor to President Jimmy Carter, argues in a new book, *The Grand Failure: The Birth and Death of Communism in the Twentieth Century*, that Mr. Gorbachev will fail because "social receptivity to the needed reforms is lacking" and that the likeliest outcome to perestroika and glasnost is a breakup of the Soviet Union as nationalist conflicts break free of Moscow's control. Another scenario sees conservative forces uniting to oust Mr. Gorbachev and restore policies that are hostile to Western business interests.

Although these outcomes are certainly possible, we believe that unmistakable world trends are forcing the Soviet Union to pursue reforms or risk falling behind a united Europe and an emerging Japan and even China as a superpower. Mr. Gorbachev and his advisors have apparently understood that the dynamics of world leadership have shifted from the military to the economic sphere and that the Soviet system cannot compete in that arena without substantial changes. No matter who is in charge of the Soviet Union, the need to import Western technology and economic ideas will not diminish.

There are risks to the West in helping the Soviet Union make those changes, and certainly there are risks for Western companies planning investments there. On balance, however, we believe that the West can best assure the good behavior of its Soviet neighbor by helping rather than obstructing Mr. Gorbachev. The opportunity is to become so essential to the well-being of the Soviet economy that the relationship can never be broken. A close relationship between capitalists and Marxists is slowly but surely being constructed in China, and there is reason to hope that it can be built in the Soviet Union as well.

For business managers, of course, the issue is whether the investments required to create this relationship will result in profits. Even barring an economic or political disaster, Western investors are likely to wait many years before a significant market for technology-related products emerges in the Soviet Union. Learning to live and do business there will be a difficult experience. Risks, including political risks, are high. For those companies willing and able to persevere, however, the payoff will be a stake in what may be the last great untapped market opportunity of the 20th century.

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Dataquest Inquiry Summary

Semiconductors

June 8, 1992

This month's questions

Products

Markets and Applications

Technologies

Company and Other Issues

In addition to current deliverables, clients will receive an *Inquiry Summary* every month. This issue is the Semiconductor Group's first *Inquiry Summary.* It is intended to keep readers abreast of hot topics and to provide a snapshot of the types of inquiries Dataquest has answered during the past month. Individual summaries are submitted from around the world by Dataquest's staff of Semiconductor Group analysts.

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Products

Q1

What are the current production lead times for gate arrays and CBICs, on average?

A

The current production lead time for gate arrays is 8 to 10 weeks; for CBICs it is 10 to 12 weeks. The lead time average is lengthening because of lower learning curve yields related to newer designs in the 0.8-micron technologies that utilize additional wafer starts. As yields improve, lead times should stabilize and decline slightly.

By Bryan Lewis

Q2

What is happening in 3V static RAMs?

A

Although there is a lot of activity, no real trends are arising. First, let us define what we mean when we say 3V, because there is some confusion.

There are two kinds of 3V SRAMs: those destined for use in battery-operated systems, and those that use reduced voltage swings to improve output speed.

In the first realm, several manufacturers have 3V designs in engineering to support a possible explosion of battery-operated applications, ranging from camcorders and video games up to handy terminals and portable PCs and workslates. Several are screening existing product to operate at reduced speeds at 3V. Micron has introduced a 3V, 20ns, 16Kx16-bit SRAM specifically targeted at battery-operated cache applications, in which it claims that a cache can produce substantial power savings over the same system without a cache. If this is true, expect an explosion in demand of high-speed 3V 8- and 16-bit-wide SRAMs. However, this trend appears more to exist in the minds of SRAM suppliers than in the minds of laptop designers at present. Most 3V applications are still slow SRAM applications.

The reduced voltage swing version of 3V appears to be a field that has only been exploited to date by Performance Semiconductor with some very fast 4Kb SRAMs. This market will emerge much more slowly and will suffer the chicken-and-egg syndrome because 3V very high speed SRAMs will be used in systems with similar logic and processors, whose availability promises to be weak for the near term.

These two different markets share some commonalities. First, EIA's JEDEC standards committee has been working to assure mutually agreed-upon specifications for the logic levels used in both sorts of systems. Second, both trends will be driven somewhat by semiconductor suppliers' desires to use 3V 0.4 micron (and smaller) processes.

Still, Dataquest expects it to be quite a while before either 3V standard becomes the dominant voltage level in the SRAM market.

By Jim Handy

Q3

I understand that analog gallium arsenide (GaAs) IC revenue grew dramatically in 1991. What is driving this growth?

A

In 1991, GaAs analog IC shipments grew to $308 million, an increase of 27.3 percent over 1990. Two primary factors helped boost the sales of these ICs. First, the successful insertion of GaAs ICs in major weapons systems in North America and Europe required production quantities of many types of GaAs ASICs. The second factor was the successful commercialization of GaAs microwave monolithic ICs (MMICs). These ICs found their way into satellite and fiber communications systems, cellular phones, TV receivers, navigation receivers (such as portable GPS types), traffic control, and security systems. The growth by category is shown in Table 1.

By Gary Grandbois

Q4

What are some of the recent developments in flash memory and SSDs?

A

AMD announced the first single-transistor cell 1Mb flash memory device that operates from a single 5V supply. The Am29F010 is by far the fastest flash memory chip with a 45ns read access time, a feature that may eliminate the need to download the flash data to SRAM in order to improve execution time. The Am29F010 is segmented into eight 16KB sectors that can be independently programmed/erased. Endurance is 100,000 cycles per sector.

Table 1
Estimated Merchant Revenue, GaAs Analog ICs (Millions of Dollars)

Product	Revenue 1991	Revenue 1990	Percentage Growth
NRE	47	48	-2.1
MMIC Amps	54	42	28.6
ASICs	164	114	48.9
Others	43	38	13.2
Total Analog GaAs	308	242	27.3

Source: Dataquest (June 1992)

Intel announced an 8Mb flash memory device and the series-2 flash memory cards based on this new flash chip. The 28F008SA can store 1MB of data or code, and by virtue of its pricing ($29.90) comes close to DRAM cost per megabyte. The device uses a 5V power supply for read operations and a 12V supply for write/erase. A 3.3V (read) version is available for portable applications. This traditional single-transistor cell-based design offers 100,000 cycles for endurance rating and 85ns access time. The memory array is segmented into 16 64KB blocks that can be independently erased/programmed. The 28F008SA is the highest-density flash memory offering to date. The series-2 memory cards are based on this new 8Mb flash memory and come in 4MB, 10MB, and 20MB densities priced at $163.50, $331.50, and $611.50, respectively. These cards are clearly aimed at mass storage applications.

AT&T entered the memory card and solid-state disk market by second-sourcing Sun Disk's IDE interface SSD subsystem and card architectures.

Microsoft announced the Flash File System (software), which supports Intel's 8Mb devices. The FFS-2 is now in beta sites and should be available later this year. Microsoft's Flash File software is a key component and necessary for solid-state disk subsystems that (unlike the SunDisk solution) will use off-the-shelf flash memory ICs.

The Personal Computer Memory Card International Association (PCMCIA) has ratified the technical content of two new standards for mass storage on memory cards. The PCMCIA-ATA (AT Attachment) specification incorporates the ATA mass storage protocol as a PCMCIA standard for mass storage on a memory card. The Auto Indexing Mass Storage (AIMS) specification is for memory cards that will be used in electronic imaging and multimedia applications.

By Nick Samaras

Q5 Every day, it seems, I read about a new company entering into or a new product being offered to the memory card market. Are there any guidebooks available that provide a snapshot of all the choices available for memory cards for our printer application?

A Although printers are not the most lively area for using memory cards, there are some examples of printer companies beginning to use such cards to add different fonts.

A good source of information of suppliers of memory cards and connectors is a guide published by AP Research, 19672 Stevens Creek Boulevard, Suite 175, Cupertino, CA 95014-2465; telephone (408) 253-6567/Fax (408) 253-5794.

AP Research offers a directory entitled "IC Cards: A Definitive Reference Guide," which is a comprehensive source of information on memory cards and connectors. Containing over 300 pages, it describes the specifications for more than 800 memory cards and 150 connectors and lists the companies that supply the market. It catalogs a complete listing of PCMCIA/JEIDA cards, JEDEC cards, and other custom memory cards. Each entry describes the producing company, the memory technology employed in the card, pin count, bus width, memory size, and applicable industry standard.

Key suppliers listed in the reference guide include AMP, DDK Electronics (Canada), Datakey, Du Pont Electronics, Epson America, FDK America, FOXCONN International, Fujikura America, Fujitsu Microelectronics, Hirose Electric (USA), ITT Cannon, and dozens more. The guide costs $375 plus sales tax and shipping.

By Lane Mason

Q6 What impact will the Micron Technology dumping suit against Korean DRAM makers have on the market?

A We believe that the impact will be temporary and rather small. It certainly will have nowhere near the impact that the claims filed in 1985 had.

In our view, the aggressive pricing seen in March and April was the result of inventory sell-offs in Japan. The Japanese market has been weak since late 1991, and, with the fiscal year ending March 31, 1992, there was some very aggressive selling to reduce inventories before year-end. This depressed the Japanese market price to below those in the rest of the world. Some of this low pricing, down as low as $2.50 for 1Mb DRAMs and near $10.50 for 4Mb DRAMs, leaked out into the U.S. and Far East markets. The newer DRAM players (such as Hyundai and Goldstar) sometimes met these low prices. Of course, this hurt Micron Technology, which is still 80 percent DRAMs, and a rather late entrant into the 4Mb fray itself. Whether these pricing actions by Hyundai, Goldstar, and Samsung constituted "dumping" is still an open issue.

Nonetheless, we believe that the caution in the market and the firming we have seen in low-end pricing since the suit was filed in April will be temporary, and that prices will resume their steady downward march by midyear.

By Lane Mason

Markets and Applications

Q7 How large is the worldwide cordless telephone market in units? How fast is it growing and how is it distributed geographically?

A Table 2 provides an overview of the worldwide cordless telephone market.

Table 2
Worldwide Cordless Telephone Market*

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Worldwide (Millions of Units)	18.5	22.6	27.5	33.6	38.6	41.5	44.4	14.5
North America Market (%)	65	61	56	49	45	42	40	
European Market (%)	18	20	23	26	28	30	32	
Japan/Asia/ROW Market (%)	17	19	21	24	26	27	28	

*Excludes PCN communicators
Source: Dataquest (June 1992)

Q8

What is the mix of analog and digital in today's systems designs?

A

Based upon a recently completed survey of end users by Dataquest, we believe that today's typical board design in North America is 82 percent digital and 18 percent analog. In Japan, the typical board design has 1 percent more analog functionality, or an 81/19 digital/analog split. Users indicate a small trend to increase the amount of digital functionality, and Dataquest anticipates that in the next three years the typical board design will consist of 83 percent digital functionality and 17 percent analog functionality.

By Bob Beachler

Q9

In "Users Beware of a Truncated 1.5-Micron Gate Array Life Cycle," in the November 25, 1991 Semiconductor Procurement *Dataquest Perspective*, Dataquest warned of the potential impending departure of suppliers from the 1.5-micron CMOS gate array business. What has happened in this market since then?

A

The article proved accurate. For example, during the first quarter of 1992, VLSI closed its 1.5-micron gate array lines. Although 1992 production volume is not negligible, there are few new 1.5 micron designs (for example, low-gate devices).

Based on some user input and related industry sources, Dataquest believes that LSI Logic and Motorola have in effect left the 1.5-micron CMOS gate array business. The financial difficulties of another supplier—IMP—signal the same reality. Fujitsu's view for 1992 is that the company will continue to support users but expects the life cycle to terminate during 1993. National Semiconductor and Toshiba remain committed to serving user demand over the medium term.

By Ronald Bohn

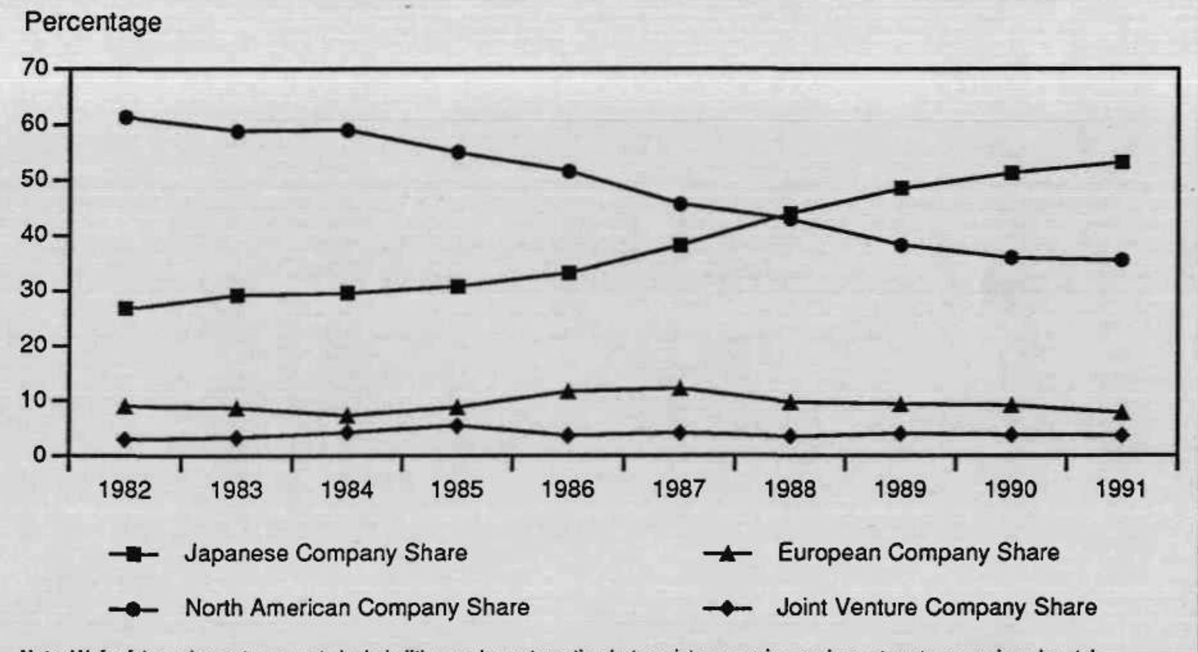
Q10

What has been the trend in regional company ownership of the wafer fabrication equipment market? Are North American companies gaining any market share?

A Trends in regional company market share are a perennial topic of interest in the semiconductor industry, be it for devices, equipment, or materials. Figure 1 shows that the steady increase in market share by Japanese companies throughout the 1980s was mirrored by a similar loss in share by North American companies for key segments of wafer processing equipment. Although North American companies still lost market share last year, the pattern of market share erosion appears to have slowed somewhat. The worldwide market share of North American companies declined only a half of a percentage point in 1991, in contrast to the average 3 percentage point decline observed throughout the 1980s.

On a regional basis, North American companies gained market share position in Japan and Europe last year, and lost share in Asia/Pacific and their home market of the United States. The gain in wafer fab equipment market share in Japan should garner much interest in light of the market access disputes and trade friction that currently characterize U.S./Japanese relations. While the Japanese equipment market experienced only modest growth of 1 percent in 1991, North American wafer fab equipment companies increased their sales in Japan by 19 percent. This increased sales

Figure 1
Worldwide Market Share of Regional Companies for Key Equipment Segments, 1982-1991 (Percentage Revenue in Dollars)



Note: Wafer fab equipment segments include lithography, automatic photoresist processing equipment, wet processing, dry etch, dry strip, deposition, diffusion, rapid thermal processing, ion implantation, critical dimension, and wafer inspection tools.

Source: Dataquest (June 1992)

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activity resulted in a 2.8 percent market share gain for North American companies in Japan, and covered a broad number of equipment categories including lithography, CVD, PVD, silicon epitaxy, ion implantation, and rapid thermal processing equipment.

By Peggy Wood

Q11

Who were the top 10 1991 MOS gate array suppliers in North America?

A

The top 10 suppliers, according to Dataquest's preliminary 1991 market share survey, are listed in order as follows:

- LSI Logic
- Toshiba
- NEC
- VLSI
- Motorola
- Fujitsu
- Seiko
- Oki
- National
- NCR

By Bryan Lewis

Q12

What is the current status of new 16Mb DRAM fab lines in Japan?

A

For 16Mb DRAM production, 19 new fab lines (including planned lines) have been announced in Japan. In 1992, 5 fab lines for 16Mb DRAM are scheduled to start operation (see Table 3).

Table 3
16Mb DRAM Fab Line Plans in Japan

Company	Plant Name	Fab Name	Operating Year	Wafer Size (Inches)
Hitachi	Kofu	K-2	1992-1993	8
Matsushita	Uozu	NA	1992-1993	6
NEC	NEC Kyushu	No. 8	1992	8
Oki	Oki Miyazaki	M3	1992	6
Toshiba	Oita	Step 4	1992	6

NA = Not available
Source: Dataquest (June 1992)

However, two are postponed to 1993 because of the sluggish Japanese semiconductor industry condition.

By Junko Matsubara

Technologies

Q13

What is the status of laser drilling in the PCB market?

A

Laser drilling of PCBs became popular in about 1988. Mechanical drilling and punching are the most common forms of providing interconnect holes for components to boards. Most laser drilling is for high-frequency microwave devices that incorporate TAB bonds. The majority of the boards produced are currently 15 to 20 layers. Laser drilling works extremely well in a software-controlled automated environment.

Laser drilling is more cost-effective than mechanical punching in high-volume production and in areas requiring smaller vias. Mechanical drilling and punching becomes very difficult at 4 to 6 mils. Fifteen layers of tape average 300 vias per layer, with 50 circuits at a cost of 0.03 cents per via; 10,000 circuits cost 0.01 cent per via, and 200,000 circuits cost 0.07 cents per via. NRE charges vary by application, volume, and company from no charge to $100 per layer. Besides improved costs, laser-drilled via holes are round and their shape is always consistent.

By Mary Olsson

Company and Other Issues

Q14

Why is National Semiconductor expanding in Scotland?

A

National announced a $90 million expansion of its manufacturing facility in Greenock, Scotland. The expansion will add facilities for handling 6-inch silicon wafers for the production of bipolar linear or analog circuits to the existing 6-inch line for bipolar logic circuits. First production at the new 6-inch facilities is expected to begin in May 1993.

National is currently running about 65 percent utilization on its fabs. The company has set a goal of raising that utilization rate, and it has announced plans to close three four-inch fabs in Santa Clara, California. Much of this production will be shifted to the Greenock fab running 6-inch wafers. Dataquest estimates that the net result will be 90 percent fab utilization rates, lower manufacturing costs, and improved productivity. In short, it should be a good move for the bottom line.

By Mark FitzGerald

Q15 Please define the Japanese "keiretsu" system and describe how it relates to the Japanese electronics industry.

A Broadly speaking, a keiretsu is a network of corporations that may not have any explicit ownership bonds but, nevertheless, have synergistic relationships. There are two major types of keiretsu: bank-centered and independent keiretsu. Both types have been involved in the Japanese electronics industry.

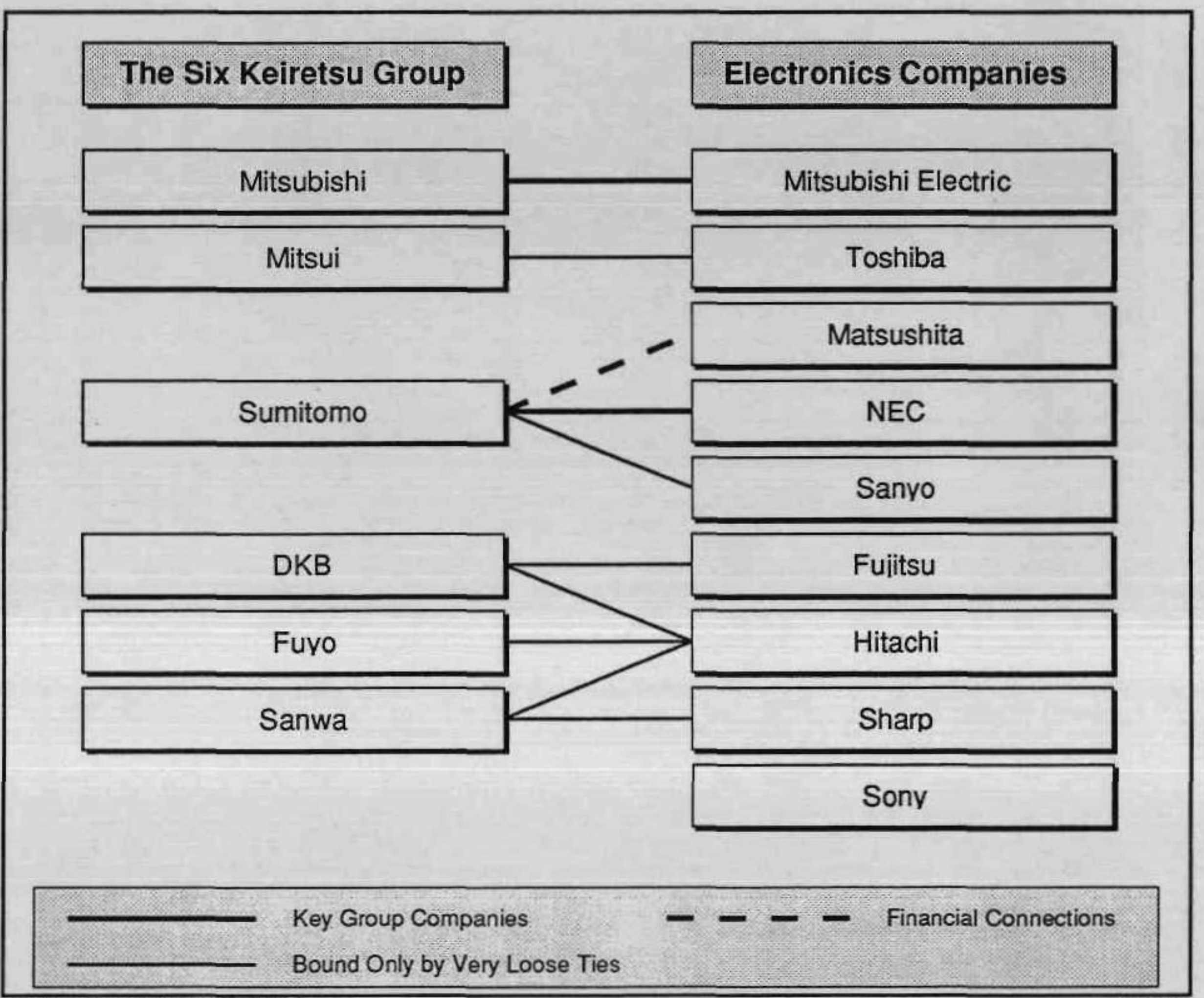
Among the six major bank-centered keiretsu, Mitsui, Mitsubishi, and Sumitomo are direct descendants of the pre-World War II zaibatsu, or family-owned conglomerates. The remaining three are groups centered on the Fuyo (Fuji Bank), Dai-ichi Kangyo, and Sanwa institutions. The bank-centered groups are loosely affiliated and highly diversified. The members have business ties with each other and use the powerful bank in each group as their primary link.

The second type is the so-called independent (or supply) keiretsu. Though a wide variety of groups fall in this category, they are all centered on a large business, usually a manufacturer, and are more specialized than the bank-centered type. The independent groups can be further divided into five subtypes based on their growth mechanisms, as follows:

- Groups containing companies, each in a field different from the parent organization, that have grown into major, semi-autonomous corporations that have in turn spawned their own networks of diverse affiliates and subsidiaries. The group led by Hitachi is representative of this subtype.
- Groups formed by dividing a parent company into operating divisions that have set up separate companies and subsequently grown independent, frequently resulting in overlap, redundancy, or even direct competition. The Matsushita group is a typical example.
- Groups created when a dominant parent/customer company organizes its subcontractors, usually involving the parent's manufacturing processes, into a vertical, multilayered structure. The group formed by Toyota is good illustration of this subtype.
- Groups led by companies that have granted independence to their regional manufacturing subsidiaries and expanded into new fields by spinning off satellite companies and fostering a diversity of affiliates. The subsidiaries forming the NEC group belong to this category.
- Groups of related companies united through the strong leadership of the parent company's founder or owner. The real estate and leisure companies under Seibu Railway form one such group.

Figure 2 shows the relationships between Japan's six major bank-centered keiretsu groups and their relationships to electronic companies. The bank-centered groups are not actually as closely

Figure 2
The Relationships between Six Japanese Keiretsu Groups and Electronics Companies



Source: Dataquest (June 1992)

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bound as foreigners often assume. Cross-shareholding is a common practice among bank-centered keiretsu members and is frequently criticized by foreign investors. However, keiretsu members have found cross-shareholding to have many fringe benefits. It represented an effective means of deterring hostile takeovers and usually provided access to parent company information that could strengthen the financial position of a keiretsu member. For example, Sumitomo Bank was instrumental in providing NEC, a member of the Sumitomo group as well as head of its own subgroup, with timely information in connection with several of NEC's major investments in the semiconductor field. All members of the group benefited. Those that do not benefit from these relationships are those that do not belong to a large keiretsu group. Evidently this places pressure on smaller corporations to join a keiretsu, which in turn raises issues concerning antitrust principles.

In today's electronics industry, technology exchanges across company boundaries are a virtual necessity as no single company or keiretsu can compete as a totally independent or isolated entity. The resources, in terms of capital investment, R&D expense, and personnel required to successfully produce a single leading-edge product is simply too great, or rather the risk burden is too great, to bear. Witness the joint venture Display Technologies, formed by an alliance between Toshiba and IBM in an effort to supply thin film transistor-based LCD display panels.

Keiretsu will probably continue to flourish in one form or another in Japan. As far as the electronics industry is concerned, one could say that the traditional keiretsu is evolving. Replacing the interdependent family of companies of the old keiretsu is a more loosely grouped organization that participates in joint ventures and alliances with any number of nonkeiretsu companies.

By Junko Matsubara

Q16 What does Goldstar's R&D picture look like?

A

Since the opening of Korea's first privately owned R&D center in 1975, the Goldstar Central Research Laboratory, Goldstar has placed great emphasis on developing its own technology. In 1990, there were 3,550 researchers at the Central Research Laboratory, Information Systems Laboratory, Production Engineering Research Laboratory, Quality Assurance Laboratory, and seven regional laboratories. Goldstar also has three overseas research laboratories, one each in California, Japan, and Ireland. In 1990, Goldstar spent 165 billion won on R&D, representing 5.5 of sales for that year. Goldstar plans to devote 7 percent of annual sales to R&D by the year 2000. The number of R&D personnel is expected to increase from 8 percent of the company's total employees in 1990 to about 15 percent by the year 2000.

The following are Goldstar's semiconductor R&D spending from 1986 to the present (U.S. dollars):

- 1986, $10 million
- 1987, $36 million
- 1988, $45 million
- 1989, $50 million
- 1990, $30 million
- 1991, $50 million
- 1992, $70 million (estimated)

By J.H. Son

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Semiconductors *Worldwide*
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Products

Q1

Which ASIC suppliers have announced sub-0.8-micron ASIC products to date?

A

There have been three announcements to date, as follows:

- On April 6, 1992, LSI Logic announced a 0.6-micron (drawn) gate array line with up to 600,000 usable gates.
- On April 14, 1992, Toshiba announced a 0.5-micron (drawn) gate array line with up to 560,000 usable gates.
- On June 8, 1992, AT&T announced a 0.6-micron (L-effective) CBIC line with both 3V and 5V libraries.

By Bryan Lewis

Q2

What is the component cost of a typical 386SX personal computer today?

A

The typical component cost of a basic 386SX PC selling for $1,500 is $935. The remaining $565 cost includes labor, overhead, sales and general administration, and markup. Table 1, which is based on Semiconductor Applications Market Service I/O analysis, shows the estimated cost breakout.

Table 1
Cost Breakout for a Basic $1,500 386SX

Component	Cost ($)	% of Total Cost
VGA Monitor	200	13
Motherboard	180	12 (assuming some I/O)
Keyboard	75	5
Disk Drive	240	17
Memory Modules	140	9
Graphics	100	6
Total	935	62

Source: Dataquest (July 1992)

By Greg Sheppard

Q3

What are the monthly 1Mb DRAM and 4Mb DRAM North American price trends from April 1992 through mid-June 1992?

A Table 2 shows the price trends for both products.

Table 2
Price Trends for 1Mb and 4Mb DRAMs

Date	1Mb DRAM	4Mb DRAM
4/1/92	$3.15-$3.50	$12.25-$12.85
5/1/92	$3.10-$3.30	$11.85-$12.35
6/1/92	$3.15-$3.35	$11.65-$12.00
6/15/92	$3.15-$3.25	$11.45-$12.00

Source: Dataquest (July 1992)

By Mark Guidici

Q4

What have you been seeing in volume discount pricing on the 1Mb DRAM from the first quarter of 1991 to the second quarter of 1992?

A Table 3 shows typical pricing for lots of 100k to 200k pieces. The discount can range anywhere from 2 to 10 percent with a purchase of 1 million units or more.

Table 3
1MB DRAM Pricing in Lots of 100K to 200K

Quarter	Price ($)
Q1/91	4.55
Q2/91	4.50
Q3/91	4.33
Q4/91	4.00
Q1/92	3.80
Q2/92	3.50

Source: Dataquest (July 1992)

By Ronald Bohn

Markets and Applications

Q5

In a May 18, 1992 *Dataquest Perspective* article published by the Semiconductor Equipment, Manufacturing, and Materials Service, you described how Japanese wafer fab equipment companies have continued to gain market share in the worldwide wafer fab equipment market. Has this market share gain been observed in all major segments of equipment?

A

In the past five years, Japanese equipment companies increased their share of the worldwide wafer fab equipment market from 38 percent share in 1987 to 53 percent share last year. As Table 4 shows, the Japanese equipment companies have achieved market share gains in all major categories of front-end wafer fab equipment. Japanese companies accounted for 50 percent or more of worldwide sales in 7 of the 11 categories of equipment identified in Table 4, In 1991. U.S. companies still hold a strong position in the CVD and implant equipment markets.

Japanese companies have established dominant share in these equipment categories through a combination of domestic technology development and acquisition of overseas companies and their technology. In the cases of diffusion and critical dimension (CD) measurement equipment, Japanese companies led the way in establishing vertical diffusion and CD SEM systems as next-generation replacement technologies for the more traditional segments of horizontal diffusion furnaces and optical CD measurement. The Japanese companies hold a strong position in the stepper market because powerhouse optics companies Nikon and Canon chose to manufacture full stepper systems rather than just supply sophisticated lens optics to other stepper vendors. Tokyo Electron's buyout of the TEL/Lam and TEL/Thermco joint ventures added dry etch and tube LPCVD technology, originally developed at U.S. companies, to an already flourishing technology base in Japan. In 1990, dominant share of the PVD market shifted from U.S. companies to the Japanese, in large part because Sony acquired sputter equipment manufacturer Materials Research Corporation.

Table 4
Japanese Company Share of the Worldwide Market for Key Segments of Wafer Fab Equipment (Percentage of Dollars)

Equipment Category	1987	1991	Gain in Share
Steppers	68	82	14
Wet Process	40	67	26
Track	46	62	16
Diffusion	23	61	38
Critical Dimension	54	61	7
PVD	41	57	16
Dry Strip	47	50	2
Dry Etch	24	45	21
Wafer Inspection	27	42	15
CVD	14	26	13
Implant	14	18	4

Source: Dataquest (July 1992)

By Peggy Wood

Q6

Is the static RAM market about to be taken over by alternative technologies?

A

Static RAMs are now, always have been, and will probably always be in what appears to be a precarious position. All of today's SRAM applications will eventually be displaced by either increased integration, where the SRAM will be pulled into the device that currently accesses it, better alternatives such as fast DRAM, or inexpensive flash memories, or simple obsolescence, where the need for the end system disappears. On the other hand, the majority of today's SRAM applications were unheard of 10 years ago, and the applications that will consume the majority of SRAMs 10 years from now have yet to be explored.

As an example, back in 1982, microcontrollers had no more than 256 bytes of internal SRAM, there were no DSP chips or ASICs, all modems were straight linear designs, mainframes tended to use SRAMs for main memory, fax machines were rare, and cache memories were only used in the most esoteric mainframe computers and certain superminicomputers. Hot consumer products included phone recorders, movie cameras, and personal stereos. Twelve-inch laser disks were being touted as a means of showing movies in the home. The PC was just catching on, usually with a

300K 5-inch floppy disk as the only mass storage device. The state-of-the-art production SRAM was a 70ns 2Kx8, and the worldwide SRAM market was about $540 million.

Today, microcontrollers have anywhere up to 16KB of internal SRAM displacing the SRAM previously used in small systems, DSPs and ASICs with internal SRAM abound, and most 32-bit microprocessors have internal caches of up to 8KB. Mainframes have all but stopped using SRAM as main memory, in favor of DRAMs augmented by fast SRAM caches. Faxes are everywhere, about half of all desktop computers offer external SRAM caches, and the preferred modem implementation is based on DSP. Hot consumer products include hand-held camcorders and musical 5-inch laser disk (CD) players. Burgeoning SRAM applications are taking root in hand-held computing and hard disk caches, things unthought-of 10 years earlier. The state-of-the-art production SRAM is a 15ns 1Mb, and the worldwide SRAM market is expected to be closing in on $3 billion.

In 2002, DSP will find itself in consumer applications ranging from HDTV to digital cellular telephones, as well as in compressing faxes. Typical DSPs, microcontrollers, and ASICs are likely to contain up to 1MB of SRAM, and microprocessor chips will offer cache sizes of up to 512KB, probably in support of multiple CPUs. The popularity of external SRAM caches in personal computing systems will probably have died, and extremely fast DRAMs likely will find prevalence in large computer caches. New applications for caches, which may be serviced by a combination of SRAM and DRAM, should arrive in data communication within personal systems. Flash memory will have replaced SRAM in many battery-operated computing applications. The state-of-the-art SRAM should be a 6ns 128Mb device. The SRAM market will have continued to grow to about the $15 billion level.

SRAM has been threatened at each of these stages. At each stage the major applications of SRAMs have been radically different than for either the preceding or following decade. Dataquest expects SRAM to continue to grow, with increases in density, speed, and economy driving the invention of new applications.

By Jim Handy

Q7 What is Dataquest's latest Japanese electronic equipment production forecast?

A See Table 5.

Table 5
Dataquest's Japanese Electronic Equipment Production Forecast (Billions of Yen)

	1991	1992	1996	CAGR (%) 1991-1996
Data Processing	6,977	7,191	8,786	4.7
Communication	3,118	3,250	4,800	9.0
Industrial	3,888	3,960	5,533	7.3
Consumer	8,389	8,707	11,014	5.6
Transportation	2,261	2,269	2,795	4.3
Total	24,633	25,377	32,928	6.0

Source: Dataquest (July 1992)

By Kun Soo Lee

Q8

What is the mil/aero market for analog ICs?

A See Table 6.

Table 6
Estimated 1991 Mil/Aero Market for Analog ICs

	1991 Mil/Aero Revenue ($M)
Analog Monolithic	660
Linear	293
Mixed-Signal	313
Analog Hybrids (from Semiconductor Vendors Only)	85

Source: Dataquest (July 1992)

By Greg Sheppard

Q9

What is the size of the market and market share for charge-coupled device (CCD) image sensors?

A Optical CCDs have shown strong growth in recent years because of their use for image sensing in camcorders and fax machines. Because of the strong consumer market for these devices, the leading consumers and manufacturers are in Japan. Dataquest's 1991 market share estimates are in Table 7.

Table 7
1991 Market Share Estimates for CCDs

Rank	Company	Market Share (%)	Revenue ($M)
1	Sony Corp.	34.5	194.0
2	Matsushita Electronics Co.	32.9	185.0
3	Texas Instruments	7.5	42.0
4	Toshiba Corp.	7.1	40.0
5	NEC Corp.	5.9	33.0
6	Sharp	3.9	22.0
7	Sanyo	1.8	10.0
8	Hamamatsu Photonics K.K.	1.8	10.0
9	Fujitsu	1.2	7.0
10	Tektronix Inc.	0.9	5.0
	Others	2.5	14.0
Total		100.0	562.0

Source: Dataquest (July 1992)

By Gary Grandbois

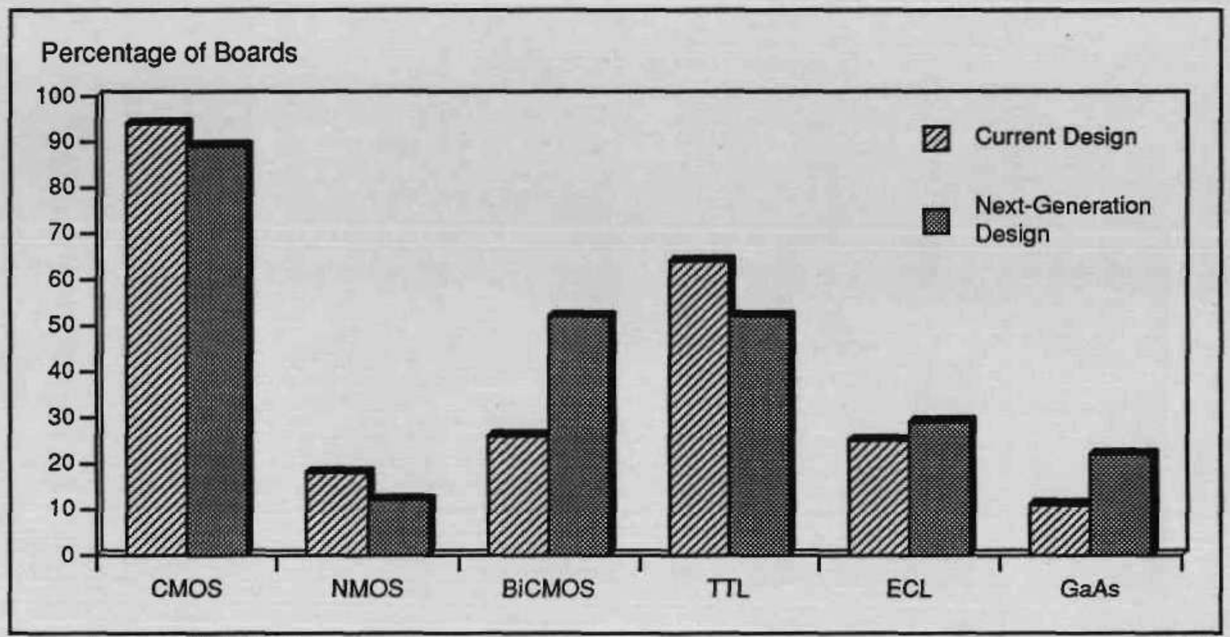
Technologies

Q10 What technologies are designers using for their standard ICs?

A Dataquest investigated technology usage by North American designers and asked them what types of technologies they were using for standard ICs (see Figure 1). As expected, CMOS and TTL were the most widespread technologies. However, North American designers will begin to experiment with more GaAs and BiCMOS devices for speed-critical and high-drive applications. This information should be used for technology acceptance purposes only, as Dataquest believes that the majority of volume opportunities will be dominated by CMOS technologies for the next three to five years.

By Robert K. Beachler

Figure 1
North American Standard IC Technology Use



Source: Dataquest (July 1992)

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Company and Other Issues

Q11 Who are the largest mass merchandisers of electronics in the United States?

A See Table 8 for the top 10 in terms of 1991 electronic sales, according to *TWICE*, an industry trade journal.

Table 8
Top 10 Mass Merchandisers

Company	Sales ($)
Radio Shack	2.75 billion
K Mart	2.74 billion
Sears	2.6 billion
Circuit City	2.3 billion
Service Merchandise	1.5 billion
Wal-Mart	1.1 billion
Target	900 million
Silo	816 million
Sam's Wholesale Club	780 million
Montgomery Ward	763 million

Source: TWICE

By Greg Sheppard

Q12

We depend heavily on DRAMs from Siemens for our European operations. Recent articles in various trade journals, and Siemens' pullback from the 64Mb program with IBM, both indicate a reduced commitment by Siemens to being a first-tier player in the DRAM business. What should we do?

A

Perhaps no company has agonized more, for longer, than Siemens about its DRAM future. Still, it has managed to maintain a solid competitive position as the sole native European DRAM supplier--price competitive and with state-of-the-art product. It has achieved this through licenses with Toshiba for its successful 1Mb program, through government and Siemens Corporate funding for the 4Mb program, and through 64Mb and 16Mb technology in the past 18 months from its joint ventures with IBM. On June 19, Siemens announced a pullback from its 64Mb program, but vowed to continue to participate through the 16Mb generation. It has decided against building an additional advanced 64Mb facility.

The forward economics of DRAM process development and facilities are forbidding, especially for a company never recognized as a low-cost manufacturing powerhouse. Even in 1989, the second of the most recent DRAM glory years, Siemens lost money. From a profitability standpoint, 1990 and 1991 must have looked horrendous, with Siemens having a smaller presence in the 4Mb than it had in the 1Mb in 1988 to 1990, plus advanced development costs to support the IBM DRAM ventures.

But Siemens is hanging in there, and we believe that IBM has little intention of letting the last thread of "domestic European sourcing" pass through its hands. Already, though, Siemens' own commitment to a second fab was withdrawn. It also has already announced availability of 16Mb DRAMs from the IBM joint venture. With the 16Mb DRAM already coming on, and IBM as a partner, that takes one close to the end of the decade.

For its own part, IBM has made immense efforts to shore up the non-Japanese competitive semiconductor market over the past 5 to 6 years, with some success, through joint venture, technology licensing, and other alliances. Siemens may very well appear as IBM's surrogate entry into the merchant semiconductor business, or merely the European marketing arm for IBM's announced entry into the merchant DRAM market. As it stands now, Siemens is now, in many ways, already a seller of IBM rebranded DRAM products with whom one can be assured of technical leadership (via IBM).

But clearly, with the changes that have happened in the industry in the past four to five years--technology disassociated from manufacturing from marketing, plus the political constraints in which the industry must operate--the procurement questions are far more complex. At the same time, RAM users have a far wider range of supplier relationships to choose from. Users that feel a weakening commitment to domestic European DRAM supplies would do well to evaluate their procurement options in light of where the industry has been the past four to five years, and look at equity relations with European suppliers, binding purchase commitments, or relations with reliable Japanese, U.S., or Korean sources now being established in Europe.

By Lane Mason

Q13

How many FPD fab lines of Japanese manufacturers are scheduled to start production in 1992?

A

A total of nine lines of flat panel display (FPD) are planned to start production in 1992. See Table 9.

By Junko Matsubara

Table 9
Flat Panel Display Fab Lines (Production Starts in 1992)

Company	City	Fab Name	Production Starts	Product
Citizen	Hachinohe	NA	4/92	STN
Hoshi	Kobe	Nishijin	1992	a-SiTFT
Matsushita	Ishikawa	Ishikawa	3/92	10-inch TFT
Mitsubishi	Kumamoto	Advanced Display	Q1/92	10-, 15-inch TFT
Optrex	Amagasaki	Amagasaki 2	1992/1993	TN, STN
Seiko Epson	Malaysia	Penun	1992	TN
Sharp Electronics	Taiwan	SET	2/92	STN assembly
Sony	Nagasaki	Nagasaki	Q1/92	10-inch TFT
Toshiba	Fukaya	Pilot Line	Q3/92	TFT

NA = Not available
Notes:
FPD: Flat Panel Display
LCD: Liquid Crystal Display
TFT: Thin Film Transistor
MIM: Metal Insulator Metal
TN: Twisted Nematic
STN: Super Twisted Nematic
Source: Dataquest (July 1992)

Q14

Do you have a measure of the royalty flows throughout the semiconductor industry for the past several years, and who the biggest payers and beneficiaries are?

A

Texas Instruments, of course, is by far the most visible, especially since it raised the ante in the 1987 round of licensing negotiations. In 1992, net royalty income for TI from its patent portfolio (mostly semiconductors) was $256 million. Although not nearly so public with its licensing program, or its income derived from royalties, perhaps SGS-Thomson Microelectronics is the second biggest winner, with press reports last year estimating its returns since 1987 at more than $350 million. Much of its portfolio was obtained through its purchase of Mostek Corp. in 1987 for $70 million, and with it Mostek's substantial DRAM and memory patent portfolio. In fall 1990, Motorola also announced a microcontroller licensing agreement with Mitsubishi expected to net $100 million over the life of the agreement. Intel and IBM, though far quieter about their efforts, are also big gainers. Standard Microsystems' broad licensing agreements from the 1970s and 1980s were substantial, but truly pale against those that have come later. Just this past quarter, NSC announced fiscal fourth-quarter gains of $11 million from licenses, substantially greater than it had ever gained.

The biggest payers are the DRAM makers. Micron Technology has paid out (or given debt) of about $50 million to both Intel and IBM since 1989, for technology licenses. Its payments have averaged more than 9 percent of sales for each of the past three years. The Korean DRAM makers each are paying an estimated 10 percent or more of revenue back to the key DRAM patent holders, including many leading Japanese DRAM makers. Of course, all the Japanese themselves are licensees of Texas Instruments and of STM, also.

Newcomers to the DRAM business obviously face a formidable barrier to entry in the IPR arena. But although such licenses are expensive, they can be overcome. And unlike in non-DRAM areas, the licenses are available and can be had for a price. While such sums are significant, one might ask at the same time whether a company such as AMD would rather pay a 10 percent per-unit fee to Intel for rights to the 3h86, or be excluded entirely.

These are only the most visible transactions, in which money changed hands. However, the vast majority of returns on IPR results from superior products that incorporate proprietary technologies. Also, often IPR is traded for other valuable compensation, such as foundry rights, cross licenses, or marketing rights. Each of these also contains an implicit "return on IPR" that is difficult to value precisely.

By Lane Mason

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Semiconductors *Worldwide*

September 14, 1992

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SCWW-COR-IS-9204

Products

Q1

What is the latest quarterly single in-line memory module pricing in Japan?

A See Table 1, which is based on volume mean prices in Japan.

Table 1
SIMM Volume Mean Price in Japan (Yen)

Configuration	Q1/92	Q2/92	Q3/92	Q4/92
1Mbx9	5,250	4,400	3,940	3,640
512Kbx36	-	10,270	8,710	7,800
1Mbx36	-	14,950	13,650	12,480
2Mbx36	-	31,200	28,080	25,480

Note: 4Mbx16 price is about ¥2,000 less expensive than the x36 version. The price for parity check version has about a 10 percent premium.
Source: Dataquest (September 1992)

Akira Minamikawa

Q2

What is Dataquest's definition of MCM-L?

A In its market coverage of the multichip module (MCM) market, Dataquest adheres to the IPC definitions of the MCM market. MCM-L modules use PWB technology of reinforced laminates. The MCM-L category of the total MCM market represents a very low cost module with moderate performance improvements over single-chip designs. The laminate designs will serve 50-MHz to 60-MHz systems. Design applications for the MCM-L category are expected to be newer miniature-designed PCs such as pocket computers, as well as memory modules such as stackable memory designs, and multiple COB design applications with low I/O and lower speed demands. A comparison of individually packaged chips with MCM-L designs indicates that costs should be comparative if the module yields are good.

Mary Ann Olsson

Q3

What are the estimated 4Mb DRAM shipments for the first half of 1992?

A See Table 2.

Lane Mason

Table 2
Estimated 4Mb DRAM Production Rates, 1991-1992 (Millions of Units)

	1991	Q1/92	Q2/92
Fujitsu	12.8	5.4	5.8
GoldStar	2.6	4.0	5.0
Hitachi	26.0	11.1	12.7
Hyundai	3.8	2.6	4.0
Intel	0	0	0
Matsushita	1.6	1.0	1.1
Micron Tech	1.8	1.5	3.1
Mitsubishi	13.2	7.4	9.5
Motorola	2.6	1.6	1.9
NEC	16.6	7.8	9.5
NMB	0.2	0.1	0.1
Oki	8.3	4.1	5.0
Samsung	21.0	12.5	16.5
Sanyo	0	0	0.1
Sharp	0.4	0.3	0.3
Siemens	3.9	3.1	3.8
Texas Instruments	7.8	5.4	7.6
Toshiba	22.0	9.8	11.7
Vitelic	0	0	0
Total	144.6	77.7	97.7
ASP ($)	17.62	13.00	11.70
Revenue ($M)	2,548	1,010	1,143

Source: Dataquest (September 1992)

Markets and Applications

Q4 What is the size of Japanese semiconductor gas market?

A See Table 3.

Kunio Achiwa

Table 3
1990 Japanese Semiconductor Gas Market (Millions of Dollars)

Bulk Gas	
Nitrogen	189.8
Hydrogen	32.5
Oxygen	10.0
Argon	18.7
Bulk Gas Total	251.0
Specialty Gas	
Silicon Precursor	30.3
Dopant	13.4
Etching	20.7
Reactant	6.2
Others	1.1
Specialty Gas Total	71.7
Total Japanese Gas Market	322.7

Source: Dataquest (September 1992)

Q5 Who were the top 10 semiconductor suppliers to the communications market for 1991?

A See Table 4.

Gregory Sheppard

Table 4
Worldwide Semiconductor Shipments to Communications Applications (Millions of Dollars)

	1990	1991	Growth (%) 1990-1991
Motorola	896	1,027	14.6
NEC	783	859	9.7
Toshiba	624	687	10.1
Fujitsu	624	649	4.0
AT&T	539	520	-3.4
Hitachi	457	452	-1.1
Texas Instruments	397	411	3.5
SGS-Thomson	352	359	2.0
National Semiconductor	364	352	-3.2
Philips	297	303	2.1
Top 10 Total	5,333	5,620	5.4

Source: Dataquest (September 1992)

Q6

Can you provide some insight on the cache-tag RAM market?

A

Few markets are as shrouded in obscurity as the cache-tag RAM market. This comes from a lack of deep study by market research companies because of the market's low sales and small number of contributors.

Dataquest estimates the worldwide cache-tag market to be between U.S.$10 million and U.S.$20 million. This is in sharp disparity, we are told, with the figure from our competitor, In-Stat, which estimates the market to be about $110 million. Why the difference? Because Dataquest reports only those specialty SRAM devices designed to be cache-tags, whereas we hear that the In-Stat number includes standard SRAMs used in cache-tag applications. This is not necessarily a bad approach, because it is an indication of the available market. However, the Dataquest figure is meant only to state the actual market for the specialty devices themselves, rather than to include alternatives.

The market for cache-tag SRAMs has not thrived, even though devices have been available from the cache-tag pioneer, Texas Instruments, since about 1984. One good reason is that these devices are rarely multiply sourced. Thus system designers are inclined to use alternative routes when designing caches, in order to keep costs down (sole-sourced devices are not subject to competitive pressures as fiercely as are widely sourced devices). These alternatives come in several forms, driven quite simply by the vast number of ways that exist to partition cache designs. A cache-tag RAM is a somewhat standard SRAM with a high-speed comparator incorporated. Some designs use a standard SRAM with an external comparator as an alternative, and others put the comparator into an ASIC, along with the other logic required to implement the cache. Finally, some designers absorb both the comparator and the SRAM into a cache controller chip.

Dataquest does not expect any big changes in this scenario. Companies that now offer cache-tag SRAMs will continue to offer them, but some may choose not to add new offerings. Few new manufacturers are expected to join the fray, and we do not expect this market to ever reach the $100 million mark.

Jim Handy

Q7

What is Dataquest's analysis of the semiconductor market in Latin America?

A

The Latin American semiconductor market is increasingly interesting, with the coming of more open, market-oriented economies. Last year, Brazil made significant reductions in its long-standing trade barriers, opening the market for sales of foreign computers, telecom equipment, and components, and for foreign investment. Argentina, Mexico (especially with the coming North American Free

Trade Agreement, or NAFTA), and Chile are also increasingly attractive for investment and sales opportunities.

Many are prone to dismiss Latin America because of its government policies and relatively lower per-capita incomes. But with a combined population of 450 million, a substantial middle class of final consumers is spread through Latin America. Liberalized investment policies will certainly act to increase the domestic electronics production and semiconductor consumption.

Brazil, with a population of 165 million, is by far the largest semiconductor market. According to a recent report by the American Consulate in Rio de Janeiro, the Brazilian IC market for 1991 was estimated to be about $460 million (up to 50 percent larger if illegal imports were included). The reduction of stiff import restrictions will undoubtedly move "contraband" into legitimate channels.

According to U.S. Department of Commerce export-import data, U.S. net exports of semiconductors to Mexico in 1991 were about $85 million, and the overall consumption may be 1.5 to 2.5 times that amount, if all net sales into Mexico from other countries are included. The Argentine market is about $80 million to $100 million, and the markets of other countries are smaller still. Argentina and Brazil also have some domestic semiconductor production capabilities, which are largely confined to older bipolar technologies.

For Mexico, NAFTA should be a significant stimulus to investment and consumption for semiconductors throughout the decade.

Lane Mason

Q8

What is collimated sputtering and what effect will it have on the CVD metal market?

A

Collimated sputtering is a technique in which a collimator, which is a type of filter, is placed between the sputtering source and the wafer in a conventional sputtering system. The collimator only permits metal atoms to pass that are nearly perpendicular to the wafer, and blocks divergent atoms. The result is that metal deposition can be realized in small, high-aspect-ratio contacts and vias with excellent step coverage. Experimental studies have successfully deposited metal into contacts with aspect ratios as high as 7:1. However, for practical applications, the technique will probably not be economical beyond the 0.35-micron technology generation, which will utilize via aspect ratios of between 2:1 and 3:1.

Dataquest believes that the dominant applications for collimated sputtering will be the deposition of diffusion barrier materials and adhesion layers for CVD tungsten deposition. The most widely used materials are Ti/TiN or TiW for diffusion barriers, and TiN for the tungsten adhesion layer. Collimated sputtering has several inherent advantages over CVD for these materials. The film is deposited at low temperature, possesses known properties, and utilizes a mature equipment technology with a relatively inexpensive modification. The only major drawback is that the net deposition rate is reduced by the collimator, thereby reducing throughput. The collimator also presents a potential source of particles, but existing techniques for particle control should prevent that from becoming a serious problem.

The net result is that the Ti and TiN sputter applications market will grow at a healthy rate, at least through 1996. Table 5 shows the forecast revenue growth in the sputter market segmented by film application. The market for Ti and TiN sputtered films is expected to grow at 16.7 percent and 19.1 percent CAGR, respectively. This growth will be driven by the increased use of Ti/TiN barriers and tungsten for contact/via plugs and interconnect in process flows as a greater fraction of the fab capacity shifts to 0.35- to 0.5-micron technology levels. Dataquest therefore believes that the market for CVD TiN will not begin to develop until the 1995-1996 time frame.

Charles Boucher

Table 5
Worldwide Sputtering Equipment Market Forecast, by Film Application (Millions of Dollars)

Sputtered Film	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Aluminum Alloys	281	265	290	339	394	452	10.0
TiW	24	20	21	20	20	22	-1.8
TiN	42	45	53	69	85	102	19.6
Titanium	55	57	67	85	102	120	17.1
MoSix	15	12	10	10	11	12	-4.0
WSix	8	8	9	10	11	12	8.2
Other Films	13	11	11	11	12	13	0.1
Total Worldwide	438	416	460	546	637	734	10.9

Source: Dataquest (September 1992)

Company and Other Issues

Q9 In reviewing Dataquest's recent capital spending forecast and semiconductor production forecast, we noticed that the ratio of capital spending to production in the United States has dropped. Please explain your reasoning behind this trend.

A The reasoning is as follows:

- In the short run, the worldwide overcapacity situation means that revenue can grow without additional capacity.
- Over the longer term, Dataquest expects device makers to focus on raising their fab utilization rates. National is a good example. It has gone from 55 percent utilization to more than 70 percent by closing older fabs. Further evidence of this trend is the increased level of fab closures in the United States (19 in the last two years).
- Dataquest believes that the number of "green-field" sites in the United States will decline dramatically from historical levels. Consequently, land purchases and building infrastructures will decline as companies focus more on upgrading or retrofitting existing facilities.
- Military capital spending is expected to decline. Though small, these cuts will pull down the ratio because military capital spending is high relative to the IC revenue generated.
- Though equipment ASPs are increasing quickly, we expect productivity gains to keep ahead of the ASP curve. The sharp decline in the annual unit shipment of steppers is a prime example.
- The growing trend toward alliances as evidenced by the recent spate of announcements will spread the capital investment over several companies, thereby slowing capital spending.

Table 6 provides the historical ratio of U.S. capital spending to U.S. production. Table 7 provides the forecast ratio of U.S. capital spending to U.S. production.

Mark FitzGerald

Table 6
Historical Ratio of U.S. Capital Spending to U.S. Production, Merchant and Captive Semiconductor Company Data (Millions of Dollars)

	1985	1986	1987	1988	1989	1990	1991
Device Production	12,654	14,456	16,712	20,171	21,324	22,789	25,103
Capital Spending	2,629	2,082	2,594	3,434	3,875	4,088	3851
Capital Production (%)	20.8	14.4	15.5	17.0	18.2	17.9	15.3

Source: Dataquest (September 1992)

Table 7
Forecast Ratio of U.S. Capital Spending to U.S. Production, Merchant and Captive Semiconductor Company Data (Millions of Dollars)

	1992	1993	1994	1995	1996
Device Production	27,695	31,136	34,542	36,063	38,592
Capital Spending	3,559	3,754	4,344	4,883	5,688
Capital Production (%)	12.8	12.1	12.6	13.5	14.7

Source: Dataquest (September 1992)

Q10

What is the status of and justification for the legislation before the United States Congress to adjust the depreciation schedule of semiconductor equipment from five to three years?

A

In October 1991, legislation was introduced in Congress to address the gap in capital spending between the United States and Japan by adjusting the depreciation schedule of semiconductor equipment from its present level of five to three years. Dataquest understands that there are 80 sponsors of the bill in the House of Representatives and 30 sponsors in the Senate. The bill has been submitted to the appropriate committees of Congress, including the powerful House Ways and Means Committee. Dataquest understands that as yet, there has been no action on the bill because the committees have not been allowing any new issues for review. Because the November general election looms, Dataquest believes that it is unlikely that any action on this bill will be taken until the end of the year or in early 1993.

The main justification for going to a three-year depreciation schedule is that the technological life of a majority of semiconductor equipment is less than five years. The pace of technological change is the main driver behind this rapid rate of obsolescence. Thus, the window in which semiconductor manufacturers can hope to recover their investment is very narrow. Another justification for a three-year depreciation schedule is to offset the tax advantages of the United States' competitors. For example, if a Japanese semiconductor manufacturer operates its equipment more than eight hours per day, it can write off up to 50 percent of the equipment cost in the first year, compared with 32 percent written off in the United States. This difference represents a significant advantage because most Japanese manufacturers have 24-hour-per-day operations. Also, Japanese manufacturers can recover 100 percent of the equipment cost in one year if the equipment is utilized for a joint R&D venture. Tax policy is clearly a key competitive issue for the semiconductor industry because of the high capital costs associated with device manufacturing.

Peggy Marie Wood
Julie Ruiz

Q11

Where in the product development flow do you expect the ANSI IEEE 1149.1 boundary scan test bus to have the greatest impact?

A

Boundary scan's impact will be in the debug of system-level products. Research by Dataquest shows that electronic designers would like to shrink their board-level design cycle by 30 percent over the next three years. Indeed, after board prototypes are received, more than 50 percent of electronic designers in North America find that functional violations consume more debug time than timing errors, and boundary scan will be a key element in reaching the designers' time-to-market reduction goal. Semiconductor manufacturers will need to continue to broaden their offerings of JTAG-compliant devices to help shorten the electronic designers' product development cycle.

Bob Beachler

Q12

What are the key electronic equipment companies in the five Asia-Pacific regions of China, Hong Kong, Singapore, South Korea, and Taiwan?

A

See Table 8.

Table 8
Key Asia-Pacific Electronic Equipment Companies, by Application

Country Field	Application
China	
AEG China Ltd.	Industrial
Apple Computers	Computers
AT&T of Shanghai Ltd.	Telecommunication
Beijing IC Design Center	SC
China Huajing Electronics Group	SC
Chinatron Corporation	LCD
Dazix	EDA
General Electric	Telephones
Hewlett-Packard	Data processing
Hewlett-Packard	Industrial
IBM	PCs/motherboards
Magtron (Taiwan)	Data processing
Mitsubishi	Consumer
Philips	Consumer
Philips	Data processing

(Continued)

Table 8 (Continued)
Key Asia-Pacific Electronic Equipment Companies, by Application

Country Field	Application
China (Continued)	
Philips Semiconductor Corporation	Semiconductors
Shangai Belling Microelectronics Manufacturing Ltd.	Semiconductors
Shanghai Bell	Communication
Sharp	Consumer
Siemens A.G.	Communication
Stone Group	Data processing
Toshiba	Consumer
Varitronnix International	Consumer
Hong Kong	
AST Research	Computers
General Electric	Communication
Informtech	Motherboards
Informtech Ltd.	Data processing
Porro Technologies	Motherboards
Porro Technologies Ltd.	Data processing
Renful International	Data processing
Semi-Tech	Motherboards
Universal Code Ltd.	Data processing
Video Tech	PCs/games
Singapore	
AIWA	Audio
Apple Computers	Computers
Compaq	Invest PCB
Conner Peripherals	Data processing
Fujitsu	Data processing
General Motors	Automotive/radios
Giant Fujitsu	Telecommunication
Hitachi Electronic Devices	Invest capacitors
Integrated Peripherals (Colorado)	Data processing
International Applications Solutions (IBM/Hong Kong Leong)	Data processing
Matsushita Refrigeration	Invest refrigerator
Maxtor	Data processing
Miniscribe	Data processing
Minister Peripherals	Data processing
Motorola	Pagers
Murata	Components

(Continued)

Table 8 (Continued)
Key Asia-Pacific Electronic Equipment Companies, by Application

Country Field	Application
Singapore (Continued)	
Seagate	Data processing
Seiko	Clocks
Sony Precisions Engineering	Video
Toshiba Data Dynamics	Data processing
Western Digital	Data processing
South Korea	
Daewoo	Consumer
Daewoo Telecom	Telecommunication
Datacommunications Corporation	Telecom
Electronic and Telecommunications Research Institute (ETRI)	Government
ETRI	Communication
Europe	VCRs
Goldstar Electron	Consumer
Goldstar Information Communications Co. Ltd.	Telecommunication
Hyundai	Consumer
Korea Telecom	Telecommunication
Korean Telecommunications Authority (KTA)	Telecommunication
Korean Aerospace Research Institute (KARI)	Aerospace
Koryo Systems	Computers
Oriental Telecommunication Co.	Telecommunication
Samsung	Consumer
Samsung Aerospace (with General Dynamics)	Aerospace
Samsung Electronics Company	Telecommunication
Taiwan	
Accys Technology Corporation	Telecommunication
Acer Inc.	Computers
Action Electronics Company Ltd.	Aerospace
Aquarius Systems Inc.	Computers
ARC	Computers
Arche	Computers
AST	Computers
Atari	Computers
Auto Computer Corporation	Computers
Autocomputer	Computers
Capital Spending	R&D
CCL	Computers

(Continued)

Table 8 (Continued)
Key Asia-Pacific Electronic Equipment Companies, by Application

Country Field	Application
Taiwan (Continued)	
Centron Electronics Co. Ltd.	ISDN
Chen Tech Taiwan Industries Corporation	Military/aerospace
Chicony Electronics Corporation	Computers
Commodore	Computers
Compall Electronics Inc.	Computers
Copam Electronics Corporation	Computers
Datatech Corporation	Computers
Elite (Computer) Group	Motherboards
Elitegroup	Computers
EMMT Systems Corporation	Aerospace
Far East Machinery Company Ltd.	Industrial
First International Computer Corporation	Computers
Great Electronics Corporation	ISDN
Industrial Technology Research Institute (ITRI)	Aerospace
Kingtel Telecommunications Ltd.	ISDN
LEO	Computers
Masbe Corporation Ltd.	Aerospace
Microelectronics Technology Inc.	Aerospace
Microsoft	Software
Microtek	Premise
Mitac	Computers
Nantan Computer Corporation	Computers
NEC	Computers
Northman Company	Aerospace
Sampo	Computers
Sharp Flat Panel Display Manufacturing Co.	LCD
Sun Moon Star Co. Ltd.	ISDN
Synopsis Inc. (US)	Components
Systex	Computers
Taichung Machinery Works Company Ltd.	Industrial
Taicom	ISDN
Taiwan Aerospace	Aerospace
Taiwan Telecommunications Industry Co.	ISDN
Tatung	Aerospace/computers
Thunder Tiger Model Company	Aerospace
Twinhead International Corporation	Computers

(Continued)

Table 8 (Continued)
Key Asia-Pacific Electronic Equipment Companies, by Application

Country Field	Application
Taiwan (Continued)	
Vita Technology	Motherboards
Wyse	Computers
Zenith	Computers

Source: Dataquest Taiwan (September 1992)

Conference Announcement

Dataquest's 18th Annual Semiconductor Industry Conference

Each October, Dataquest brings together the top executives in the electronics industry for a forum on the latest issues facing this industry. This year's conference will focus on today's semiconductor marketing and technology issues, and preview tomorrow's major semiconductor applications that are *Fueling the Engines for Growth.*

Highlights of the conference are as follows:

- Special guest speaker: David Packard, Cofounder and Chairman of the Board of Hewlett-Packard.
- Eleven top industry executives sharing their insightful perspectives, real-world experiences, lessons, and bottom-line analyses.
- Two interactive panel discussions covering ASICs and strategic processor directions. Panels will be moderated by Dataquest and feature key industry leaders.
- Four breakout sessions presented by Dataquest senior analysts. The sessions will focus on manufacturing trends, semiconductor procurement issues, and two emerging applications areas: personal information and communications devices (PICDs), and multimedia.

In addition to the presentations and panel discussions, this year's agenda has been designed to allow social time for conferring with your peers on the critical issues and challenges facing the industry. You'll find the two days interesting, very informative, and, we hope, thoroughly enjoyable.

Seats are limited for this premier semiconductor event. To register for this conference, or to request a complete conference agenda, please call our toll free number, 1 (800) 457-8233, today!

Semiconductor Industry Conference

Monterey Conference Center
Monterey, California
October 5 and 6, 1992
Dataquest Client Rate: $1,095
Nonclient Rate: $1,295

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Fax: (805) 298-4388
18265 Soledad Canyon Road
Canyon Country, CA 91351

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Dataquest Inquiry Summary

Semiconductors *Worldwide*

December 21, 1992

This month's questions

For more information on the semiconductors worldwide industry, please call Rick Spence at (408) 437-8642

SCWW-COR-IS-9207

Products

Q1

Intel makes two claims for its recently introduced i486SL: that it provides twice the performance of its predecessor, the i386SL, while using one-half the power and 60 percent of the board space that the i386SL does. How is this possible?

A

The comparisons Intel is making refer to fully configured systems. For example, for purposes of this comparison, Intel assumes the use of the i387SL coprocessor as well as 8KB of external primary cache in the i387SL calculation. The i486SL integrates all of these functions on-chip.

Additionally, the i486SL uses a 3.3V power supply. The combination of the four-chip i386SL solution into one i486SL chip provides the 60 percent power savings. The integration also contributes to the power savings; however, the prime contributor is the reduction in the processor's power supply from 5V to 3V. Based on this power savings, Intel believes that the full-on power consumption of a typical PC motherboard will be reduced from 4W to 2W. This 50 percent power savings on the motherboard translates into a 25 percent savings for the whole system.

Jerry Banks

Q2

Why are analog ICs found in digital mass storage devices such as rigid disk drives?

A

Analog and mixed-signal ICs, with 1991 revenue of U.S.$488 million, represent close to 30 percent of the IC value in the disk drive market. Analog ICs are used for the fundamental reason that signals, not numbers, are stored on the magnetic medium of the disk. The disk drive mechanism has a read-write amplifier in close proximity to the read-write head. Further analog signal processing is provided by analog signal processing that precedes the digital data extraction.

A further use of analog or mixed-signal ICs is to control the two motor assemblies, the head positioning motor and the spindle driver motor. Digital ICs provide the controller logic and the digital data processing beyond the basic rigid disk mechanism. As drives get smaller, the limited space available has pressed integration substantially. The result is a few mixed analog/digital ICs to provide the complete read-write and motor control electronics.

Gary Grandbois

Q3

What prices do you expect to see for 64-bit microprocessors through 1996?

A

Table 1 shows Dataquest's price range estimates for the emerging market of 64-bit MPUs. These data are based on current average prices and historical high-end 32-bit microprocessor price curves.

Table 1
64-Bit MPU Price Range Forecast: 1992 to 1996 (U.S.$)

	1992	1993	1994	1995	1996
Price Range	700-1,300	500-800	350-600	300-500	250-450
Average Selling Price	900	600	450	400	375

Source: Dataquest (December 1992)

Mark Giudici

Q4

What's the biggest static RAM (SRAM) cache that can practically be put on a hard disk drive?

A

Probably the single most important use of slow SRAMs in North America is in caches for hard disk drives. These caches serve the following two purposes:

- To reduce the average access time of a hard disk (for example, from 17ms to 11ms)
- To cut power consumption

The first purpose is equally important in both battery-operated and desktop computers; the second is mostly for battery-operated devices.

The theory behind hard disk caches is driven by the assumption that software reads data from a disk in sequence. If a given sector is accessed, it is likely that the next sector is the next thing that will require access from the disk. When a disk sector is accessed by a program, the disk controller will automatically read one or more succeeding sectors into the cache in anticipation of these sectors' future use. If the next access can be serviced by the cache, the cycle is called a "hit"; but if the cache does not contain the appropriate word, the cycle is a "miss," and the hard disk will need to be accessed directly (with correspondingly different succeeding sectors read into the cache). A standard 20MB hard disk will often feature a 32KB cache. This size of cache typically affords a 30 percent hit rate—that is, the cache can be accessed instead of the disk for approximately one-third of all would-be disk accesses. This hit rate can be used either simply to speed up the apparent access time of the drive or to allow the disk motor to be powered down until a cache miss occurs.

It follows that the largest possible cache is a RAM equally as big as the disk drive. Similarly, if the entire disk is read into this RAM during the first cache miss cycle, all succeeding cycles will be hits; and the disk will never again need to be read into the cache. In this event, the cache hit rate will be 100 percent.

Dataquest asked hard disk drive designers about this, and they reported that they would use the largest possible device that meets the following three important criteria:

- The entire cache must be as small as possible (a single chip).
- Power dissipation must be as low as possible (again, a single chip).
- Cost must be as low as possible.

The last criterion is the one that seems to motivate disk drive manufacturers' current widespread use of 256K bit devices. Dataquest believes that, as the price of SRAMs of higher densities continues to decay, ever-larger devices will find their way into this important application. With hard disk drives' densities continuing to escalate, there appears to be no end to the size of cache that will be used in tomorrow's systems.

Jim Handy

Markets and Applications

Q5 What are the worldwide growth opportunities for video compression ICs and video codes?

A The main growth opportunities for video compression ICs are video telephony and multimedia—which includes videophones, PC videophones, and videoconferencing. This can be split into equipment supporting full-motion video (FMV) and still-frame display. Table 2 presents the Dataquest forecast for this area.

David Moorhouse

Table 2
Worldwide Video Compression IC and Video Code Market Forecast in Units and Revenue (Thousands of Units)

	1991	1992	1993	1994	1995	1996
Videoconferencing						
Telephone	6	85	138	218	366	628
Telephone (U.S.$M)	13.6	36.9	50.7	68.4	89.3	115.2
FMV Semiconductors	3	139	933	3,873	8,817	14,045

Source: Dataquest (December 1992)

Q6

What are the major worldwide electronic data processing (EDP) applications that use microcontrollers?

A

Table 3 shows the key EDP applications that use microcontrollers and our forecast for 1996. (The word length of the controller and what this is forecast to be in five years is also included in this table.)

Table 3
Worldwide Unit Forecast for Key EDP Applications (Millions of Units)

	Production		Word Length (Bits)	
	1991	1996	Current	Future
Keyboards	32.0	54.0	8	8
Disk Drives	32.0	70.0	8	16
Printers	16.0	19.0	8	8
Terminals	5.6	6.1	8	8
Tape	2.3	3.6	8	16
Copiers	2.5	3.0	8/16	16

Source: Dataquest (December 1992)

Mike Glennon

Q7

What percent of the 1992 North American gate array design starts are being captured below 1 micron?

A

According to Dataquest's latest ASIC supplier survey, 32 percent of the designs are being captured below 1 micron. The following shows the percent of designs being captured by each drawn line width in North America:

Less than 2 micron—1 percent of design starts

1.6 to 2 micron—2.5 percent of design starts

1.1 to 1.5 micron—20.2 percent of design starts

0.9 to 1 micron—44.3 percent of design starts

0.7 to 0.8 micron—28.1 percent of design starts

Less than 0.7 micron—3.9 percent of design starts

Bryan Lewis

Technology

Q8

How are microprocessors acting as process technology drivers?

A

Microprocessors may not be driving new processes in terms of minimum feature size as DRAMs do, but they are serving as a vehicle for the development of multilevel metallization process flows. Table 4 shows the process technology and selected parameters for several current and future microprocessors.

The different processors shown in Table 4 can be characterized as being highly integrated: they tend to incorporate the CPU, FPU, data and instruction cache memory, cache control logic, memory management unit (MMU), bus control logic, and other functions integrated on the chip. Many new microprocessors are also shifting to 64-bit internal bus architecture. Clearly, the incorporation of memory, control, and test logic onto the same chip as the integer and floating-point execution units creates a large demand for additional interconnect layers to route the increased number of signals and to maintain a manageable die size. This trend is expected to continue as future processors become even more highly integrated, with multiple processors integrated onto a single chip as well as associated complex logic, higher levels of test support, error detection and correction, and other functions.

Because complex microprocessors and application-specific standard products (ASSP) derived from the processor cores comprise an increasing portion of total semiconductor production, advanced

Table 4
Process Technologies for Current Microprocessor Products

Manufacturer	Microprocessor Architecture	Minimum Line Geometry (microns)	Number of Metal Interconnect Layers	Die Size (sq. mm)	Number of Transistors (millions)
Intel	486	0.8	3	82	1.2
AMD	486	0.7	3	NA	1.2
Intel	Pentium	0.8	3	264	3.1
IBM/Motorola	Power PC 601	0.65	4*	103	2.8
Motorola	68060	0.5	3	149	2.8
TI	SuperSPARC	0.8	3	255	3.1
Digital	Alpha	0.75	3	233	1.7

NA = Not available
*Uses a metal local interconnect layer in addition to four full interconnect layers
Source: Dataquest (December 1992)

multilevel metal processes will constitute a larger fraction of the worldwide production capacity. This carries some strong implications for the wafer fab equipment industry. For a three-layer metal process, the number of process steps from the beginning of the process to the point at which the first metal layer is deposited is approximately equal to the number of process steps from that point to the end of the process flow. In other words, the three-layer metal process is the point at which the multilayer metallization process steps become equal to all of the front-end process steps.

The mix of wafer fabrication equipment will, therefore, tend to be more heavily weighted toward process tools that are used in the multilevel metal process module—sputter deposition systems, metal chemical vapor deposition (CVD) systems for contact and via plugs, dielectric CVD and PECVD systems for the intermetal dielectric (IMD) deposition, dry-etch systems for contact and via etching, and process tools for planarization of the IMD and the tungsten contact and via plugs.

Starting in about 1988, the purchases of CVD/physical vapor deposition (PVD) equipment and dry-etch/dry-strip equipment have risen as a percentage of total spending, while the purchases of lithography/track equipment have fallen. This shift in equipment spending has been caused by greater use of multilevel metallization processes and by the evolution from batch to single wafer-processing equipment, particularly for intermetal dielectric processes. Dataquest expects this trend to continue as multilevel metal processes find greater use in production and the number of interconnect layers continues to grow.

Charles Boucher

Company and Other Issues

Q9 What is the latest update on Japanese semiconductor capital spending?

A Table 5 shows historical capital spending trends and the latest update for six major Japanese semiconductor companies.

Table 5
Japanese Semiconductor Capital Spending Trend (U.S.$M)

	1989	1990	1991	1992
Fujitsu	595	622	703	519
Hitachi	643	738	650	516
Matsushita	486	547	462	355
Mitsubishi	475	583	665	476
NEC	616	703	752	615
Toshiba	679	816	789	496
Others	2,247	2,141	2,166	1,754
Total	5,740	6,150	6,186	4,732

Note: Columns do not add to totals shown because of rounding.
Source: Dataquest (December 1992)

Kazunori Hayashi

Q10

I heard that the Electronics Industry Association of Japan (EIAJ) recently opened an office in the San Francisco Bay Area. What is the purpose of this opening and how can EIAJ be reached?

A

EIAJ and an affiliate organization established by EIAJ members, known as the Users' Committee of Foreign Semiconductors (UCOM), have jointly opened a new office in Foster City, California. The general charter of this office is to promote commerce between U.S. and Japanese electronics industries.

UCOM, which currently includes a membership of 62 Japanese semiconductor users, will specifically serve as an information clearinghouse with the intention of providing knowledge that will facilitate access to the Japanese semiconductor markets by foreign chip suppliers. Facts concerning such things as Japanese end users' activities, needs, and chip requirements—as well as sales protocol and distributor information—will be disseminated by UCOM California. In addition, data regarding U.S. technical trends, requests, and product updates will be forwarded to the Japanese members of UCOM.

In joint efforts with the Semiconductor Industry Association of the United States, UCOM California has and will continue to conduct trade mission seminars and symposia designed to expedite the communication of both engineering requirements and marketing information from U.S. semiconductor suppliers to potential Japanese chip consumers. In particular, the office in Foster City intends to give special attention to U.S. vendors that are either neophytes in the

Japanese market or do not have marketing representation in Japan. UCOM California can be reached at the following location:

- Address
  - UCOM California
  - Metro Center Tower
  - 950 Tower Lane, Suite 825
  - Foster City, CA 94404
- Telephone—(415) 570-5018
- Facsimile—(415) 570-5270

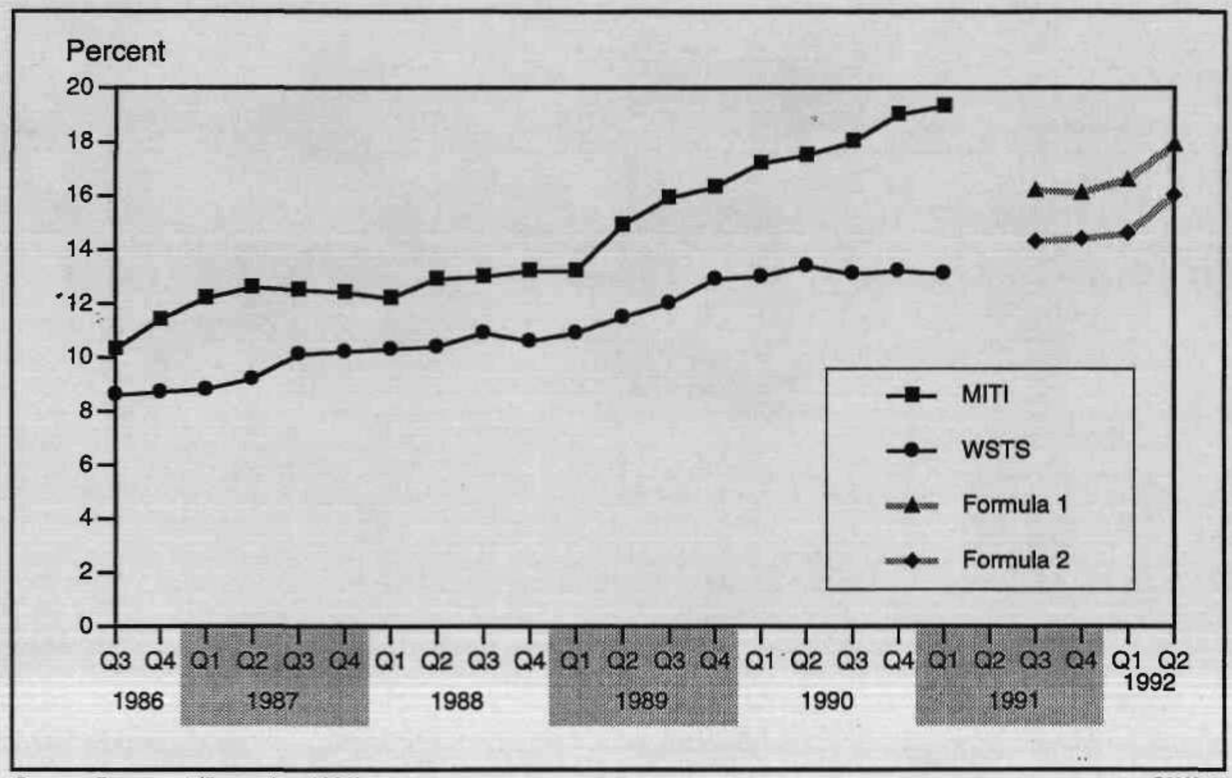
The new semiconductor trade agreement, which was renewed in August 1991, mandates that 20 percent of Japanese chip consumption should be supplied by foreign-based companies by the end of 1992. The governments of the United States and Japan have also agreed to the methods and formulas used to measure the progress toward the targeted goals specified by the trade agreement.

Previously, the often conflicting numbers calculated by the Ministry of International Trade and Industry and World Semiconductor Trade Statistics have only aggravated the disputes over market share trends and the achievement of a specified degree of foreign supplier presence in the Japanese semiconductor markets. Currently, 17.9 and 16 percent are two estimates of foreign supplier market share—computed using two of the standardized formulas approved by both governments—of the second-quarter 1992 Japanese semiconductor market.

Although many Japanese semiconductor companies have made conspicuous efforts toward increasing their levels of foreign chip procurement, many people in the Japanese chip industry remain skeptical that the 20 percent goal will be accomplished by the end of this year. It is hoped that the Japanese government and semiconductor industry's collective effort to establish a liaison office in Silicon Valley will provide a vehicle for more U.S. suppliers to successfully compete in the Japanese market, as well as demonstrate Japan's willingness to buy products from any supplier.

The historical market share numbers for the foreign-made chips in the Japanese semiconductor market are shown in Figure 1.

Figure 1
Foreign Semiconductor Market Share in Japan (Percent)



Source: Dataquest (December 1992) G2002581

Junko Matsubara

Q11

Have you heard of the company Semitherm Inc.? I'd like some basic information.

A

Semitherm Inc. is an R&D and manufacturing house for computerized wafer-processing equipment. Founded in 1987, it employs 15 people and has estimated 1992 projected sales of U.S.$3 million. Semitool Inc., of Kalispell, Montana—which was started in 1977—is allied with Semitherm Inc. through common ownership and/or financial interest. Semitool of California and Semitool LTD, of Cambridge, United Kingdom, operate as distribution points for the Semithern/Semitool equipment. Raymon F. Thompson is the President.

You can reach the company at the following location:

- Address
  - Semitherm Inc.
  - Box 2136
  - 4051 Highway 93 S
  - Kalispell, MT 59901

Mary A. Olsson

Q12 Our corporate management has started a new program to benchmark the performance of company functions including IC purchasing. We are a vertically integrated electronics manufacturer with facilities in most world regions including Europe, North America, and Asia. Can you give me some background?

A This has been a hot subject for many of our Procurement clients. For some Semiconductor Procurement Service (SPS) clients, benchmarking is a relatively new concept, while others have been benchmarking their operations and processes for the last 5 to 10 years.

Xerox Corporation has been a leading proponent and beneficiary of benchmarking since the early 1980s. At Japan-based manufacturers, benchmarking is generally an ingrained aspect of the strategic planning/market intelligence function, although the word benchmarking is not used.

To date, benchmarking has been applied more by electronics manufacturers than other manufacturers or service firms and more by U.S.-based companies than Europe-based companies. For example, Digital Equipment, Hewlett-Packard, IBM, and Motorola have well-established benchmarking programs.

There are several similar, but slightly different, definitions of benchmarking. Xerox originally defined benchmarking as "...the continuous process of measuring products, services, and practices against the toughest competitors or those companies recognized as industry leaders."

In effect, there are three types of benchmarking—internal, competitive, and best practices—all of which can be illustrated by examples from Xerox. Internal benchmarking is exemplified by Xerox's benchmark comparison of manufacturing processes and efficiencies in North American, European (Rank Xerox), and Japanese (Fuji Xerox) plants. Competitive benchmarking is exemplified by the product tear-downs conducted by Xerox of competitors' systems regarding components and technology. Xerox's competitors also tore down Xerox's systems. And, best practices benchmarking is exemplified by Xerox's discovery through market research that L.L. Bean—a relatively small Maine (U.S.)-based company that is not involved in the electronics industry—operated a world-class warehousing function, against which Xerox benchmarked—and then modified—Xerox's warehousing practices.

Ronald Bohn

Q13 What can you tell me about the company named Euphonics?

A Euphonics, founded in 1987 by Dr. Jeffrey Barish, is an R&D consulting company that provides solutions throughout the development process to audio and electronic music products through the use of digital technology. Euphonics offers a range of services including product conceptualization, hardware design, programming, DSP coding, and signal processing and analysis. Clients of Euphonics include Analog Devices, Crystal Semiconductor, Yamaha, Ford Motor Company, E-mu Systems, Jensen, Kawai, Sanyo, Digidesign, and other companies.

For more information Euphonics can be reached at the following location:

- Address
  - Euphonics
  - 61 Pine Tree Lane
  - Boulder, CO 80304
- Telephone—(303) 938-8448
- Facsimile—(303) 938-8885

Rick Spence

Q14

What is the 1993 semiconductor capital spending outlook in Japan?

A

One only has to look at the flurry of poor quarterly reports coming out of Japan to understand why semiconductor capital spending in Japan will continue to decline in 1993. By our estimates, spending will fall 12.7 percent in 1993 following a precipitous drop of 28.7 percent in 1992.

Across the board, Japanese device makers are reporting miserable earnings, and they are scrambling to shore up their balance sheets by cutting spending. A downturn in all the major semiconductor end-user markets in Japan is causing companies to be more cautious. Data processing, consumer electronic, automobile, and communications applications are all suffering.

Mainframe demand, which is the largest data processing segment using ICs, was negative in 1992, and it is unclear when financial and manufacturing companies will begin buying these systems again. A fierce price war in overseas markets is exposing the vulnerability of Japanese PC makers. Already, U.S. and Taiwanese companies are targeting Japan with their lower-priced machines, which is widely expected to enable them to gain market share at the expense of the established domestic vendors.

Japanese consumer electronics sales are weak, causing companies to cut production of semiconductors going into this application. Pressure on household incomes continues to erode consumer confidence, which is being translated into reduced consumption expenditure.

Vehicle sales have fallen on a year-over-year basis for the last 18 months, with the exception of June 1992. Reflecting difficulties in the automobile sector, Nissan Motor—Japan's second-largest car manufacturer—reported its first pretax loss since World War II and suspended its dividend for the first time.

The communications sector is also weak as NTT—Japan's domestic telephone company—cut its capital spending budget dramatically. As a result, telecommunications systems are also recording weak sales.

Structural Change for Japanese Industry

The current downturn in Japan is driven by domestic asset deflation and the reversal of the credit cycle of the late 1980s. Stock prices are more than 50 percent below their peak, and urban land prices have fallen approximately 20 percent. Negative money supply growth demonstrates the severity of the financial system's capital shortage.

We believe that 1993 is likely to be marked by a softening in the labor market through further reductions in compensation growth and cutbacks in regular employment growth. It is very likely that the slower growth in wages is the endgame of an adjustment process that began in the fall of 1990 with a tightening of monetary policy by the Bank of Japan.

Consequently, we expect to see an improved environment for semiconductor capital spending in 1994 and beyond. But, the unbridled spending spree by Japanese companies is not likely to be repeated. Slower domestic gross national product growth, mounting competitive pressures, and lopsided trade imbalances suggest that the scramble for semiconductor market share will no longer be the main strategy for Japanese device makers.

Mark FitzGerald

Q15 It is my understanding that the antidumping law, under which Micron Technology has filed against the Korean DRAM makers, requires an 8 percent pretax profit margin by the seller to avoid being guilty of sales below fair market value, as defined by the law. However, very often semiconductor makers seem to be unable to make profits that high, especially in tough times. How often has Micron been able to achieve such a pretax profit rate?

A Since 1983—its first fiscal year—Micron's pretax profits have fallen below 8 percent in 24 of the 40 quarters. These 24 quarters include 10 in a row during the first dumping debacle and 10 of the last 12 since the company's 1990 fiscal year began in September 1989. The company lost money in 14 of these 40 quarters; it made pretax profits greater than 35 percent in 9 quarters.

One could argue, of course, that one company is forced to sell below cost to meet the price of other dumpers, as was certainly the case in 1985 to 1987. Then, any company that did not meet the market price was forced to stop shipping altogether, which would mean going out of business for Micron.

A reconstructed cost comparison is only one of the criteria of this law; another important one is the assessment by the International Trade Commission that the domestic industry has been damaged by the sales below fair market value.

Lane Mason

Q16

Please provide an assessment of semiconductor distribution in Taiwan, South Korea, and Singapore.

A

Distribution profiles for these countries are given below.

Semiconductor Distribution Profile: Taiwan

The following are highlights of Taiwan's semiconductor distribution:

- The primary means of distribution in Taiwan's dynamic and competitive semiconductor market is through distributors and direct branch office sales. The means and mix of distribution depends on the origin of the company, the product lines sold, and the size of the accounts being served.
- All semiconductor companies utilize distributors in addition to their direct house accounts. As far as determining a percentage of semiconductors sold through distributors versus through branch offices, this varies so widely from company to company that it is very difficult to assess the total market. The means of sales to a customer can change at times when the quantity and/or product purchases change.
- Distribution segments in terms of niche products versus broad-line products can determine whether a distributor is used. In most cases, companies will use distributors to sell standard products to nonmajor account clients. However, in the case of custom products, a company will service the account directly, even though the sales quantity is minor.
- Gross margins of distributors again depends on the products being offered. The market norm in Taiwan is a 5 percent margin for distributors. For DRAMs, the margin might be slightly lower than the norm, or closer to 4 percent. At the lowest end of the market, for example in mask ROMs, distributors' gross margins might be as low as 3 to 4 percent.
- Distributors in Taiwan play an active role in the marketplace. If creating demand means aggressively pushing sales of all old and new products, then distributors play a very important part in influencing consumption.
- The degree of technical expertise among the distribution companies in Taiwan depends on the size of the distributor. Small distributors with 5 to 15 employees will likely employ one field application engineer (FAE). Middle- and large-scale distributors will have as many as 5 to 10 FAEs. In situations where technical support is an important part of

the distributor's business, there will be a larger proportion of engineers relative to standard product distributors.

- The customer base of distributors, as previously mentioned, is determined by the criteria of the supplier. The most basic and important criterion is the size of the account; the second most important criterion is the technology being sold. In cases where there is a gray area as to the size or technology being purchased by a new client, the branch office is likely to allocate the account to the person or distributor that closed the first sale.
- Customer needs are adequately satisfied by local distributors that have an intimate understanding of the market and the ability to foster long-term relationships.
- No significantly new distribution trend is developing in Taiwan. U.S. and European companies that want to make rapid inroads to the Taiwanese market will be best serviced by utilizing a variety of distributors that usually speak English and understand the business culture.
- The factors that determine the success of distributors in Taiwan are, simply stated, everything: Pre-, during-, aftersales service; delivery; engineering services; product reliability; and pricing.
- More than 10 "major" distributors are in Taiwan. This figure excludes the distributors of Japan-made semiconductors because Japanese companies will utilize distributors that only sell their own products. Furthermore, distributors of Japanese semiconductors in Taiwan are Japanese companies, not Taiwanese companies. U.S. and European companies, for the most part, will choose their distributor regardless of whether other U.S. companies are being represented (again, this depends on products and companies).
- The first distributor that comes to mind is World Peace, which represents Texas Instruments, Chips & Technologies, IDT, and Rockwell. This company generates about U.S.$80 million in monthly sales revenue. Other major distributors include Acer, Mitac, and Mercuref & Associates Ltd. (representing Motorola and Kyocera, about U.S.$40 million per month).
- As previously mentioned, distributors offer expertise, relationships, and market inroads that branch offices must spend years to develop.

Semiconductor Distribution Profile: South Korea

The following are highlights of South Korea's semiconductor distribution:

- The three basic semiconductor sales channels in South Korea are stock sales, representative sales, and direct branch office sales (major accounts). In cases such as SPARC product, which require a high degree of technical competence, branch offices or major agents will distribute rather than stock sell, which affords no technical support.

- The percentage of semiconductor components sold through distributors depends on the size of the account and the nature of the product being sold. Because of the predominant consumer electronics equipment demand, about 60 percent or more of commodity-related semiconductors are sold through distributors.
- Gross sales margins generally are 25 percent for stock-based transactions and 5 percent for representative offices.
- Distributors in South Korea do not significantly impact or create the market demand, but aggressive agents and competitive pricing will impact sales quantity.
- Technical expertise among distributors in South Korea generally is weak, in part because the nature of the semiconductor market—which is predominantly consumer applications of commodity products—requires little technical expertise.
- The customer base of distributors' versus vendors' branch office or headquarters varies according to account size. While minor accounts rely on distributor support, the major accounts will work directly with an agent of a branch office or headquarters.
- Customer needs in South Korea do not differ from anywhere else in the world and rank according to quality, delivery, and price.
- Distributors in South Korea generally are small-scale operations. Vendors are able to provide volume and technical support better than small distributors, which have difficulty expanding their business volume because of inferior service.
- We do not have a list of these small distributors in South Korea, but there are many.
- The primary benefits of using a distributor in South Korea are the minimal risk involved and the absence of the need for a newcomer to fully understand the local market.

Semiconductor Distribution Profile: Singapore

The following are highlights of Singapore's semiconductor distribution:

- Distribution channels in Singapore are much more straightforward than those in Taiwan because semiconductor sales accounts are serviced predominantly by multinational branch offices and there is little use for using distributors except in the case of small accounts of standard products.

- Based on the percentage of electronics equipment production done by large multinationals, it is fair to say that more than 90 percent of semiconductors used are sold directly, while less than 10 percent are sold through distributors.
- Most semiconductor suppliers with niche products prefer to sell directly if they are customized in Singapore. For example, Texas Instruments offers a variety of bipolar products sold directly because of their custom nature.
- Distributors' gross margins will vary according to their products as in other parts of the world, but margins remain comparable with Taiwan at about 5 percent.
- The degree of technical expertise is relatively weak among Singapore's distributors, in part because of the nature of the market and the availability of FAEs willing to work as distributors in Singapore.
- Customer base of distributors is, again, small-scale manufacturers or niche users of relatively standard technology products.
- Customer needs in Singapore are based on a major account mentality emphasizing quality and reliability, service, product migration, technical competence, and on-time delivery.
- The current trend of direct account sales will continue in Singapore. However, there is a growing need for distributors in neighboring Malaysia because a large number of small- and medium-scale Taiwanese, Korean, and Hong Kong electronics equipment companies are establishing manufacturing facilities in the region.
- The success of distributors in Singapore depends on the factors of service, price, on-time delivery, and quality/reliability mentioned previously.
- The benefit of using a distributor in Singapore is less cultural than in Taiwan because the market is almost totally controlled by multinational manufacturers. Therefore, the major benefit to using a distributor is to service small accounts that otherwise would be ignored by the branch office.

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Internal Distribution