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FEDERAL RESEARCH

SEMATECH's Technological Progress and Proposed R&D Program

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Resources, Community, and
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The Honorable Daniel K. Inouye
Chairman, Subcommittee on Defense
Committee on Appropriations
United States Senate

Dear Mr. Chairman:

You requested that we review the progress, funding, and expenditures of SEMATECH, a government-industry research and development (R&D) consortium formed in 1987 to enable the United States to regain world leadership in semiconductor manufacturing. In particular, this briefing report discusses (1) SEMATECH's progress in achieving its technological objectives, (2) the views of the Department of Defense and SEMATECH's member companies about continued federal funding for SEMATECH after fiscal year 1992, and (3) SEMATECH's expenditures during its first 5 years and its proposed budget after 1992. This information is primarily based on written responses by SEMATECH, its member companies, and Defense to a series of detailed questions we prepared with the concurrence of your office.

In response to your request, we briefed your office on the results of our review on June 9, 1992. This briefing report outlines our overall findings and observations and serves to formalize the information we presented during the briefing.

Background

During the 1980s, the U.S. semiconductor industry lost to Japan a significant portion of its market share for semiconductors—components that allow computers and other electronic products to process and store information. In response to this loss, several U.S. semiconductor and computer companies formed SEMATECH in August 1987 to conduct R&D on advanced semiconductor manufacturing. The National Defense Authorization Act for Fiscal Years 1988 and 1989, enacted in December 1987, authorized the Secretary of Defense to make grants to SEMATECH to defray R&D expenses. It was anticipated that the federal government would provide $100 million per year to SEMATECH over a 5-year period ending in fiscal year 1992, which would match the contributions of SEMATECH's member companies. In April 1988 the Secretary of Defense delegated responsibility for overseeing SEMATECH to the Defense Advanced Research Projects Agency (DARPA).

We have issued several reports on SEMATECH in response to a legislative requirement that we review the annual audit of SEMATECH's financial statements and a request from the House Committee on Science, Space, and Technology that we issue annual reports on SEMATECH's operations. (A list of related GAO products appears at the end of this briefing report.)

Results in Brief

In summary, SEMATECH appears to be on schedule for achieving, by the end of 1992, its overall objective of demonstrating the capability to manufacture state-of-the-art semiconductors using only U.S. equipment. However, according to SEMATECH and several of its members, this capability will enable the U.S. semiconductor industry just to reach parity with—but not surpass—its Japanese competition in terms of semiconductor manufacturing equipment capability at that time. In addition, published data indicate that U.S. semiconductor equipment suppliers and semiconductor manufacturers have arrested their decline in the worldwide market share; how much of this change is attributable to SEMATECH's efforts, however, is not clear.

DARPA proposes to phase out funding specifically designated for SEMATECH after the government's 5-year funding commitment ends this year. DARPA plans to spend $80 million per year to support semiconductor manufacturing R&D during the next 5 fiscal years as part of its larger semiconductor R&D program. While all of the $80 million to be spent in fiscal year 1993 is designated for SEMATECH, DARPA plans to award funding in subsequent years for projects at SEMATECH and other organizations that best achieve DARPA's R&D program objectives.

SEMATECH's member companies cited the importance of continued federal support for SEMATECH to improve the competitive position of the U.S. semiconductor industry, stating in particular that (1) advanced semiconductors are critical components of weapons systems that provide the United States a technological edge in war and (2) a more competitive semiconductor industry strengthens the entire U.S. electronics industry and benefits the nation's economy. Both DARPA and member companies believe that SEMATECH's programs to develop computer-integrated manufacturing and flexible manufacturing will yield a high return on investment by enabling semiconductor manufacturers to respond effectively to customers' needs and substantially reduce manufacturing costs.

Of $990 million that SEMATECH spent between 1988 and 1992, about $371 million, or 37 percent, supported external R&D and $349 million, or 35 percent, supported the construction and operation of SEMATECH's facilities. The remaining 28 percent was spent for employee salaries, purchased services, and other expenses. Because of the expense involved in developing new technologies, SEMATECH has directly worked with only a relatively small number of equipment and materials suppliers to develop advanced equipment. In particular, SEMATECH's largest R&D effort—with expenditures of $145 million between 1988 and 1992—has primarily involved the development of advanced lithography equipment[1] with two suppliers.

Section 1 of this briefing report provides responses from SEMATECH, its member companies, and DARPA to questions we asked about SEMATECH's technological progress. Section 2 provides their responses to our questions about funding for SEMATECH's proposed program after 1992. And section 3 provides data in response to our questions on SEMATECH's expenditures from 1988 through 1991 and its proposed budget for 1992 through 1997. A glossary providing definitions of semiconductor manufacturing terminology appears at the end of this briefing report.

Agency Comments

We discussed the contents of this briefing report with officials from SEMATECH and DARPA's Offices of the Comptroller and Electronics Systems Technology. These officials agreed with the briefing report's technical accuracy and provided some additional clarifying information, which we incorporated, as appropriate.

Scope and Methodology

To obtain information about SEMATECH's technological progress and funding for its proposed program after 1992, we requested that SEMATECH, each of its original 14 member companies,[2] and DARPA respond in writing to our questions. (App. I lists the 14 original member companies.) We also interviewed officials of Dataquest, Inc., and VLSI Research, Inc.—independent research organizations that monitor the worldwide semiconductor industry. However, because of time constraints for meeting your reporting needs, we did not obtain the views of executives of semiconductor manufacturers not involved in SEMATECH. To provide data on SEMATECH's expenditures and proposed budget, we reviewed SEMATECH's

[1]Lithography equipment is used to transfer integrated circuit patterns onto semiconductor chips.

[2]Each member company responded, except Micron Technology, Inc., which recently announced plans to withdraw from the consortium.

management and financial documents, including expenditures data from 1988 through 1991 and budgetary data for 1992 through 1997. Our work was conducted between February 1992 and June 1992.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after the date of this letter. At that time, we will send copies to the Secretary of Defense; the Chief Executive Officer of SEMATECH; and the Director, Office of Management and Budget. We also will make copies available to others upon request.

Please contact me at (202) 275-1441 if you or your staff have any questions. Major contributors to this briefing report are listed in appendix III.

Sincerely yours,

for Victor S. Rezendes
Director, Energy and
Science Issues

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Tables

Abbreviations

AT&T	American Telephone and Telegraph Company
CIM	computer-integrated manufacturing
DARPA	Defense Advanced Research Projects Agency
DOD	Department of Defense
DRAM	dynamic random access memory
GAO	General Accounting Office
IBM	International Business Machines Corporation
R&D	research and development
SEMATECH	SEmiconductor MAnufacturing TECHnology

SEMATECH's Technological Progress

Question

SEMATECH's mission is to provide the U.S. semiconductor industry with the domestic capability for world leadership in manufacturing. SEMATECH established a 5-year, three-phased program that would achieve manufacturing parity with Japan upon the completion of phase 2 and reclaim world semiconductor manufacturing leadership upon the completion of phase 3 by the end of 1992. What progress is SEMATECH making to achieve this mission?

Response

SEMATECH appears to be on schedule for achieving its overall technological objectives of demonstrating the capability to manufacture 0.35-micron semiconductors using only U.S. equipment by the end of 1992. However, according to SEMATECH and several of its members, this capability will enable the U.S. semiconductor industry just to reach parity with—but not surpass—its Japanese competition in terms of semiconductor manufacturing equipment capability by the end of 1992.

SEMATECH stated that it will have achieved by the end of 1992 each of the eight objectives approved by its Board of Directors in February 1990. (See app. II). The following are examples of the extent of SEMATECH's progress:

- SEMATECH has demonstrated its capability to fabricate semiconductor devices with 0.5-micron linewidths on 150-millimeter (6-inch) wafers using only U.S.-supplied equipment. SEMATECH also has demonstrated at least one process module on each piece of equipment using 0.5-micron linewidths and 200-millimeter (8-inch) wafers. According to SEMATECH, next-generation manufacturing technology—for fabricating semiconductor devices on 200-millimeter wafers and 0.35-micron linewidths—is on schedule for completion by the end of 1992.
- Several member companies stated that one of SEMATECH's primary contributions is as a forum for communication within the semiconductor industry. By sharing precompetitive data, SEMATECH has (1) shifted the industry's culture from one exhibiting a competitive, arms-length relationship between semiconductor manufacturers and their suppliers toward a culture that establishes long-term relationships between semiconductor manufacturers and their suppliers; (2) improved strategic planning within the industry by, for example, developing a consensus among member companies on performance requirements and timing for next-generation equipment; (3) developed common methods for evaluating, improving, and qualifying equipment and associated software; and (4) begun to develop industrywide standards for computer-integrated manufacturing (CIM).

- Overall, SEMATECH has worked with only a relatively small number of U.S. equipment and materials suppliers to improve their products because of the expense involved in developing new technology. As of April 8, 1992, SEMATECH had announced the award of 30 joint development contracts, 13 equipment improvement contracts, and 8 contracts with members and other organizations to improve existing equipment or develop next-generation technology.

  SEMATECH's most extensive effort to assist key U.S. equipment suppliers has been to work with GCA, a subsidiary of General Signal Corporation, and Silicon Valley Group Lithography Systems to develop advanced lithography steppers—critical equipment used to transfer integrated circuit patterns onto semiconductor chips. During the 1980s Japanese competitors made substantial performance advances, enabling them to control more than 80 percent of the worldwide market by 1991. As a result of SEMATECH's projects, GCA and Silicon Valley Group have introduced lithography steppers that close this technology gap. Digital Equipment Corporation will use GCA's XLS I-line steppers in its new facility to fabricate semiconductor chips with 0.5-micron linewidths and indicated that these steppers may be gaining market share in Korea at the expense of comparable Japanese equipment. At least two other member companies also have purchased GCA's advanced XLS deep-ultraviolet steppers to develop processes for fabricating chips with 0.35-micron linewidths. In addition, on June 15, 1992, Silicon Valley Group unveiled its Micrascan II for fabricating semiconductor chips with 0.35-micron linewidths.

- SEMATECH's CIM program is expected to substantially reduce manufacturing costs by standardizing hardware and software interfaces between different pieces of equipment and improving controls over the manufacturing process. Three member companies expressed dissatisfaction with SEMATECH's initial efforts, which included the publication of SEMATECH's CIM Architecture Concepts Guide in April 1990. However, one of these companies cited the progress of SEMATECH's strategic cell controller program, initiated in October 1990, in assisting CIM tool suppliers to make their products compatible and integrating these products into complete shop floor control systems at two member companies' sites.

Question

How do U.S. semiconductor manufacturing yield rates and costs compare with those in Japan and Europe?

Response

VLSI Research credits SEMATECH with (1) reducing Japanese semiconductor manufacturers' average probe yield[1] advantage over U.S. manufacturers from 15 percent in 1986 to only 9 percent in 1991 (see table 1.1) and (2) improving equipment utilization. According to the President of VLSI Research, Japan's continuing cost advantage is the result of its higher yield, or percentage, of semiconductors meeting specifications on each wafer processed. In contrast, VLSI Research reports that U.S. and Japanese costs to fabricate semiconductor chips on a wafer are now about equal primarily because of the appreciation of the yen and higher labor, land, and financing costs, but also because of improved equipment utilization by U.S. manufacturers.

Table 1.1: Average Probe Yields for U.S. and Japanese Semiconductor Manufacturers

Yields in percent

	Yield						
Country	**1981**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
United States	55	60	60	67	74	80	84
Japan	45	75	79	81	85	89	93

Source: VLSI Research.

SEMATECH estimates that the yields of European semiconductor manufacturers are more than 10 percent lower than those of U.S. manufacturers.

Question

SEMATECH and its member companies generally consider market share to be the best measure of the U.S. semiconductor industry's ability to compete. To what extent has SEMATECH helped U.S. semiconductor equipment suppliers and semiconductor manufacturers improve their worldwide market share?

Response

Published data indicate that U.S. semiconductor equipment suppliers and semiconductor manufacturers have arrested their decline in the worldwide market share.

- Between 1981 and 1986, U.S. semiconductor equipment suppliers' market share declined at a 4.5-percent compound annual rate, according to VLSI Research. In comparison, Dataquest reported that all U.S. equipment

[1]Probe yield is the last electrical test for functionality before semiconductor chips are cut from the wafer, packaged, and assembled.

suppliers lost only 0.5 percent in market share in 1991, and VLSI Research reported that the five largest U.S. equipment suppliers gained 2.8 percent in market share in 1991.

U.S. semiconductor equipment and materials suppliers have been primary beneficiaries of SEMATECH's manufacturing research and development (R&D) program. In early 1989 a SEMATECH study found that member companies expected to buy less than 40 percent of the equipment needed for their advanced fabrication facilities (those making semiconductor devices with less than 1-micron linewidths) from U.S. suppliers and more than 60 percent from Japanese suppliers. Similarly, European semiconductor manufacturers reported that they expected to buy only 30 percent of their advanced equipment needs from U.S. suppliers. SEMATECH concluded that without a major effort and a massive refocus, U.S. equipment suppliers would not survive the forecasted loss of market share.

As a result of SEMATECH's efforts to work with U.S. equipment suppliers, several member companies reported plans to increase their purchases of U.S. equipment. In particular, Motorola's new MOS-11 fabrication facility will contain almost 80 percent U.S.-manufactured equipment, although most of the equipment originally was anticipated to come from outside the United States. Similarly, Intel Corporation plans to purchase an additional $150 million of U.S. equipment and materials that would have gone to foreign suppliers; U.S. suppliers will provide over 50 percent of the equipment in Intel's new or upgraded facilities.

- VLSI Research reported that U.S. semiconductor manufacturers reduced the rate at which they were losing worldwide market share from a compound annual rate of 3.1 percent in 1985 to a compound annual rate of 0.5 percent since SEMATECH was started. Dataquest reported that U.S. semiconductor manufacturers increased their market share from 34.9 percent in 1990 to 36.5 percent in 1991.

SEMATECH noted that U.S. market share is affected by such factors as differences in the cost of capital, depreciation and tax policies, and access to markets, as well as by manufacturing capabilities. Furthermore, American Telephone and Telegraph Company (AT&T) cautioned that the U.S. semiconductor industry typically has done "well" in holding or gaining back its market share during recessions, but has lost its market share dramatically during market recovery periods. Dataquest officials similarly

cautioned that current data are insufficient to determine whether the U.S. semiconductor industry has regained its competitive position.

Question

How do member companies evaluate their overall return on investment from participating in SEMATECH?

Response

The member companies reported returns on investment that ranged from quite favorable to less than originally expected. One member noted that several key projects are long-term initiatives that have not been completed and pointed out that some next-generation technologies will not be used until existing fabrication facilities are expanded or new facilities are built. Another member cited the difficulty of quantifying such intangible benefits as improved working relationships with suppliers and helping key U.S. equipment suppliers to survive.

- Six companies—Advanced Micro Devices, Inc.; Hewlett-Packard Company; International Business Machine Corporation (IBM); National Semiconductor Corporation; NCR Corporation; and Motorola, Inc.—reported that, overall, they were either breaking even or receiving greater returns than their contributions. In particular, NCR Corporation stated that new technology was introduced into its manufacturing process 9 to 12 months sooner as a result of SEMATECH's programs. In addition, Advanced Micro Devices, Inc., conservatively estimated a two-fold return on its future annual investment as a result of such programs as SEMATECH's future factory design, which includes flexible manufacturing, CIM, and contamination-free manufacturing.
- Two companies—AT&T and Texas Instruments, Inc.—stated that in 1991 they broke even or had a positive return on an annual basis for the first time.
- Both Harris Corporation and LSI Logic Corporation said that they have not received the returns they expected when they joined SEMATECH. Both companies were more interested in pursuing SEMATECH's initial strategy to improve yields and reduce costs through better manufacturing methods than in working with suppliers to develop next-generation equipment.
- Three companies—Digital Equipment Corporation, Intel Corporation, and Rockwell International Corporation—did not give an overall response to the question, although they provided examples of benefits they have received.

Question

What have been SEMATECH's most important initiatives from the member companies' perspective?

Response

Overall, SEMATECH's member companies reported that SEMATECH's most important initiatives were to (1) encourage member companies to establish long-term relationships with their key suppliers through its Partnering for Total Quality program; (2) develop a standard model for calculating the cost of ownership for equipment, a standard method for qualifying the performance of equipment against specifications, and generic equipment performance specifications; (3) work with selected equipment suppliers to improve existing or develop next-generation equipment; (4) improve the yield of semiconductor chips from each wafer; and (5) design the factory for the future, using CIM and flexible manufacturing. The first four initiatives generally emulate Japanese industry practices by working with key suppliers to develop next-generation equipment; reducing costs through better equipment reliability and more efficient manufacturing methods; and improving the yield, or percentage, of semiconductor chips that meet performance specifications on each wafer. The last initiative would build on U.S. leadership in computer software applications. Member companies cited the importance of these efforts for allowing faster startup of new fabrication facilities and equipment, improving equipment utilization through improved reliability, and lowering the cost of fabricating each chip.

- SEMATECH's Partnering for Total Quality Program fosters closer long-term working relationships between semiconductor manufacturers and their key suppliers. One member noted that many equipment suppliers are small companies that do not have the financial capability to develop and implement world-class reliability, total quality, and customer satisfaction programs. As part of the program, SEMATECH has (1) developed for suppliers 16 training courses related to the theory and application of total quality concepts, statistical methods, and reliability engineering; (2) encouraged member companies to share with their key equipment and material suppliers information about their strategic plans, including technical requirements and competitive analysis information; and (3) developed and tested total quality management programs at ATEQ Corporation; Westech Systems, Inc; GCA; GCA Tropel; and Silicon Valley Group's Tracks, Thermco, and Lithography Systems divisions.

VLSI Research, in its 1990 survey on customer satisfaction with semiconductor equipment,[2] found that equipment downtime, which invariably had ranked first in negative comments during the previous 15 years, had dropped to sixth place. According to VLSI Research, SEMATECH has fundamentally changed the equipment industry, perhaps most significantly by spotlighting process failure mechanisms induced by the equipment itself.

- Because its member companies represent about 80 percent of the U.S. semiconductor manufacturing capacity, SEMATECH has established standard analytical models to assess equipment cost and performance and uniform specifications for equipment performance.

  SEMATECH's Cost of Ownership model has been adopted by at least 8 of the 13 member company respondents. The model assists in making equipment purchase decisions by evaluating cost on the basis of purchase price, operating costs, and wafer yields. More than 100 suppliers also have requested the software.

  SEMATECH's equipment qualification and characterization procedure is a standardized method to validate the performance of new equipment by using statistical data evaluation, thus reducing the time and cost associated with equipment and fabrication facility startup. One company said that it has adopted SEMATECH's methodology of using (1) statistically designed experiments to determine the best operating point for the process and (2) marathon runs to measure a tool's capability. The program also gives equipment suppliers important feedback for improving the quality of tools being designed and produced.

  Establishing uniform specifications for equipment performance has helped suppliers reduce costs. For example, one member mentioned that the Silicon Valley Group, in response to several semiconductor manufacturers' requests for custom modifications, initially attempted to develop 28 subsystems at the same time for its Series 90 resist processing track. A SEMATECH team reduced the development time by 9 months by prioritizing subsystem needs; the first 10 subsystems became the standard system.

- SEMATECH's member companies identified several important successes as a result of SEMATECH's equipment improvement and joint development

[2]VLSI Research, Inc., "1990 Customer Satisfaction Report on Semiconductor Capital Equipment," Aug. 1991.

projects. In particular, they cited projects to develop (1) advanced lithography steppers with GCA and Silicon Valley Group Lithography Systems and (2) high-density plasma etch equipment with Applied Materials, Inc., and Lam Research Corporation because these projects have established U.S. suppliers for essential equipment. SEMATECH's cost of ownership model indicated that improvements to a Genus Incorporated tungsten deposition tool saves over $2 million per tool per year under full utilization, while improvements to an Applied Materials, Inc., tungsten etch tool saves $180,000 per tool per year. Several member companies also mentioned projects with Westech Systems, Inc., to develop a chemical-mechanical planarization tool and process and with GCA to improve the performance of its AutoStep series. For some projects, SEMATECH's members have installed equipment on their production line to test it in a high-volume production environment.

- Member companies cited the importance of developing a disciplined approach for reducing particles and eliminating contamination to improve the yield of semiconductor chips that meet specifications from each wafer. According to Texas Instruments, Inc., SEMATECH's cost of ownership model shows that the cost of defective wafers often far outshadows purchase price and operating expenses in assessing equipment costs.

  Member companies mentioned improvements associated with SEMATECH's yield analysis methodology and particularly with a new wafer-sleuth system for automatic wafer-tracking and data analysis. In addition, as a result of SEMATECH projects, Texas Instruments, Inc., reported that a new wafer-clamping mechanism on Applied Materials' systems for depositing tungsten has reduced defects on the wafers by a factor of two. SEMATECH has established a major new R&D program—or thrust area—for contamination-free manufacturing, including a research center at Sandia National Laboratories.

- SEMATECH's member companies believe that CIM and flexible manufacturing potentially have high payback by enabling semiconductor manufacturers to reduce costs, improve yield, and respond effectively to customers' needs. One company noted that SEMATECH can impose needed standardization among equipment and software suppliers, which no semiconductor company alone could do.

Question

To what extent can U.S. semiconductor manufacturers that are not members of SEMATECH benefit from SEMATECH's R&D program?

Response

U.S. semiconductor manufacturers that are not members of SEMATECH can benefit from much of SEMATECH's R&D program because its primary objective has been to strengthen the U.S. semiconductor equipment supplier base. In particular, about 48 percent of SEMATECH's 1991 budget supported external R&D, primarily through contracts with equipment and materials suppliers to improve existing equipment or develop next-generation manufacturing technology. In addition, SEMATECH is the focal point for (1) improving long-term relationships between semiconductor manufacturers and their key equipment and materials suppliers through its Partnering for Total Quality program and (2) developing industrywide standards for semiconductor manufacturing equipment through its total cost of ownership model, equipment qualification and characterization procedure, CIM, and flexible manufacturing programs.

According to SEMATECH, nonmembers can benefit from SEMATECH's R&D program through cost savings, earlier access to the latest tools, better customer support, and a technology base for a continuing supply of critical tools. However, because many SEMATECH projects have long-term objectives, advanced equipment and other resulting technology are only beginning to become available to semiconductor manufacturers.

Question

What have SEMATECH and its member companies done to provide U.S. semiconductor manufacturers that are not SEMATECH members with access to improved semiconductor manufacturing equipment?

Response

In 1991 SEMATECH decided to allow equipment and materials suppliers that participate in a joint development of equipment improvement project to make improved equipment available to nonmembers sooner. SEMATECH's initial contract clause for joint development and equipment improvement contracts gave member companies exclusive rights to purchase new or improved technology for 1 year. SEMATECH revised this clause to reflect U.S. equipment suppliers' need to compete worldwide to succeed. Under the new clause, member companies have the more limited right to order and receive the technology first, while the supplier can sell a product worldwide, including to SEMATECH members' Japanese competitors, when it is ready for market.

- Rockwell International Corporation pointed out that the United States can achieve parity with Japan in semiconductor manufacturing only if U.S.

equipment suppliers are competitive with Japanese suppliers. However, sales of advanced U.S. equipment to Japanese semiconductor manufacturers, coupled with their manufacturing discipline, minimizes the potential edge for U.S. semiconductor manufacturers, thus creating a paradox for SEMATECH's members.

- The President of VLSI Research noted that unless SEMATECH provides specific competitive benefits to member companies, it will face a "free-rider" problem that enables nonmembers to receive benefits comparable to those received by SEMATECH's dues-paying members.

Question

Have SEMATECH's member companies revised the dues structure to encourage new members to join?

Response

The member companies have not revised the dues structure under which (1) a small company might pay proportionately higher dues than a large company and (2) companies wishing to join SEMATECH currently are required to pay "back dues" for each year since SEMATECH's inception.

- Members' dues, which are determined on the basis of each company's semiconductor sales and/or purchases, generally range from $1 million to $15 million annually. Under this structure, a small company might pay a greater proportion of its sales than a large company to reach SEMATECH's minimum dues requirement. According to SEMATECH, this structure ensures equality between small and large members because (1) each company has a single vote on SEMATECH's Board of Directors, (2) dues are structured so that larger members cannot dominate the consortium, and (3) all members have equal access to SEMATECH and its technology.
- The requirement that new members pay back dues was imposed when SEMATECH was initially established to discourage companies from postponing membership in the consortium until it had succeeded. SEMATECH stated that its Board of Directors has agreed in principle to delete its back-dues requirement after 1992; the actual change to the participation agreement has not been made in the absence of a serious applicant.

Question

What other federal agencies are supporting R&D similar to SEMATECH's semiconductor manufacturing program?

Response

The Department of Defense's (DOD) Defense Advanced Research Projects Agency (DARPA) states that because of its makeup, the SEMATECH consortium is uniquely able to effectively address many of the semiconductor manufacturing technology issues that are the focus of its R&D program. In addition to DARPA, the principal DOD organizations supporting semiconductor and other microelectronics R&D are the Defense Nuclear Agency; the National Security Agency; the Army's Electronics Technology and Devices Laboratory and Harry Diamond Laboratories; the Navy's Naval Command, Control and Ocean Surveillance Center and Naval Research Laboratory; and the Air Force's Rome Laboratories and Wright Laboratories. The principal non-DOD agencies supporting basic microelectronics R&D that feed into SEMATECH's R&D program are the National Science Foundation, the Department of Commerce's National Institute of Standards and Technology, and the Department of Energy's Oak Ridge National Laboratory and Sandia National Laboratories. According to DARPA, most of these laboratories support R&D on microelectronics, as opposed to microelectronics manufacturing technology focused on developing advanced semiconductor manufacturing equipment, materials, and systems.

Question

To what extent has SEMATECH's R&D program been coordinated with DARPA's, DOD's, and other federal agencies' R&D programs?

Response

According to DARPA, SEMATECH's R&D program is closely linked with, but does not duplicate, DARPA's microelectronics R&D program and other federally funded R&D. In particular, the objective of DARPA's programs is to demonstrate the feasibility of new technologies, while SEMATECH's objective is to further develop new technologies by integrating them into manufacturing systems.

- DARPA program managers and other DOD representatives are involved in overseeing SEMATECH's R&D programs through participation on SEMATECH's Executive Technical Advisory Board, focus technical advisory boards, and technology transfer committee. Similarly, SEMATECH thrust area managers participate in various DARPA program reviews and workshops. For example, DARPA's lithography program director is DOD's representative on the SEMATECH lithography focus technical advisory board, and SEMATECH's lithography thrust area manager participates in DARPA's lithography working group. SEMATECH and DARPA are coordinating work on x-ray lithography, including the development of a point x-ray source suitable for

future lithography systems, and SEMATECH plans to integrate advanced optical 193-nanometer lithography developed by DARPA in a product.

- SEMATECH is using the results of the microelectronics manufacturing science and technology program—jointly funded by DARPA, the Air Force, and Texas Instruments, Inc.—as the basis for its future factory design program. Specifically, SEMATECH is (1) using elements of the microelectronics manufacturing science and technology program's approach to develop equipment interface standards for CIM and (2) working jointly with Texas Instruments, Inc., and other software vendors to develop an advanced manufacturing system based largely on the microelectronics manufacturing science and technology work. DARPA stated that R&D also is being coordinated between SEMATECH's modeling and simulation program and DARPA's Concurrent Semiconductor Equipment Development program, the SEMATECH/MCC Known Good Die effort and DARPA's Application Specific Electronic Module, and SEMATECH's CIM program and (1) DOD's MANTECH program and (2) the National Center for Manufacturing Sciences.
- Sandia National Laboratories is participating in SEMATECH's R&D program through its Semiconductor Equipment Technology Center. In particular, the center has developed an equipment reliability analysis and modeling program that is being tested at four equipment suppliers. The center also worked with SEMATECH to develop an improved user interface for GCA's XLS lithography stepper and has projects on software quality, plasma diagnostics, and low-pressure chemical vapor deposition processes. Sandia currently is establishing a Contamination-Free Manufacturing Research Center.

In addition, several meetings are held each year to promote collaboration between various DOD laboratories and SEMATECH, and SEMATECH has funded research involving the National Institute of Standards and Technology and Oak Ridge National Laboratory.

Question

Has SEMATECH-developed technology been transferred to DOD semiconductor fabrication facilities?

Response

DARPA stated that its primary reason for investing in SEMATECH and DOD's biggest benefit is the improvement of the U.S. semiconductor manufacturing base; the transfer of semiconductor manufacturing technology to DOD organizations is a secondary objective. Table 1.2 shows that 6 current SEMATECH members and 1 former member were among the

top 10 companies supplying integrated circuits to DOD in 1991. Overall, DARPA said that SEMATECH's member companies supply about 70 percent of the semiconductors used in DOD systems.

Table 1.2: Top 10 Companies in Sales of Integrated Circuits to DOD in 1991

Dollars in millions

Company	Estimated sales
Harris Corporation	$ 240
National Semiconductor Corporation	210
Texas Instruments, Inc.	140
Analog Devices	125
Advanced Micro Devices, Inc.	110
Intel Corporation	85
Motorola, Inc.	77
LSI Logic Corporation	70
Raytheon	50
Integrated Device Technology	40
All other companies	313
Total	**$1,460**

Source: Integrated Circuit Engineering Corporation.

The National Security Agency; the Naval Command, Control and Ocean Surveillance Center; and Wright Laboratories have had assignees at SEMATECH and have received such SEMATECH-developed technology as information on fabrication facility design and operation, improved manufacturing processes and equipment, and improved CIM software.

- The National Security Agency and the Naval Command, Control and Ocean Surveillance Center were among the first facilities to receive GCA XLS lithography steppers. Both organizations participated in SEMATECH's joint development project through assignees who now oversee their lithography operations using the XLS steppers. The Naval Command, Control and Ocean Surveillance Center plans to use SEMATECH's methodology for qualifying new equipment and the 0.5-micron lithography process for the XLS stepper, which will substantially reduce the time and costs associated with integrating the XLS stepper into its production line.
- SEMATECH transferred reactive ion etch technology to the Naval Command, Control and Ocean Surveillance Center, thus saving the center considerable development time and allowing rapid integration into its fabrication process.

- The National Security Agency, which is participating in SEMATECH's future factory design and CIM efforts, will work with SEMATECH to implement a model for using modular equipment.
- SEMATECH has supported the National Security Agency's fabrication facility by providing 35 technical transfer reports between September 1987 and May 1991 on such subjects as capital equipment installation, bulk and specialty gas specifications, and vibration monitoring.

SEMATECH Beyond 1992

Question

Does DARPA have a plan to phase out funding for SEMATECH?

Response

DARPA stated in its written response that it plans to phase out funding specifically designated for SEMATECH after the government's 5-year funding commitment ends this year. Specifically, DARPA has budgeted $80 million per year from fiscal years 1993 through 1997 for microelectronics manufacturing R&D, with all of its fiscal year 1993 budget designated for SEMATECH. However, in subsequent years DARPA would award microelectronics manufacturing R&D funding for projects at SEMATECH, individual companies, or universities that best address DOD's needs for high-performance information systems.

DARPA's objective in supporting microelectronics manufacturing R&D is to provide DOD with access to semiconductor manufacturers capable of producing state-of-the-art logic chips (1) with multiple part types and processes, (2) in small-to-moderate volumes at low cost, and (3) with rapid turnaround. To meet these requirements, DARPA said that U.S. semiconductor manufacturers need to change to a low-cost, flexible-manufacturing capability; currently they use an economy-of-scale approach, optimized for high-volume production of a fixed product. DARPA is particularly interested in SEMATECH'S R&D in lithography, computer-integrated manufacturing, ultra-clean manufacturing, modeling and simulation, and modular process equipment.

As shown in table 2.1, the microelectronics manufacturing program is part of $337.6 million that DARPA proposes to spend on microelectronics R&D in fiscal year 1993. These funds will support microelectronics projects in four major program areas.

Table 2.1: DARPA's Proposed Funding for Microelectronics R&D in Fiscal Year 1993

Dollars in millions

Programs	Proposed funding for microelectronics
Defense Research Sciences	
Electronic Sciences	$ 28.8
Materials/Electronics Technology	
Electronics processing	16.3
Optoelectronics	15.4
High-temperature superconductivity	23.1
Manufacturing Technology	
Semiconductor manufacturing technology	80.0
Microwave and millimeter-wave integrated circuits	88.5
Infrared focal plane arrays	21.7
Electronic module technology	20.4
Computing Systems and Communications Technology	
Strategic computing	4.6
Gallium arsenide	1.2
High-performance computing	37.6
Total	**$337.6**

Source: DARPA.

DARPA stated that (1) federal funding was critical for starting SEMATECH in 1987, when many experts believed that an R&D consortium could not succeed because industry members could not cooperate, and (2) SEMATECH has been a tremendous success, resulting in broad infrastructural changes within the industry. However, DARPA added that the industry should bear the primary responsibility for ensuring continued support for SEMATECH because it is an industry-led consortium addressing industry needs.

Question

Has SEMATECH developed a firm plan with clearly stated technical objectives for its R&D program after fiscal year 1992?

Response

SEMATECH's new mission for its R&D program from 1993 to 1997 is to create fundamental change in manufacturing technology and the domestic infrastructure to provide U.S. semiconductor companies with the capability to be world-class suppliers. SEMATECH established the following objectives to accomplish this mission:

- Provide unit processes and generic manufacturing methods for members to integrate into their proprietary process flows and products.
- Ensure that there is a viable supplier infrastructure capable of meeting the members' requirements for key equipment modules, materials, and manufacturing systems.
- Reduce sensitivity of cost to manufacturing volume.
- Provide programmable factory systems capable of responding to process changes with first-pass success.
- Cooperate with the Semiconductor Research Corporation, DARPA, and national laboratories to develop a research and educational infrastructure necessary to sustain U.S. leadership in semiconductor technology.
- Maintain open forums for effective communications, collaboration, and consensus building with the SEMATECH community.

DARPA believes that SEMATECH's operating plan has clearly stated technical objectives that are broken down into measurable criteria and linked to SEMATECH's thrust areas. DARPA also noted that the plan (1) has an execution strategy for the overall research program and individual projects; (2) identifies performance metrics, deliverables, and detailed technical milestones for each project; and (3) is sufficiently flexible to enable SEMATECH to update the metrics as needed.

Question

What would be the impact on SEMATECH's R&D program if federal support is reduced to $80 million or less beginning in fiscal year 1993?

Response

According to SEMATECH, its goals for the next 5 years cannot be met if funding is reduced below the current $200 million per year. SEMATECH added that its Board of Directors, working with DARPA, would have to take a look at the options available, should funding fall below $200 million annually.

Question

If federal support for SEMATECH is reduced from $100 million per year to $80 million per year, are member companies willing to increase their funding to maintain SEMATECH's current annual budget of $200 million?

Response

Ten of SEMATECH's current 12 member companies either stated or indicated that they are unwilling to increase their funding for SEMATECH above current levels, citing the following reasons:

- Dataquest's surveys show that semiconductor manufacturers generally reinvest about 10 percent of sales in R&D and 15 percent of sales in new facilities and equipment. For example, Intel Corporation will reinvest about 30 percent of its revenues into R&D and equipment and facilities this year, while NCR Corporation will reinvest 12 percent of its semiconductor sales in R&D, including 1 percent of sales for SEMATECH. Intel Corporation pointed out that each new generation of fabrication facilities is more capital intensive, which substantially increases the cost to construct and equip them. (Table 2.2 uses the capital costs for facilities that fabricate dynamic random access memory (DRAM) chips to illustrate the rising capital costs.)

Table 2.2: Capital Costs for Equipment and Facilities to Fabricate Each New Generation of DRAM Semiconductor Chips

DRAM equivalent (megabits)	Critical dimension (micron)	Year introduced	Capital costs[a] (millions)
1	1.0	1987-88	$200
4	.8	1990-91	360
16	.5	1993-94	720[b]
64	.35	1996-97	1,500[b,c]

[a]Assumes a throughput of 6,000 wafers per week.

[b]Two hundred-millimeter wafers.

[c]Estimated capital costs.

Source: Intel Corporation.

- Member companies would have to reduce funding for internal R&D projects. Texas Instruments, Inc., stated that such a shift was very unlikely because it would have to reduce spending in other areas, such as new product development, to increase funding for SEMATECH. Similarly, AT&T stated that such an increase would have to be at the expense of internal R&D projects that almost have the funding needed for successful completion.

  In contrast, Motorola, Inc., said that if the government contributes only $80 million, SEMATECH's members will find an appropriate solution to identified needs. As examples of the semiconductor industry's willingness to support necessary R&D, Motorola, Inc., cited industry members' decisions to establish and fund the Semiconductor Research Corporation in 1982 and SEMATECH in 1987. Digital Equipment Corporation did not respond to this question.

Question

Why should the federal government continue to support SEMATECH's program beyond its initial 5-year commitment?

Response

SEMATECH and its member companies stated that federal support for SEMATECH is appropriate and in the nation's economic and defense interest for the following reasons:

- DOD is a primary beneficiary of SEMATECH's R&D program. Although DOD accounts for a small portion of U.S. semiconductor manufacturers' sales revenue, advanced semiconductors are critical components of weapons systems that have given DOD a technological edge in war. To assess the benefits of continued federal support of SEMATECH, one member company said that the government needs to first determine whether and to what extent the United States can depend upon an industrial infrastructure located outside the United States and under the political control of other countries for its critical microelectronics needs.[1] And second, if the government is unwilling to accept substantial dependency on foreign sources, the government needs to determine whether federal funding for SEMATECH will acceptably reduce such dependency and minimize the risk of dependency more effectively than other expenditures or actions the government could take.
- SEMATECH's efforts to strengthen the U.S. semiconductor industry benefit the entire U.S. electronics industry and the U.S. economy through an increased market share in high technology and more employment. For example, as a result of SEMATECH's efforts (1) several member companies have increased their purchases of U.S., instead of foreign, semiconductor manufacturing equipment and (2) semiconductor manufacturers and their suppliers are working to standardize manufacturing processes that in the future could give the U.S. semiconductor industry a competitive advantage over its foreign competition.
- SEMATECH's R&D program is a long-term effort to enable the U.S. semiconductor industry to regain world leadership in manufacturing. While industry statistics indicate that U.S. equipment suppliers and device manufacturers have arrested their decline in the world market share, one member said that the industry needs to regain manufacturing leadership before federal funding ends.
- Governments in Japan, Europe, and South Korea have supported their semiconductor industries through technology policies and/or financial

[1]DOD has not updated its February 1987 analysis, Report of Defense Science Board Task Force on Defense Semiconductor Dependency, which provided support for the government's original decision to support SEMATECH.

support. For example, Europe's JESSI consortium plans to spend about $4 billion over the next 5 years on semiconductor R&D.

Question

How important is computer-integrated manufacturing (CIM) to member companies and DARPA, and what are the current constraints limiting their use of CIM?

Response

SEMATECH, most member companies, and DARPA indicated that CIM is one of the highest payback investments for improving semiconductor fabrication productivity. CIM will significantly reduce the average time needed to fabricate semiconductors and improve yields by developing (1) factory control systems that reduce software malfunctions, currently the primary reason for semiconductor manufacturing equipment failures, and (2) software-and automated-materials-handling techniques that will substantially reduce product-processing mistakes and improve equipment utilization. In addition, CIM is a key element of SEMATECH's efforts to develop a shop floor system for flexible manufacturing that enables semiconductor manufacturers to respond effectively to customers' needs.

DARPA stated that CIM and modeling and simulation for developing future factory designs are key to DARPA's objectives of developing flexible manufacturing systems. DARPA supports SEMATECH's work because it can define and develop common interfaces between equipment and factory systems and between various software modules. DARPA also believes that these new manufacturing capabilities will be transferrable to other critical industries.

The use of CIM factory and process control techniques has been hampered in the semiconductor industry by a lack of standardization in hardware and software interfaces. One member company pointed out that individual semiconductor manufacturers do not have the purchase power to drive suppliers toward standard interfaces needed for CIM. Another member noted inefficiencies in its own operations because each fabrication facility uses different customized shop floor tracking and data collection systems, thus minimizing the opportunity for sharing information among facilities.

Three member companies stated that SEMATECH's initial progress was not satisfactory. However, one of them is encouraged because SEMATECH initiated a strategic cell controller program in October 1990 and has decided to use the Open Software Foundation's Unix standards as the

industrywide CIM platform, thus leading suppliers to convert their products from the previous proprietary and nonstandard platforms to systems currently available from major Unix computer makers.

SEMATECH's Expenditures and Budget

Question

How has SEMATECH spent its funds during its first 5 years of operations?

Response

As shown in table 3.1, SEMATECH's expenditures through 1991 and budgeted expenses for 1992 totaled $990 million. Of $214 million spent for facilities and other capital costs, $177 million, or 83 percent, was associated with constructing SEMATECH's semiconductor fabrication facility and central utility building and renovating its office building in 1988 and 1989. During 1991 SEMATECH's 716-member work force included 497 direct hires and 219 member company employees who have been assigned, typically for 2 years, to SEMATECH. Assignees represented nearly 60 percent of SEMATECH's technical work force.

Table 3.1: SEMATECH's Expenditures by Cost Category, 1988-92

Dollars in millions

Category	Amount	Percent
Facilities and other capital costs	$214	22
Factory supplies[a]	135	14
Labor[b]	185	19
External R&D[c]	287	29
Project capital equipment[d]	84	8
Purchased services[e]	44	4
Other costs[f]	41	4
Total	**$990**	**100**

Note: Includes SEMATECH's expenditures through 1991 and budgeted expenses for 1992.

[a]Includes clean room supplies, specialty gases, bulk chemicals, and maintenance contracts.

[b]Includes salaries and payroll costs of SEMATECH's employees and assignees.

[c]Includes (1) payments to suppliers participating in joint development and equipment improvement projects and (2) $43 million for SEMATECH Centers of Excellence.

[d]Equipment that SEMATECH has bought for specific R&D projects.

[e]Includes consultants' fees, legal fees, and other services.

[f]Includes communications, technology transfer, travel, and sundry expenses.

Question

How much has SEMATECH spent for specific R&D projects?

Response

Table 3.2 shows that SEMATECH spent $287 million for external R&D from 1988 through 1992. SEMATECH's major program segments, or thrust areas,

primarily involve projects with semiconductor equipment and materials suppliers to develop next-generation technology or to improve existing equipment. In addition, SEMATECH's 11 Centers of Excellence support basic research on semiconductor manufacturing technology at universities and national laboratories. R&D in the lithography, multilevel metals, and SEMATECH's Centers of Excellence and national laboratories thrust areas accounted for $216.9 million, or 76 percent, of the $287 million spent on external R&D during the 5-year period.

Table 3.2: SEMATECH's External R&D Expenditures by Thrust Area, 1988-92

Dollars in millions

Thrust area	External R&D expenditures
Lithography	$108.0
Multilevel metals	53.0
Furnaces and implants	7.5
CIM/Manufacturing systems	25.4
Contamination-free manufacturing	12.8
Process design and integration	3.6
Modeling, analysis, and manufacturing methods	1.2
Centers of Excellence and national laboratories	55.9
Discretionary fund	15.0
Expenditures prior to tracking by thrust area	4.6
Total	**$287.0**

Table 3.3 shows that SEMATECH's technical employees primarily worked on projects in the lithography, manufacturing systems, process design and integration, and manufacturing methods thrust areas during 1991. These thrust areas accounted for $24.7 million, or 75 percent, of $32.9 million paid for the salaries of SEMATECH's technical employees in 1991. While external payments are tracked by project, SEMATECH's accounting system does not allocate such internal costs as salaries and benefits to specific projects.

Table 3.3: Salaries of SEMATECH's Technical Employees by Thrust Area in 1991

Dollars in millions

Thrust area	Salaries
Lithography	$4.5
Multilevel metals	2.8
Furnaces and implants	2.5
CIM/Manufacturing systems	5.0
Contamination-free manufacturing	2.4
Process design and integration	5.4
Modeling and analysis	.5
Manufacturing methods	9.8
Total	**$32.9**

Question

Has SEMATECH complied with the legislative requirement that no more that 50 percent of its funding may be derived from federal, state, and local government sources?

Response

As shown in table 3.4, member companies' contributions and interest less unallowable expenses have exceeded federal and state contributions each year from 1988 through 1991. Each year SEMATECH's audited financial statements contain a schedule showing the extent to which member company contributions and interest earned from those contributions exceed the total of (1) federal grant funds, (2) the Texas State contribution (made through the University of Texas), and (3) unallowable expenses for grant-matching purposes.

Table 3.4: Cumulative Contributions to SEMATECH by Member Companies and Federal and State Governments

Dollars in millions

Members companies	1988	1989	1990	1991
Annual contributions	$78.4	$183.1	$290.5	$393.0
Receivables	0	0	4.6	4.6
Interest earned on prior member contributions	1.8	5.8	9.9	13.0
Less unallowable expenses	(.8)	(1.2)	(2.4)	(3.8)
Total	**$79.4**	**$187.7**	**$302.6**	**$406.8**
Government agencies				
DARPA contributions	77.0	181.7	265.7	370.3
DARPA matched receivables	0	0	23.4	25.9
Texas amortization	0	1.8	4.0	6.0
Total	**$77.0**	**$183.5**	**$293.1**	**$402.2**
Excess contributions by member companies	**$ 2.4**	**$ 4.2**	**$ 9.5**	**$ 4.6**

Question

How much of SEMATECH's expenses have been paid using only member companies' contributions?

Response

Table 3.5 shows that between 1989 and 1991, SEMATECH's member companies paid about $3 million for unallowable expenses under the 50-percent government matching provision. This amount includes $317,728 in 1990 and $340,404 in 1991 that SEMATECH reclassified as unmatched costs during a year-end review of the 1991 accounts. These reclassified costs, which primarily were associated with SEMATECH's Washington, D.C., office (salary, benefits, rent, and travel), are included in the public relations category.

Table 3.5: SEMATECH' Expenses Paid for Only With Members' Contributions

Dollars in thousands

	Expenses			
	1989	1990	1991	Total
Legal and consulting	$601	$307	$ 476	**$1,384**
Public relations[a]	73	587	732	**1,392**
Other unmatched costs	45	51	124	**220**
Total	**$719**	**$945**	**$1,332**	**$2,996**

[a]Includes SEMATECH's Washington, D.C., office and other internal expenses.

Question

How much has SEMATECH spent for outside legal, public relations, and consulting services?

Response

As shown in table 3.6, SEMATECH's expenditures for outside legal, public relations, and consulting services increased from $2.7 million in 1988 to $9.1 million in 1991. In particular, SEMATECH has increased its use of consultants, primarily for chemical analysis, software development, or other technical services supporting specific equipment improvement and development projects. Legal services, public relations, and consultant services accounted for about 4 percent of SEMATECH's total expenditures in 1991.

Table 3.6: SEMATECH's Expenditures for Outside Legal, Public Relations, and Consulting Services, 1988-91

Dollars in thousands

	Expenditures				
	1988	**1989**	**1990**	**1991**	**Total**
Legal[a]	$1,139	$ 710	$ 405	$1,344	**$ 3,598**
Public relations[b]	96	87	596	357	**1,136**
Consulting[c]	1,479	3,516	5,681	7,421	**18,097**
Total	**$2,714**	**$4,313**	**$6,682**	**$9,122**	**$22,831**

[a]SEMATECH retains three legal firms for advice on state and local issues, federal laws and regulations, and litigation relating to contractual disputes.

[b]In general, SEMATECH's public relations expenses were paid by its member companies without the use of matching government funds.

[c]SEMATECH's records identify the department purchasing a consultant's services and the nature of services purchased.

Question

What is SEMATECH's policy for disposing of equipment that is no longer needed?

Response

In July 1991 SEMATECH and DARPA agreed to the following priorities for disposing of surplus SEMATECH equipment: (1) if the performance of a piece of equipment is tested on a member company's fabrication line, the member has the option to purchase the equipment at book value at the end of the project; (2) use surplus equipment in another SEMATECH program; (3) trade in the equipment for upgraded equipment; (4) sell the equipment to DARPA or another federal agency; (5) sell the equipment to the highest

bidder through a broker; (6) donate the equipment to a SEMATECH Center of Excellence, a university, or DARPA; or (7) scrap the equipment.

SEMATECH has disposed of only a limited amount of surplus equipment. In particular, SEMATECH's decision in 1989 to narrow its plans to fabricate DRAM chips resulted in the purchase of some specialized equipment that it no longer needed. SEMATECH attempted unsuccessfully to cancel all of the affected purchase orders. SEMATECH's equipment disposal manager told us that because this equipment is highly specialized, its resale market is very limited. The following are three examples of equipment orders that SEMATECH could not cancel that became excess to its needs:

- An MTI Sypherline, a tool used to place molecules of a desired material on a wafer, was purchased in 1988 for $1.5 million. SEMATECH leased the tool to IBM from February 1990 through October 1990 for $510,000. IBM purchased the tool in October 1990 for $100,000, after notifying SEMATECH that it did not plan to extend the lease agreement. SEMATECH collected $610,000 on the lease and sale of the tool. The net book value of the sypherline at the time of sale was $900,000.
- SEMATECH purchased a Teradyne memory tester in May 1989 for $500,000 and sold it to Comprehensive Development Services in September 1991 for $105,000. The net book value on the date of sale was $322,214. Prior to the sale, SEMATECH had tried to sell the tool to member companies and DARPA but received no offers.
- SEMATECH purchased a Genus ion implanter for $2.02 million in June 1989 and leased it in March 1990 to Ion Implant Services for $35,000 per month or the monthly revenue generated by the tool, whichever was less. However, the company has paid only $315,000 in lease payments. SEMATECH is trying to sell the tool.

As of December 31, 1991, the total acquisition value of SEMATECH's surplus equipment was $55.2 million, and its net book value was $19.2 million. The excess equipment primarily consisted of (1) 14 of GCA's upgraded AutoStep 200 lithography steppers that were tested in members' fabrication facilities as part of SEMATECH's largest equipment improvement project and (2) equipment no longer needed when SEMATECH converted its facility during 1991 from a facility processing 150-millimeter wafers to one processing 200-millimeter wafers. Nine DOD laboratories have expressed interest in purchasing 29 of the 97 pieces of excess equipment at their net book value.

Question

How much SEMATECH-purchased equipment is located at member company facilities?

Response

As of December 31, 1991, SEMATECH had paid $31.3 million for equipment installed in member companies' fabrication facilities as part of some equipment improvement and development projects. After testing the equipment in a high-volume manufacturing environment and providing performance data to SEMATECH, a member has the option to purchase the equipment at net book value (the purchase price of the equipment less accumulated depreciation based on the double-declining method of depreciation over a 5-year life). If the member does not purchase the equipment, SEMATECH will reclaim and dispose of it in accordance with its property disposal process.

SEMATECH's largest project to test equipment on members' production lines involved the purchase of 14 GCA AutoStep 200 lithography steppers for $19 million. SEMATECH, which invited each member to participate, selected four companies on the basis of their proposals to participate in developing a significant data base of information on tool performance and supplier support for incorporation into its joint development project with GCA to develop next-generation XLS lithography steppers. After testing was completed, IBM purchased the four GCA steppers at its facility for their total book value of $2.3 million, whereas Advanced Micro Devices, Inc., has leased two steppers and returned two to SEMATECH. Motorola, Inc., and National Semiconductor Corporation are likely to purchase the steppers in their facilities.

Question

Has SEMATECH prepared a detailed budget for its proposed 5-year follow-on program?

Response

SEMATECH has prepared a detailed budget for 1993 through 1997 that assumes continued funding at $200 million per year. However, because SEMATECH considers information about its proposed funding of thrust areas and individual R&D projects for 1993 through 1997 to be proprietary, such information has not been included in this report. Table 3.7 shows SEMATECH's annual budget for external R&D, internal expenses, and discretionary uses.

Table 3.7: SEMATECH's 1993-97 Budget by Overall Category

Dollars in millions

	Budget					
Category	**1993**	**1994**	**1995**	**1996**	**1997**	**Total**
External R&D	$117	$122	$114	$112	$ 96	$ 561
Internal[a]	83	76	76	70	70	375
Discretionary[b]	0	2	10	18	34	64
Total	**$200**	**$200**	**$200**	**$200**	**$200**	**$1,000**

[a]Includes salaries, cost of facilities, and administrative overhead.

[b]Primarily used for external R&D and to provide flexibility.

SEMATECH's budget was prepared in July and August 1991 by SEMATECH's thrust area managers.[1] Budgets for each thrust area were based on specific projects identified by managers on the basis of their knowledge of the area and contacts with suppliers and experts on the semiconductor industry's needs. According to SEMATECH's Director of Strategic Integration, when the managers projected total needs that exceeded $200 million per year, SEMATECH's Office of the Chief Executive imposed the constraint of $200 million per year. The thrust area managers then reworked their budgets to fit this limitation.

Question

To what extent have member companies sought reimbursement for SEMATECH's membership dues or costs associated with SEMATECH assignees through government contracts they hold?

Response

According to SEMATECH member companies' responses, 5 of the 13 members included a portion of their SEMATECH contributions and/or assignee pay and benefits in an indirect expense or overhead pool charged to federal government contracts as follows:

- On the basis of forecasted general and administrative forward pricing rates, one member estimated that $2.4 million for SEMATECH contributions had been charged to government contracts in fiscal years 1987 through 1991.
- One member estimated that from 1989 through 1992, about $1.3 million of its SEMATECH contribution expense had been included in an overhead pool related to its Military and Aeronautics Division contracts. However, the

[1]SEMATECH currently is reviewing this budget.

member mentioned that the division had intentionally underbilled on government contracts during these 4 years by using an overhead rate set significantly lower than that required to absorb all chargeable overhead costs.

- One member included its SEMATECH contributions in general and administrative overhead as an independent R&D expense from 1987 to 1991. The company stated that the total amount recovered against federal contracts is unknown because it does not allocate sources of revenue to specific actual costs or cost pools.
- One member reported that a total of $31,841 had been charged to government contracts between 1987 and 1991.
- One member noted that only assignees' merit and performance awards are subject to allocation to government contracts but provided no estimate of the amounts involved.

Eight member companies stated that they have not included a portion of either their SEMATECH contributions or assignee pay and benefits in an indirect expense or overhead pool charged to federal government contracts awarded on a basis other than sealed bids or catalogue price.

SEMATECH's Original Member Companies

Advanced Micro Devices, Inc.

American Telephone and Telegraph Company (AT&T)

Digital Equipment Corporation

Harris Corporation

Hewlett-Packard Company

Intel Corporation

International Business Machines Corporation (IBM)

LSI Logic Corporation[a]

Micron Technology, Inc.[a]

Motorola, Inc.

National Semiconductor Corporation

NCR Corporation

Rockwell International Corportion

Texas Instruments, Inc.

[a]Withdrew from SEMATECH in 1992.

R&D Program Objectives Established by SEMATECH's Board of Directors in February 1990

- Develop key process modules for member companies to integrate proprietary process flows and products. Establish a baseline integrated process.
- Reduce member risk by delivering manufacturing processes and equipment models for use in future equipment decisions.
- Develop at least one qualified, viable U.S. supplier for each key equipment module and manufacturing system.
- Develop long-term strategic alliances with selected suppliers to develop the required capability on the required time schedule.
- Provide preferential availability of all funded equipment, systems, materials, supplies, and chemicals to the member companies.
- Drive standards and specifications for open architecture, computer-integrated manufacturing systems, including a generic cell controller.
- Continue to provide a forum for open communication. Ensure timely information transfer.
- Establish collaborative centers of manufacturing science at selected universities and national laboratories.

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Glossary

Computer-Integrated Manufacturing	The integration of computer control and monitoring into a process in manufacturing.
Deposition	An operation that places a film on a wafer without a chemical reaction with the underlying layer.
Etching	A process in which acid is used to remove previously defined portions of the silicon oxide layer covering the wafer to expose the silicon underneath. Removing the oxide layer permits the introduction of desired impurities into the exposed silicon through diffusion or ion implantation or the deposition of aluminum paths for electrical interconnection or circuit elements.
Furnace	An oven used, for example, to facilitate the reaction of gases with silicon wafers at temperatures typically greater than 800 degrees Centigrade to form carbon dioxide or to diffuse previously deposited chemicals into the wafer.
Integrated Circuit	A complete electronic circuit composed of interconnected diodes and transistors and fabricated on a single semiconductor wafer, usually silicon.
Ion Implantation	A process in which the silicon is bombarded with high-voltage ions in order to implant them in specific locations and provide the appropriate electronic characteristics.
Linewidth	The width of a patterned line measured to determine critical dimensions for maintaining device performance consistency.
Lithography	A process in which the desired circuit pattern is projected onto a photoresist coating covering a silicon wafer. When the resist is developed, portions of the resist can be selectively removed with a solvent, exposing parts of the wafer for etching and diffusion.
Multilevel Metals	This SEMATECH thrust area involves projects in etching, interlevel dielectric and tungsten deposition, and planarization.

Planarization	A process in which a flat layer of glassy material is deposited over the lower layers of an integrated circuit. This step simultaneously creates a flat surface for further processing and isolates the lower layers.
Plasma	Ionized gas used to remove resist, etch, and deposit various layers onto a wafer.
Process	A major group of sequential operations in the manufacture of an integrated circuit.
Resist	A photosensitive liquid plastic film applied to the surface of a wafer during lithography for micropatterning (also called photoresist).
Semiconductor	A material, typically silicon or germanium, that has four electrons in its outer ring and is a poor conductor of electricity. The term has come to refer to all devices made of semiconducting material, including integrated circuits, transistors, and diodes.
Stepper	A sophisticated piece of equipment used to transfer an integrated circuit pattern from a glass plate, known as a "mask," onto a disk of semiconductor material, known as a "wafer."
Wafer	A thin disk, from 2 to 8 inches in diameter, cut from silicon or other semiconductor material. The wafer is the base material on which integrated circuits are fabricated.
Yield	The percentage of wafers or semiconductor chips conforming to specifications produced in an operation or process.

Related GAO Products

Federal Research: Assessment of the Financial Audit for SEMATECH's Activities in 1990 (GAO/RCED-92-97, Apr. 9, 1992).

Federal Research: SEMATECH's Efforts to Develop and Transfer Manufacturing Technology (GAO/RCED-91-139FS, May 10, 1991).

Federal Research: Assessment of the Financial Audit for SEMATECH's Activities in 1989 (GAO/RCED-91-74, Apr. 30, 1991).

Federal Research: SEMATECH's Efforts to Strengthen the U.S. Semiconductor Industry (GAO/RCED-90-236, Sept. 13, 1990).

Federal Research: Assessment of the Financial Audit for SEMATECH's Activities in 1988 (GAO/RCED-90-35, Feb. 16, 1990).

Federal Research: The SEMATECH Consortium's Start-up Activities (GAO/RCED-90-37, Nov. 3, 1989).

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