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The Competitive Strength of U.S. Industrial Science and Technology: Strategic Issues



A Report of the
National Science Board
Committee on Industrial Support for R&D

August 1992

National Science Board

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Executive Summary

Many observers have commented that the competitive strength of U.S. industrial science and technology is declining. U.S. industry has already lost its leadership in several technologies that are critical to industrial performance, and it is weak or losing competitive strength in others. During the mid-1980s, U.S. investment in R&D increased at a sluggish pace, and the Nation's nondefense R&D expenditures did not increase as rapidly as those of many major foreign competitors. The Nation has also experienced relatively slow-paced product development and commercialization, since the results of U.S. R&D are not brought to market as effectively as those of foreign competitors. Compared to other countries, a high fraction of U.S. Government expenditures go to defense, rather than commercial, R&D.

These issues are of significance to the Federal Government, and specifically affect the National Science Foundation (NSF). Fundamental research supported by NSF in both science and engineering makes an important contribution to the competitive strength of U.S. industry.

The National Science Board (NSB), concerned about these issues, established the NSB Committee on Industrial Support for R&D to carry out a study on the nature of the problems and suggest broad remedies. The Committee felt that in addition to making general recommendations, it was important to make specific recommendations—some directed at NSF and other Federal agencies, others directed at the government in general.

This report represents the culmination of the Committee's effort to present an integrated, multidimensional view of the issues surrounding U.S. industrial R&D. This report is not intended to be a comprehensive study of U.S. international competitiveness. It focuses primarily on science and technology, particularly on the impact of R&D on U.S. competitive strength. The Committee recognizes that improving the U.S. R&D system—and, consequently, the U.S. scientific and technological position—will not in itself remedy all the ills of the U.S. economy or U.S. industrial competitiveness.

The Committee looked at R&D inputs (expenditures), intensity, content, and system outputs and compared them to those of foreign competitors. It invited several prominent authorities to express their views of industrial R&D in various industry groups. The Committee also used other recent, relevant studies and reports that have addressed these issues and the results of a survey conducted by the Industrial Research Institute (IRI) in cooperation with the Committee. The resulting composite picture throws new light on the major issues and on what should be done about them. The problems facing U.S. industrial science and technology are complex: there is no single problem, no simple solution. Policies and programs must address several dimensions simultaneously.

From its research, the Committee reached the following conclusions.

- The U.S. industrial R&D system is in trouble not only because the recent growth of R&D expenditures is lagging that of foreign competitors, but also because—in the view of many knowledgeable observers—the distribution and allocation of those expenditures is not optimal.
- Both Federal and corporate policies need to be improved if the Nation is to meet international competitive challenges.
- There are significant gaps in U.S. industrial R&D strength (e.g., in engineering research); further, a new threat is emerging to the country's traditional sources of strength—pioneering discoveries and inventions.

In short, the United States is spending too little, not allocating it well, and not utilizing it effectively.

Findings

The Committee's principal findings follow.

1. *The real rate of growth in U.S. industrial R&D spending has declined since the late 1970s and early 1980s. In addition, the Nation's position has deteriorated relative to that of its major international competitors whose investment in nondefense R&D has been growing at a faster pace than U.S. nondefense R&D since the mid-1980s.*

- Domestic industrial R&D expenditures slowed from an average annual growth rate of 7.5 percent (constant dollars) during 1980-85 to only 0.4 percent during 1985-91. The federally supported

portion of these expenditures dropped from a growth rate of 8.1 percent to -1.7 percent over these two periods; industry's own support dropped from 7.3 percent to 1.3 percent. Almost all major R&D-performing industries contributed to this reduced growth rate.

- Since 1985, U.S. growth in both total and nondefense R&D expenditures has been less than that of many of its major industrial competitors.
- The United States now trails Japan and (West) Germany, its strongest competitors, in nondefense R&D spending as a percentage of gross domestic product (GDP).

2. *The allocation of U.S. R&D expenditures is not optimal.*

- The balance between defense and non-defense expenditures is disadvantageous compared to that of foreign competitors.

International data for defense and nondefense components of total R&D expenditures (not industrial alone) as a percentage of GDP can be compared. Using six countries—Japan, (West) Germany, France, the United Kingdom, Italy, and Sweden—as a benchmark, the United States in 1989 spent almost as much as they did on total R&D, but 25 percent less on nondefense R&D.

This imbalance has been deteriorating: the fraction of U.S. R&D expenditures on nondefense decreased slightly (from 74 to 71 percent) during the 1980s, while that of the competitor group increased (from 90 to 92 percent). Thus, during the 1980s, these six

competitors moved from being 22 percent ahead of the United States in nondefense R&D expenditures to being 34 percent ahead. This increase has been driven largely by Japan's huge growth in nondefense R&D spending; today, Japan spends about 3 percent of its GDP on nondefense R&D, compared to 1.9 percent for the United States.

- Too little is spent on process-oriented R&D.

Several studies have found that U.S. industrial R&D is weighted much more heavily toward product technology rather than process technology. U.S. firms also allocate a disproportionately small share of their R&D budgets to the search for new and/or improved processes compared to their Japanese counterparts.

- Inadequate effort is devoted to fundamental engineering research.

The rapid conversion of ideas into products and processes requires command of an ever-expanding engineering knowledge base. Yet there is an insufficiently broad and deep fundamental engineering research base on which to build.

- There is insufficient emphasis on emerging and precompetitive technologies.

In the IRI survey, industry's "reluctance to invest in new enabling technologies because the R&D may be too expensive, long-term, multi-industry, and interdisciplinary" received the largest number of first place rankings as a factor adversely affecting U.S. industry's ability to compete in global mar-

kets for high-technology products under the major category of *technology management practices*.

- The United States faces an emerging risk of losing its traditional strength in pioneering discoveries and inventions.

Most pioneering advances of the past that have created the basis for new industries have originated in either the corporate laboratories of private firms or in research universities. Both of these institutions are under severe stress today.

3. *U.S. expenditures are not as effective as they should be in producing needed results.*

- The U.S. competitive position in important, technologically based industries is deteriorating.

The once strong across-the-board U.S. position of a decade ago has deteriorated substantially. U.S. industry has already lost its leadership in several technologies that are critical to industrial performance, and is weak or losing competitive strength in others.

- The U.S. time horizon has become too short, and the Nation's business decisions tend not to be based on strategic technological considerations.

In large corporations, effort is shifting away from central laboratories toward division-level effort with greater emphasis on risk minimization to meet the needs of today's customers; emphasis is also shifting away from new markets toward existing markets.

- U.S. R&D is not translated into beneficial economic and social results quickly enough.

Many companies trail their foreign rivals in the commercialization of new technology. In many U.S. industries, development of new products proceeds at a much slower pace than in other countries.

4. *The current information base on industrial science and technology is inadequate: it has gaps, is questionable in parts, and does not provide enough detail to meet the needs of policymakers.*

Recommendations

The Committee's findings lead to significant apprehension about the present trajectory of U.S. industrial R&D and to the conclusion that stronger Federal leadership is needed in setting the course for U.S. technological competitiveness. Implementation of a national technology policy, including establishment of a rationale and guidelines for Federal action, should receive the highest priority. The start of such a policy was set forth 2 years ago by the President's Office of Science and Technology Policy, but more forceful action is needed by the President and Congress before there is further erosion in the U.S. technological position.

The Committee's recommendations focus on areas where NSF or other agencies of the Federal Government may be able to contribute to strengthening U.S. industrial competitiveness. The recommendations include policy and programmatic directions. They fall short of what is ultimately needed, however. The current course of U.S. industrial

R&D demands creative policies, programs, and initiatives beyond those devised and examined by the Committee. Committee recommendations are listed below.

1. *Stimulate the resumption of more rapid growth of industrial R&D to match that of foreign competitors.*

- Adopt Federal fiscal and monetary policies that encourage strategic investment in both tangible and intangible assets for R&D.
- Encourage changes in Federal regulations and in the regulatory process to promote and facilitate technological innovation.
- Establish a permanent R&D tax credit.
- Put a permanent moratorium on Treasury Regulation 1.861-8 which can create a tax benefit for U.S. corporations with foreign sales that move some of their R&D to a foreign country.

2. *Encourage a reallocation of R&D expenditures toward*

- **nondefense R&D**

- Establish new programs to stimulate the redirection of resources from defense to nondefense R&D.
- Increase support for NSF strategic science and engineering research, particularly for activities that attract industrial cosupport. These activities include engineering research centers, science and technology centers, cooperative multi-user facilities, consortia, and individual investigator projects with coparticipation by industry.

- Expand programs that directly support technology transfer activities in Federal laboratories.

■ process R&D

- Expand and strengthen the Manufacturing Technology Centers Program and the State Technology Extension Program of the National Institute of Standards and Technology (NIST).
- Encourage substantial NSF involvement in the emerging Federal Coordinating Council for Science, Education, and Technology (FCCSET) Presidential initiative in manufacturing.

■ engineering research

- Encourage and assist in the expansion of Federal support of fundamental engineering research.
- Expand and strengthen NSF's Engineering Research Center Program.

■ emerging and precompetitive technologies

- Activate a U.S. technology policy that favors Federal R&D investment in generic precompetitive and emerging technologies important to industry.
- Encourage and assist in the expansion of Federal support of fundamental scientific and engineering research that contributes to emerging and precompetitive technologies, including the FCCSET initiatives in biotechnology, advanced materials and processing, and high-performance computing and communications.

- Expand the effectiveness, scope, and outreach of NSF's Science and Technology Centers, Industry/University Cooperative Research Centers, and other industry-related programs, and couple these programs even more closely with future industry needs.
- Further expand NIST's Advanced Technology Program.

■ pioneering discoveries and inventions

- Create more programmatic opportunities that encourage interaction of scientists and engineers in academia and industry to explore joint research interests with the potential for pioneering discoveries and inventions.
- Support traditional and nontraditional education programs that motivate creativity, innovation, and entrepreneurship.

3. *Improve the speed and effectiveness of moving R&D results from lab to market.*

- Explore the feasibility of NSF supporting joint science, engineering, and management education programs that focus on the integration of technology and management for leadership of both high-tech and traditional industries.
- Encourage NSF activities that lead to faster dissemination of knowledge and research results among researchers in academia, industry, and other sectors.

- Increase the support of science and engineering research and education programs that emphasize production systems engineering and the integration of product design and manufacturing.

4. *Improve data quality and adequacy.*

- Carry out a systematic assessment that identifies missing information and examines the feasibility and cost of developing and tracking a set of industrial science and technology indicators that would be of value to policymakers.

Introduction

Study Purpose and Design

The preeminence of U.S. industrial science and technology can no longer be taken for granted. The growing volume of evidence suggesting a relative decline in the competitive strength of U.S. industrial science and technology is receiving widespread attention at all levels of government, in the media, and in many other public forums. One of the most closely watched signals, and one that is generating much of the alarm, is the contraction—or even the evaporation—of U.S. firms' share of global markets for an increasing number of high-technology products. Another indicator, first observed by the National Science Foundation (NSF) several years ago and now receiving considerable scrutiny, is a slowdown in the rate of growth in U.S. industry's investment in research and development, a slowdown which began in the late 1980s. Although the United States still leads in both government and nongovernment R&D spending, the recent rate of growth in U.S. investment in nondefense R&D has lagged behind that of several other industrialized nations, including Japan and (West) Germany. Additional concerns have been raised by reports from various sources, all documenting widespread consensus among industry, government, and academic officials that U.S. firms have been losing ground against foreign competitors in the advancement and commercialization of new technology. All of these trends are particularly unwelcome at a time when national prosperity is becoming increasingly dependent on the ability of the industrial sector to compete successfully in international high-technology markets.

It was these concerns that led to the establishment of the National Science Board Committee on Industrial Support for R&D. The Committee was charged by the Board with investigating the significance of recent indicators of U.S. industry's sluggish performance by performing the following:

1. Reviewing and analyzing available statistical and other information on the level, content, and quality of U.S. science and technology; and identifying what factors may be responsible for the erosion in U.S. technology leadership.
2. Reporting the major findings of its investigation, especially highlighting important barriers to improved U.S. industrial performance in high-technology markets.
3. Identifying the role NSF can play in ameliorating the problems and recommending strategies that can be pursued by NSF or other Federal agencies that will help U.S. industry compete successfully in high-tech global markets.

This report represents the culmination of the Committee's work. Note that this report is **not** intended to be a comprehensive study of U.S. international competitiveness, but rather focuses primarily on science and technology, particularly on the impact of R&D on U.S. competitive

strength. The Committee recognizes that many factors besides those discussed in this report influence U.S. industrial competitiveness. Thus, improving the U.S. R&D system and the U.S. scientific and technological position will not alone be sufficient to correct all the problems of the U.S. economy or even to reverse completely the recent decline in U.S. industrial competitiveness.¹

Part I of this report, "Analysis of Available Data," is a compilation of available statistical and other information on the current status of U.S. industrial science and technology. It also contains the major results of a survey, "Potential Causes for the Erosion in U.S. Technology Leadership," conducted in conjunction with the Industrial Research Institute (IRI). The purpose of this survey was to obtain the opinions of leading industrial R&D officials to assist the Committee in determining what factors are adversely affecting U.S. technological competitiveness.

The Committee also sought the expertise of several individuals well known for the research they have conducted in this area.

- Dr. Alden S. Bean gave a presentation on his study of changes taking place in U.S. corporate laboratories.
- Dr. Frank Huband described the methodology and results of the Japanese Technology Evaluation Program.
- Dr. Maria Papadakis gave a presentation entitled "Linking R&D, Technology, and U.S.-Japanese Bilateral Competitiveness."
- A panel of five experts discussed their research on several industries.²

The Committee's analysis of the data, the IRI survey results, input from the experts, and additional staff research led to one major conclusion—that although the United States still leads the rest of the world in total scientific and engineering research expenditures, those expenditures are not translating into economic leadership in the marketplace. Moreover, the ability of lawmakers and policymakers to understand and address this issue is made much more difficult by incomplete and often inadequate data. Part II of this report, "Recommendations," is devoted to identifying areas in which NSF and other Federal agencies (e.g., the Department of Commerce) may have leverage and to the presentation of specific recommendations aimed at strengthening U.S. technological competitiveness.

¹A report, *Capital Choices: Changing the Way America Invests in Industry*, released by the Council on Competitiveness after the present report was completed, is a penetrating new study of the American system of allocating investment capital and its effect on U.S. industrial competitiveness. Its findings are much broader than, but entirely consistent with and supportive of, the present report.

²Members of the panel were Dr. W. Edward Steinmueller (Deputy Director, Center for Economic Policy Research, Stanford University); Dr. Kenneth S. Flamm (Senior Fellow, the Brookings Institution); Dr. David C. Mowery (Associate Professor of Business and Public Policy, Walter A. Haas School of Business, University of California, Berkeley); Dr. Candace Howes (Assistant Professor, Department of Economics, University of Notre Dame); and Dr. Henry Grabowski (Chairman, Department of Economics, Duke University).

Major Findings

After evaluating and synthesizing the information presented in part I of this report, the Committee narrowed the scope of its investigation, to focus its recommendation on four major findings. A brief review of these findings and the evidence supporting them follows.

1. *The real rate of growth in U.S. industrial R&D spending has declined since the late 1970s and early 1980s. In addition, the Nation's position has deteriorated relative to that of its major international competitors whose investment in nondefense R&D has been growing at a faster pace than U.S. nondefense R&D since the mid-1980s.*

- Domestic industrial R&D expenditures slowed from an average annual growth rate of 7.5 percent (constant dollars) during 1980-85 to only 0.4 percent during 1985-91. The federally supported portion of these expenditures dropped from a growth rate of 8.1 percent to -1.7 percent over these two periods; industry's own support dropped from 7.3 percent to 1.3 percent.

Almost all major R&D-performing industries contributed to this reduced growth rate.

- Since 1985, U.S. growth in both total and nondefense R&D expenditures has been less than that of many of its major industrial competitors.
- The United States now trails Japan and (West) Germany, its strongest competitors, in nondefense R&D spending as a percentage of gross domestic product (GDP).

2. *The allocation of U.S. R&D expenditures is not optimal.*

- The balance between defense and nondefense expenditures is disadvantageous compared to that of foreign competitors.

International data for defense and nondefense components of total R&D expenditures (not industrial alone) as a percentage of GDP can be compared. Using six countries—Japan, (West) Germany, France, the United Kingdom, Italy, and Sweden—as a benchmark, the United States in 1989 spent almost as much as they did on total R&D, but 25 percent less on nondefense R&D.

This imbalance has been deteriorating: the fraction of U.S. R&D expenditures on nondefense decreased slightly (from 74 to 71 percent) during the 1980s, while that of the competitor group increased (from 90 to 92 percent). Thus, during the 1980s, these six competitors moved from being 22 percent ahead of the United States in nondefense R&D expenditures to being 34 percent ahead. This increase has been driven largely by Japan's huge growth in nondefense R&D spending; today, Japan spends about 3 percent of its GDP on nondefense R&D, compared to 1.9 percent for the United States.

- Too little is spent on process-oriented R&D.

Several studies have found that U.S. industrial R&D is weighted much more heavily toward product technology rather than process technology. U.S. firms also allocate a disproportionately small share of their R&D budgets to the search for new and/or improved processes compared to their Japanese counterparts.

- Inadequate effort is devoted to fundamental engineering research.

The rapid conversion of ideas into products and processes requires command of an ever-expanding engineering knowledge base. Yet there is an insufficiently broad and deep fundamental engineering research base on which to build.

- There is insufficient emphasis on emerging and precompetitive technologies.

In the IRI survey, industry's "reluctance to invest in new enabling technologies because the R&D may be too expensive, long-term, multi-industry, and interdisciplinary" received the largest number of first place rankings as a factor adversely affecting U.S. industry's ability to compete in global markets for high-technology products under the major category of *technology management practices*.

- The United States faces an emerging risk of losing its traditional strength in pioneering discoveries and inventions.

Most pioneering advances of the past that have created the basis for new industries have originated in either the corporate laboratories of private firms or in research universities. Both of these institutions are under severe stress today.

3. *U.S. expenditures are not as effective as they should be in producing needed results.*

- The U.S. competitive position in important, technologically based industries is deteriorating.

The once strong across-the-board U.S. position of a decade ago has deteriorated substantially. U.S. industry has already lost its leadership in several technologies that are critical to industrial performance, and is weak or losing competitive strength in others.

- The U.S. time horizon has become too short, and the Nation's business decisions tend not to be based on strategic technological considerations.

In large corporations, effort is shifting away from central laboratories toward division-level effort with greater emphasis on risk minimization to meet the needs of today's customers; emphasis is also shifting away from new markets toward existing markets.

- U.S. R&D is not translated into beneficial economic and social results fast enough.

Many companies trail their foreign rivals in the commercialization of new technology. In many U.S. industries, development of new products proceeds at a much slower pace than in other countries.

4. *The current information base on industrial science and technology is inadequate: it has gaps, is questionable in parts, and does not provide enough detail to meet the needs of policymakers.*

Part I

Analysis of Available Data

Introduction

Numbers generated by the National Science Foundation (NSF) and other sources seem to indicate that U.S. industrial R&D spending stagnated in the late 1980s. NSF survey data show little real growth in industrial R&D spending after 1985, compared to the preceding 10-year period.¹ (See figure 1 and table A-1.) These time series data, however, provide an incomplete assessment, and are only one of several statistical indicators of the health of science and technology in U.S. industry.² Other available statistics need to be examined, including ratios measuring "R&D intensity," and comparisons of U.S. R&D expenditures with those of other countries.

In addition to data collected through NSF and other surveys, information comparing the United States with other countries in the advancement of selected technologies is available from several research projects, e.g., the Japanese Technology Evaluation Center (JTEC). These investigations yield qualitative rather than quantitative information and provide valuable insight into the strengths and weaknesses of U.S. science and technology vis-à-vis those of other countries.

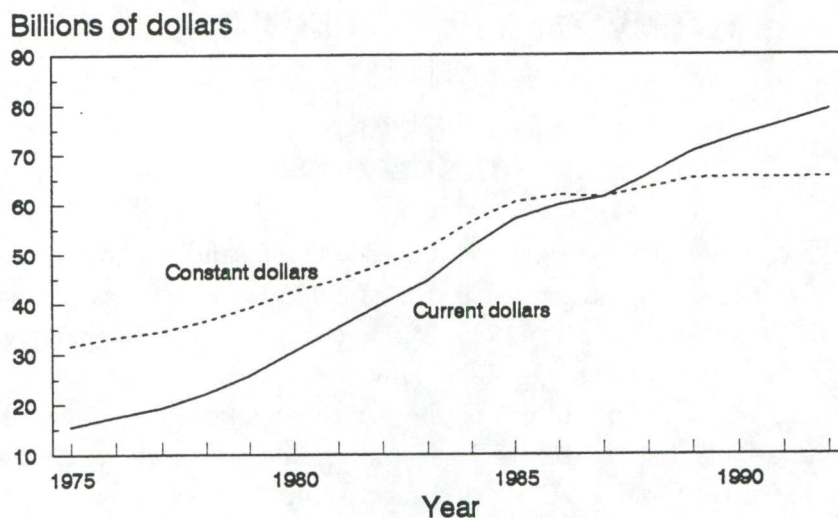
This part of the report first examines three types of information useful in diagnosing the state of U.S. industrial R&D. These measures are

- **input measures**, including aggregate levels of R&D expenditures and R&D intensity ratios;
- **R&D content**, or the allocation of R&D resources; and
- **output measures**, including findings from the studies mentioned above.

¹Industrial R&D expenditure data cited in this section of the report (unless otherwise indicated) refer to funds supporting R&D work performed within company facilities in the United States from all sources, except the Federal Government. These sources may include other companies, research institutions, colleges and universities, other nonprofit organizations, and state and local governments, as well as companies' own funds. Company-financed R&D not performed within the company is excluded. Note that foreign companies' R&D expenditures in the United States are also included. The R&D growth rate would be even lower if monies spent by foreign companies in the United States were subtracted from the total.

²Comprehensive quantitative measures of investment in science and technology do not exist. Therefore, the total amount of funds spent on R&D is commonly used as a surrogate measure.

Figure 1. Company-funded industrial R&D



The rate of increase in company-funded industrial R&D in the U.S. slowed during the late 1980s.

Notes: Company-funded R&D includes funds for industrial R&D work performed within company facilities in the U.S. from all sources except the Federal Government. The 1987 GDP implicit price deflator was used to convert current to constant dollars. (See table A-1.)

Sources: NSF, Survey of Industrial Research and Development and Industrial Panel on Science and Technology

Because the Committee felt its evaluation would not be complete without input from leading industrial R&D officials, the last section of the chapter contains a summary of the main results of a survey on "Potential Causes for the Erosion in U.S. Technology Leadership." This survey was used to obtain the viewpoints of leading industrial R&D officials. Specifically, corporate R&D directors were asked to rank series of factors thought to contribute to a decline in U.S. technological competitiveness. A fuller description of the survey results is in appendix B.

Although these data on R&D are useful in diagnosing the state of U.S. industrial R&D, taken together, they still leave unanswered questions. Compounding this dilemma are gaps and deficiencies in the quantity and quality of information collected and available on industry's investment in, and commitment to, the advancement of science and technology.

Input Measures of Industrial R&D Performance

R&D Expenditures in U.S. Industrial Laboratories

U.S. industrial firms finance R&D performed in their own domestic laboratories and also support R&D conducted in other locations, including company-owned facilities in other countries, colleges and universities, and other nonprofit organizations. Aggregate levels of R&D funding in U.S. industrial laboratories are described below.

The National Science Foundation is the major source of statistical data on U.S. industry's investment in research and development. Its information is collected with the annual Survey of Industrial Research and Development; this survey has been conducted for NSF by the U.S. Bureau of the Census for more than 30 years.³ NSF supplements the data collected through the industry R&D survey with information obtained from annual polling of its Industrial Panel on Science and Technology, which is comprised of at least 100 industry R&D officials.

Industry is the source of about one-half of the funds spent on R&D in the United States. In 1991, industrial firms spent \$76.4 billion in company funds on R&D performed in U.S. laboratories. (See table A-2.) In addition, U.S. firms spent \$30.4 billion in Federal funds on R&D; this was approximately half of all Federal monies supporting R&D. Thus, industry is by far the largest performer of R&D in the United States, accounting for 71 percent of total U.S. R&D performance

³Data collected with this survey are published annually in an NSF series, *Research and Development in Industry*. They are also published in other NSF reports, including *National Patterns of R&D Resources*, and in the National Science Board series, *Science & Engineering Indicators*. During its investigation, the Committee was made aware of deficiencies in this time series that adversely affect the quality and usefulness of data collected with this survey. Many of these problems are identified in this section. Nevertheless, it is the best available source of statistical information on industry's performance of R&D. The Committee's recommendations for improving and increasing the collection of data on industry's investment in science and technology are included in part II of this report.

in 1991. The Federal Government accounts for 11 percent, the academic sector 15 percent, and the nonprofit sector 3 percent.⁴

During the late 1980s and into the early 1990s, company spending on R&D barely kept pace with inflation. In real terms, the average annual increase between 1985 and 1990 was only 1.6 percent; the 1990-92 increase is projected to be 0.1 percent. In contrast, real average annual increases of 6.1 percent and 7.3 percent were registered during the 1975-80 and 1980-85 periods. (See figure 2.) In all major R&D-performing industries except motor vehicles,⁵ rates of growth in R&D spending in the late 1980s were significantly below those recorded in the first half of the decade. This trend is expected to continue into the 1990s. (See figure 3 and tables A-3 and A-4.)⁶

The declining growth rate has been attributed to several factors including the poor performance of the U.S. economy; poor sales, leading to lackluster profits, and resulting in a lack of funds available to expand R&D programs;⁷ reactions to high-technology import competition (Scherer and Huh 1992); the spate of corporate restructuring, especially mergers, acquisitions, and divestitures, that occurred in the mid- and late 1980s;⁸ and increasing support for externally performed R&D, including funding of R&D performed in U.S. companies' foreign laboratories, at universities and colleges, and by nonprofit organizations.

⁴Total Federal R&D support amounted to \$65.2 billion in 1991. Industry received 47 percent of that amount; 23 percent went to universities and colleges; 5 percent to nonprofit organizations; and 25 percent was spent in government laboratories.

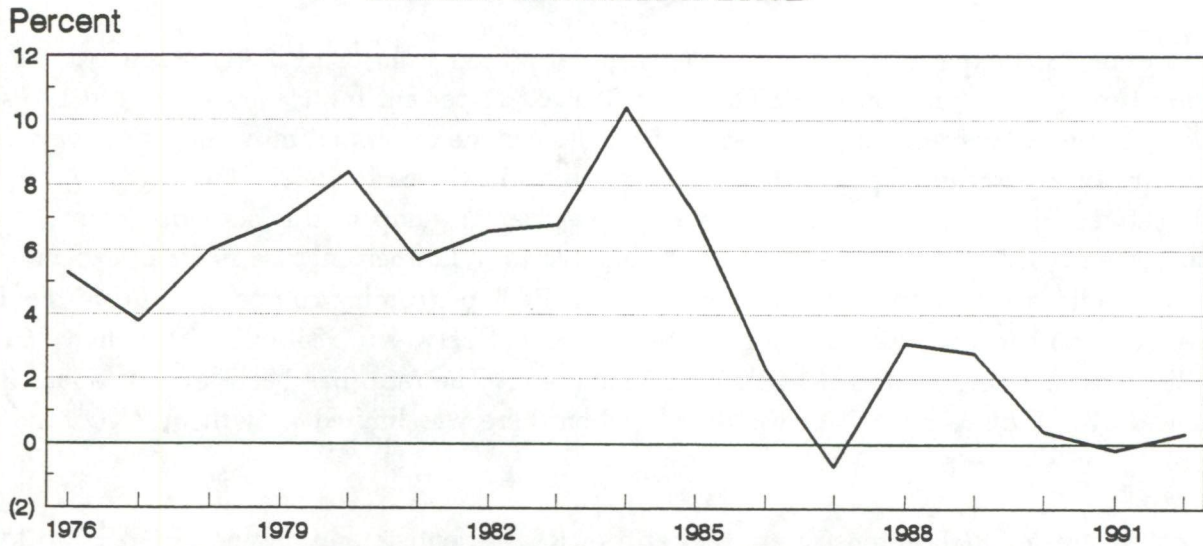
⁵Motor vehicle companies' average annual rate of growth in R&D spending increased from 1.7 percent in the early 1980s to 3.0 percent in the second half of the decade.

⁶Nonmanufacturing, or service, industries now account for approximately 9 percent of company-funded R&D performed in the United States. NSF data show more than a sixfold increase in R&D spending by this sector between 1980 and 1990, with the gain concentrated in two groups of companies: (1) computer programming and engineering services, and (2) communications services. Although many new service companies came into existence during the late 1970s and throughout the 1980s, the actual increase in R&D spending might not be as large as the data indicate, because part of the increase is probably due to improved coverage of the service sector. See Pollak (1991). Despite the apparent strength of R&D performance in the U.S. service sector, the Committee discovered that at least one industry within this group has not been doing well in terms of R&D expenditures. According to data from the Construction Industry Institute (1988), U.S. construction firms spend a total of only \$50 million annually on R&D, compared to \$2 billion spent by Japanese firms. See *Wall Street Journal* (1991).

⁷Findings from annual polls of NSF's Panel on Industrial Science and Technology are described in the following *Science Resources Studies Highlights*: NSF 86-314; NSF 88-311, NSF 89-310, and NSF 90-307, and special reports 91-306 and 92-306. Also, in discussing with the Committee their research on the integrated circuit and pharmaceutical industries, Drs. Steinmueller and Grabowski emphasized that increased investment in R&D is largely dependent on cash flow availability. See Grabowski (1989).

⁸The impact of mergers and other types of corporate restructuring, including leveraged buyouts, on industry's investment in R&D has not been definitively determined. Several researchers have examined various aspects of the issue, employing different approaches and methodologies that yielded different results. Among these studies are: "Corporate Restructuring and Industrial Research and Development," National Academy of Sciences, National Research Council, Academy Industry Program; "Corporate Mergers Implicated in Slowed Industrial R&D Spending" (unpublished NSF Paper); "The Impact of Corporate Restructuring on Industrial Research and Development," Bronwyn H. Hall, National Bureau of Economic Research, Working Paper No. 3216; and "LBOs, Debt and R&D Intensity," William Long, Center for Economic Studies, U.S. Bureau of the Census, and David Ravenscraft, University of North Carolina.

Figure 2. Real annual growth rates in company-funded industrial R&D

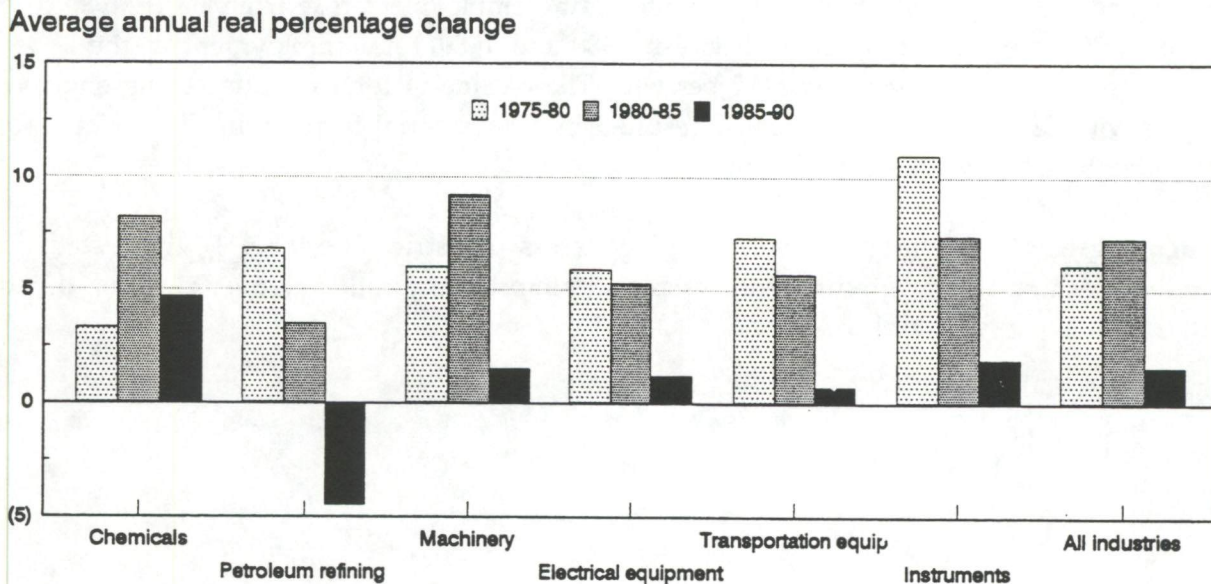


The annual percentage increase in company-funded industry R&D (in constant dollars) is now lower than it was 10 to 15 years ago.

Note: The GDP implicit price deflator was used to convert current to constant dollars.

Source: NSF, Survey of Industrial R&D

Figure 3. Rates of increase in company-funded industrial R&D in major R&D-performing industries



The rate of increase in company-funded industrial R&D slowed in all major R&D-performing industries during the late 1980s.

Note: The GDP implicit price deflator was used to convert current to constant dollars. See tables A-3 and A-4 for data on more narrowly defined industries.

Sources: NSF, Survey of Industrial R&D and Industrial Panel on Science and Technology

R&D Intensity

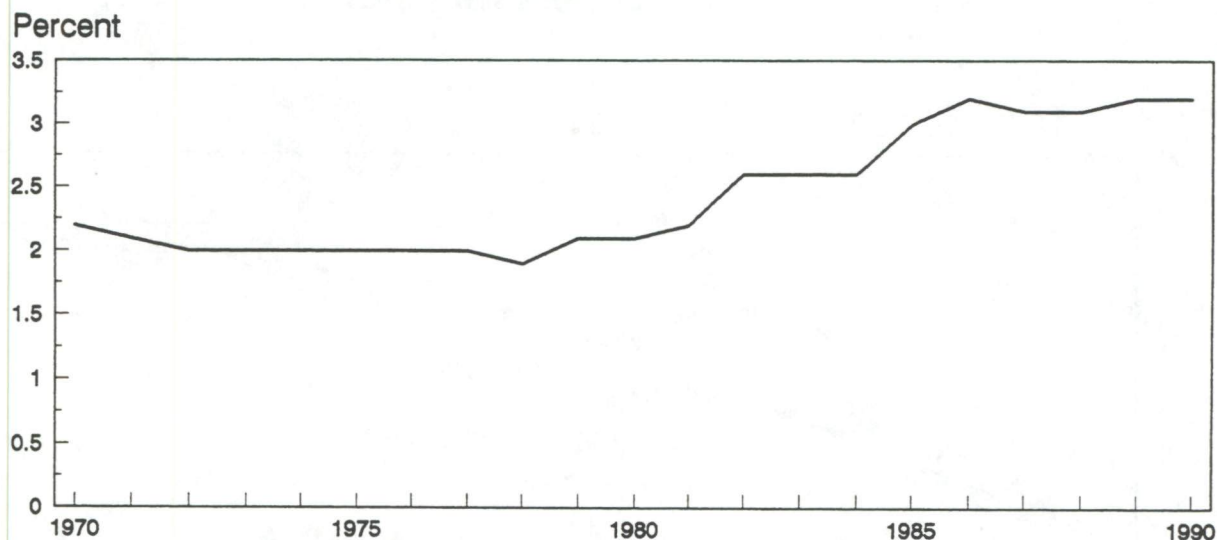
The ratio of R&D expenditures to net sales is usually used to measure R&D intensity. For all manufacturing firms performing R&D, this ratio was 3.2 percent in 1990. During the 1970s, it hovered in the 2.0-percent range, showing either no change or annual movements of only one- or two-tenths of a percentage point, then began to climb in the early 1980s. (See figure 4 and table A-5.) Between 1981 and 1982, there was an unprecedented jump in this statistic—from 2.2 percent to 2.6 percent. This 1-year increase was attributable to a 12.4-percent rise in R&D expenditures, combined with a 6.9-percent decline in net sales of R&D-performing companies during the 1981-82 recession. Another similar leap in this statistic occurred between 1984 and 1985, when R&D spending rose 9.3 percent and net sales fell 2.9 percent. The ratio has been level at about 3.2 percent during the second half of the decade when there was limited growth in R&D funding and net sales.

Other measures of R&D intensity are the ratio of R&D scientists and engineers (S&Es) to total employment in R&D-performing manufacturing companies, and the ratio of total S&Es to total manufacturing employment. These ratios increased steadily throughout the late 1980s, because employment of S&Es has been increasing at a faster pace than has overall employment in all industries. For example, there were 40 R&D S&Es per 1,000 employees in R&D-performing manufacturing companies in 1984 and 49 in 1990. (See table A-6.) During this period, R&D performing companies' total employment increased 8.4 percent, while employment of R&D S&Es increased 19.4 percent.

Similarly, the ratio of all S&Es to total manufacturing employment rose from 37 in 1980 to 51 in 1989 (NSB 1991, appendix table 3-1). Between 1980 and 1989, total employment in the manufacturing sector declined about 4.2 percent. The decline in total manufacturing employment, combined with S&E employment growth, resulted in a substantial increase in the S&E proportion of the manufacturing workforce.

Although degree of R&D intensity varies widely across industries (see table 1), these statistics have either been steady or gradually increasing in almost every industry over the past decade. (See figures 5 and 6 and tables A-5 and A-6.)

Figure 4. Company-funded industrial R&D as a percentage of net sales

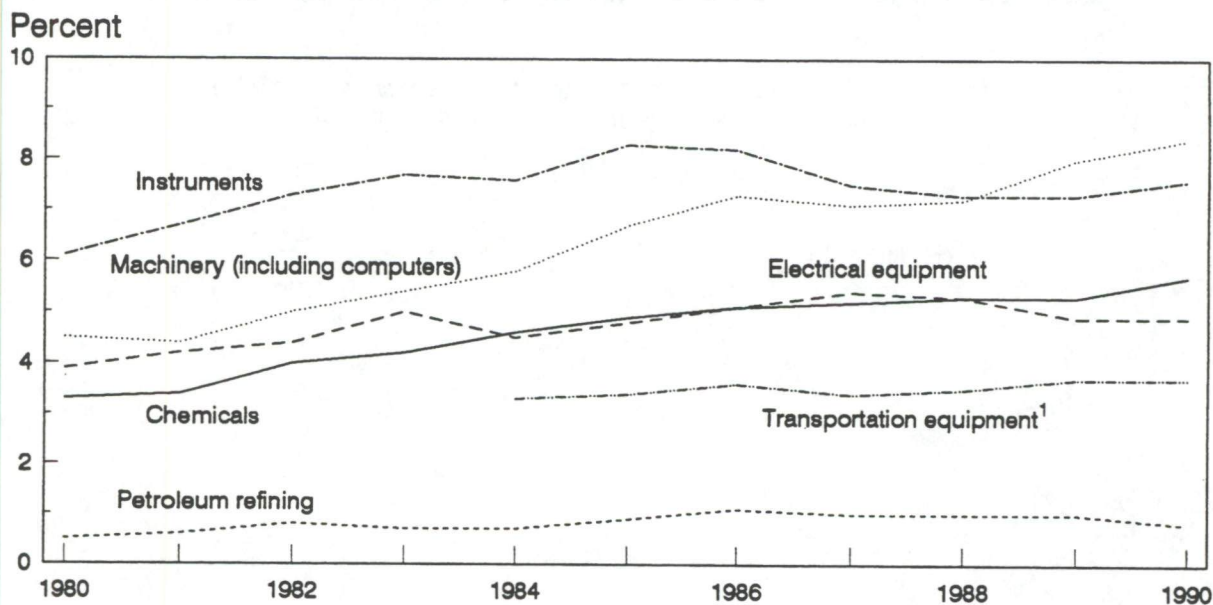


Company R&D funds as a percentage of net sales increased from 2 percent in the 1970s to 3 percent in the late 1980s.

Note: See table A-5.

Source: NSF, Survey of Industrial R&D

Figure 5. Company-funded industrial R&D as a percentage of net sales for major R&D-performing industries



R&D spending as a percentage of net sales was higher in 1990 than in 1980 in all major R&D-performing industries.

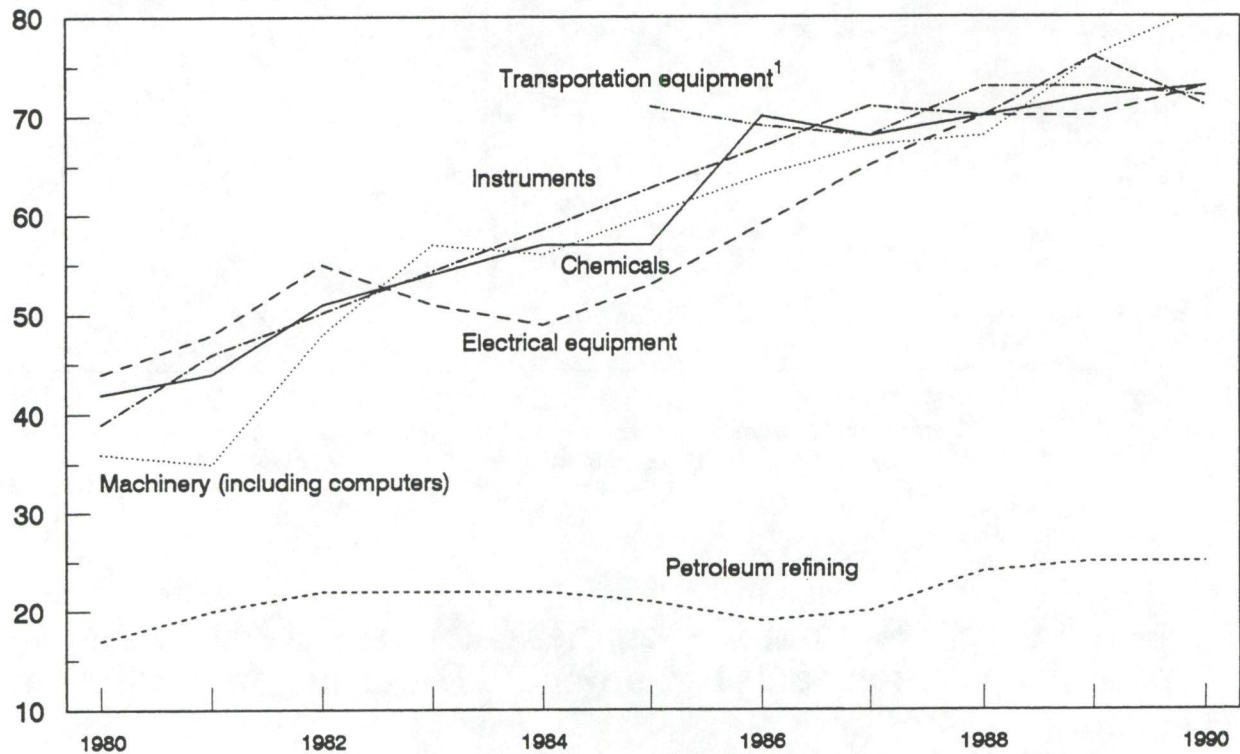
¹Data unavailable for earlier years.

Note: See table A-5.

Source: NSF, Survey of Industrial R&D

Figure 6. The R&D S&E proportion of the workforce in major R&D-performing industries

R&D S&Es per 1,000 employees



The R&D S&E proportion of the workforce increased in all major R&D-performing industries during the 1980s.

¹Data unavailable for earlier years.

Note: See table A-6.

Source: NSF, Survey of Industrial R&D

Table 1. Industry segments with the highest and lowest company R&D funds/net sales ratios: 1990
(Percent)

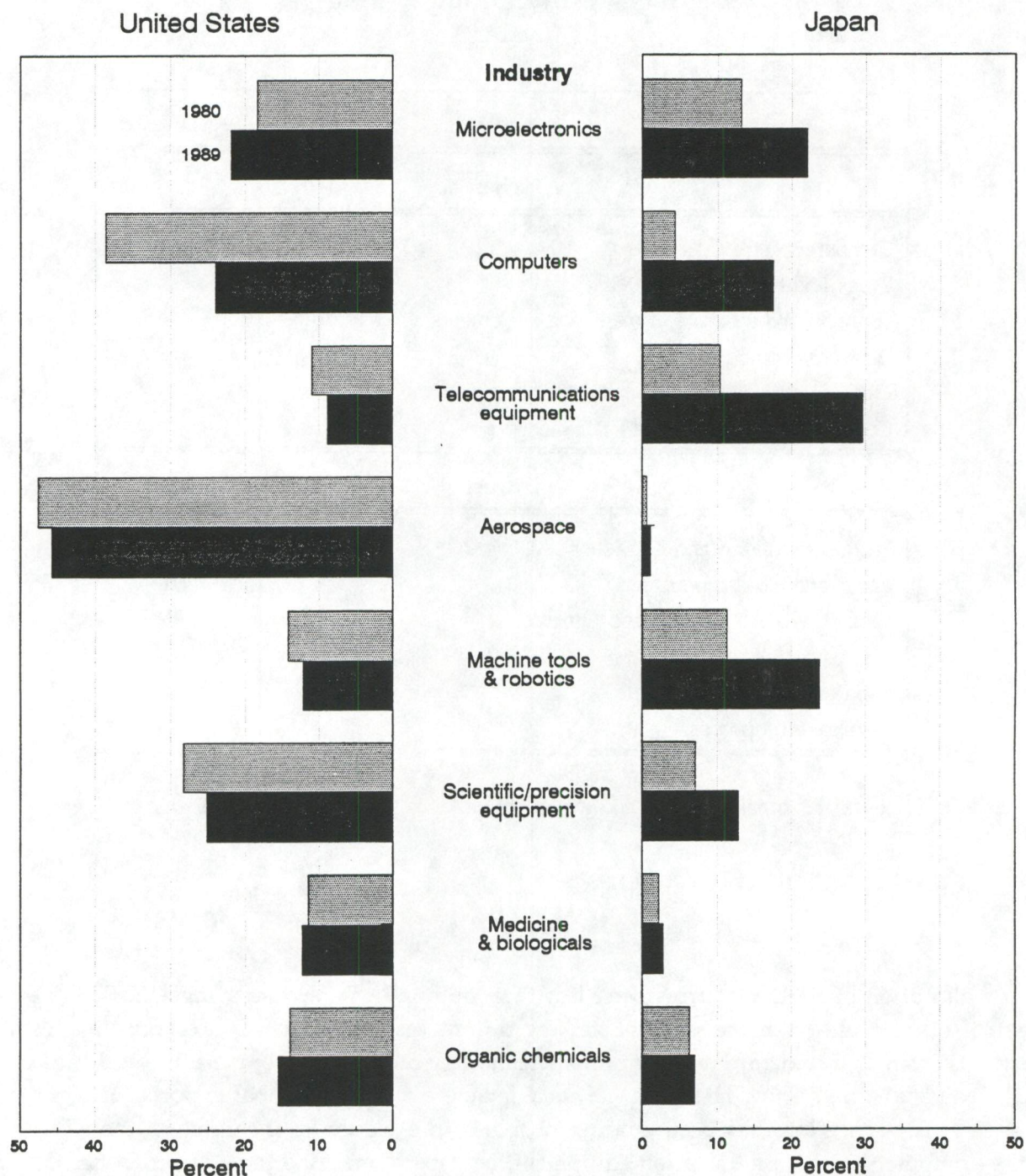
Industry segment	R&D/sales
Highest	
Computers	15.4
Drugs and medicines	9.8
Scientific and mechanical measuring instruments	9.4
Electronic components	8.6
Optical, surgical, photographic, and other instruments	6.9
Communication equipment	4.9
Lowest	
Petroleum refining and extraction	0.8
Paper and allied products	0.8
Lumber, wood products, and furniture	0.7
Ferrous metals and products	0.6
Food and tobacco products	0.5
Textiles and apparel	0.4

Source: NSF, Survey of Industrial Research and Development

R&D Content

Has the allocation of R&D resources been less than optimal? Data comparing U.S. R&D spending to that of other countries reveal several striking differences that may help explain why U.S. industry is losing ground in developing high-technology products to compete in world markets. Figure 7 and table A-7 show changing U.S. and Japanese shares of global exports for eight industries. The U.S. share has been eroding in five of the industries included on these charts—computers, telecommunication equipment, aerospace, machine tools and robotics, and scientific/precision equipment—but not in the other three—microelectronics, medicine and biologicals, and organic chemicals. The most dramatic change depicted in figure 7 occurred in worldwide exports of computers: the U.S. share of the global market dropped from 39 percent in 1980 to 24 percent in 1989. Table A-8 (prepared by Dr. Kenneth Flamm) shows the United States' declining share of sales of information systems. In contrast, the Japanese global share increased in all industries shown on these charts; for six of these industries—microelectronics, computers, telecommunication equipment, machine tools and robotics, and information systems—the gains are striking.

Figure 7. U.S. and Japanese shares of global exports for selected high-technology industries



The U.S. share of global exports has declined in several industries, while Japan's has increased.

Note: See table A-7.

Source: CIA Handbook of Economic Statistics, 1990

U.S. R&D Investment Compared to That of Other Countries

In absolute terms, the United States spends more than twice as much on R&D as does Japan,⁹ 4½ times as much as (West) Germany, and over 6 times as much as France and the United Kingdom. In relative terms, however, the picture is considerably different. Total U.S. R&D spending as a percentage of gross domestic product (GDP) lags behind spending in Japan and (West) Germany.¹⁰ While the U.S. level of 2.7 percent in 1990 is comparable to its 1970 level (2.6 percent), Japan's proportion grew from 1.9 to 3.1 percent, and (West) Germany's proportion increased from 2.1 to 2.8 percent. (See figure 8 and table A-9.)

The prominence of defense in U.S. R&D strengthens the finding of a U.S. lag of investment in R&D. If just nondefense R&D is considered, the United States invests 1.9 percent of its GDP in R&D, compared to 3.0 percent for Japan and 2.7 percent for (West) Germany. (See figure 9 and table A-10).¹¹ Perhaps the most striking indicator of Japan's escalating strength in science and technology is depicted in figure 10. Japan's investment in nondefense R&D has been increasing dramatically.

These data suggest that government plays a more prominent role in the U.S. R&D system—and in particular, in the U.S. industrial R&D system—than it does in the systems of its major trading partners. But if the U.S. Government invests more heavily in R&D, it directs that investment almost entirely toward government missions such as national security, space exploration, and health rather than to industrial purposes.

Defense accounts for about three-fifths of U.S. Government R&D spending and two-thirds of the growth in that spending between 1980 and 1992.¹² In contrast, in 1989, 9 percent of Japan's government R&D spending went to defense; in (West) Germany, this proportion was 19 percent,

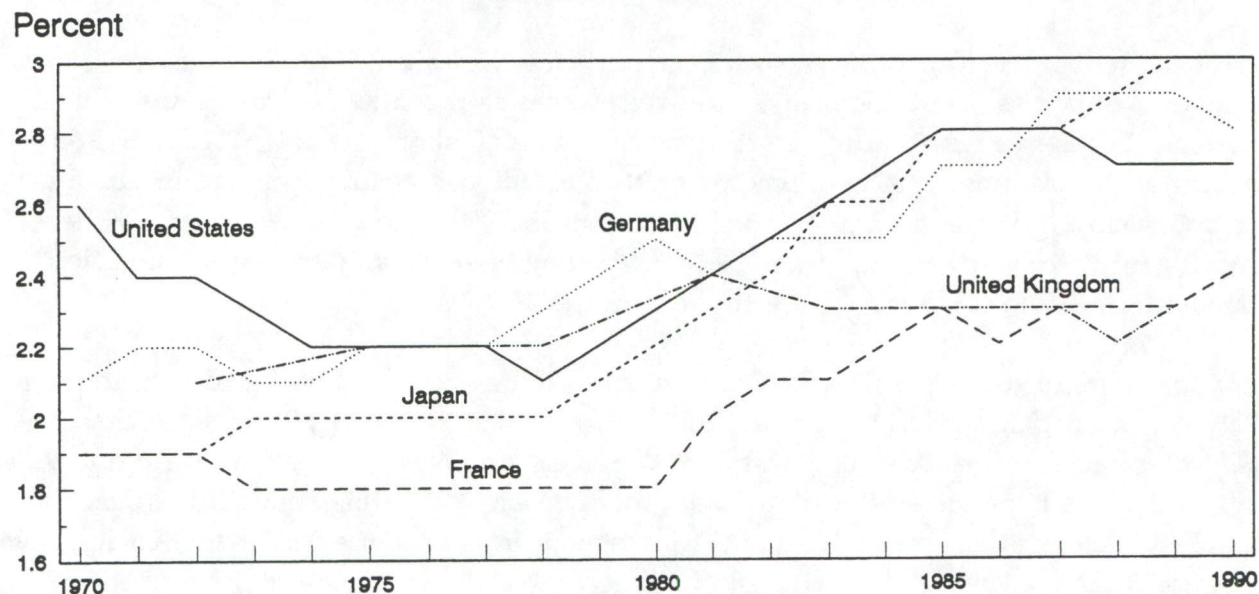
⁹A controversy recently surfaced over international comparisons of R&D expenditures—i.e., which country is spending more on R&D, the United States or Japan? The answer depends on what formula is used to convert yen to dollars. If currency exchange rates are used, Japanese industrial firms appear to be spending more on R&D than U.S. firms. NSF follows the international, long-established convention of using purchasing power parities to convert yen to dollars. Therefore, the data in this report show U.S. firms spending considerably more on R&D than Japanese firms (although expenditures by the latter have been growing at a much faster rate). For discussions of this issue, see *National Journal* (1992) and *New York Times* (1992).

¹⁰The Federal Government is now using gross domestic product instead of gross national product because GDP measures production of goods and services in the United States only, thus providing a more precise indicator of the country's economic condition.

¹¹In 1989, government funding of R&D accounted for 45 percent of total U.S. R&D, 19 percent of R&D in Japan, 33 percent in (West) Germany, 49 percent in France, and 37 percent in the United Kingdom. Government funds accounted for 31 percent of U.S. industrial R&D, but only 2 percent of industrial R&D in Japan, 11 percent in (West) Germany, 21 percent in France, and 20 percent in the United Kingdom.

¹²Growth in Federal R&D spending slowed significantly after 1987. Defense, as a percentage of total federally funded R&D, reached a peak of 69 percent in 1986 and 1987. Since then, the share of defense-related R&D outlays has fallen to (an estimated) 59 percent in 1992.

Figure 8. International comparisons of R&D expenditures as a percentage of GDP

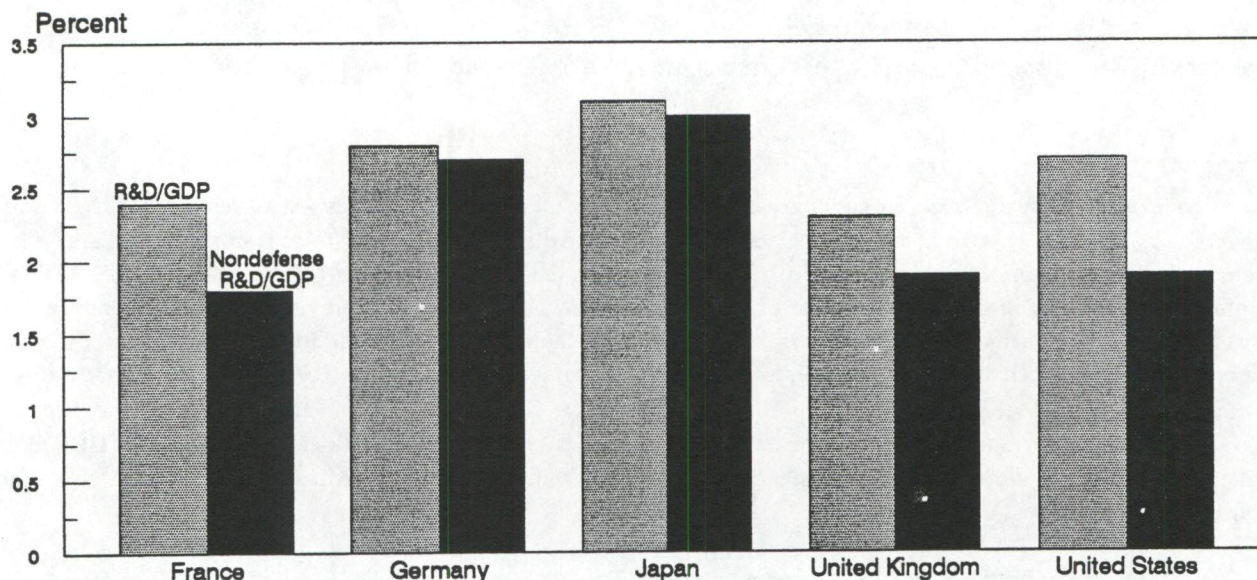


Japan and Germany have surpassed the U.S., in terms of R&D/GDP.

Note: See table A-9.

Sources: NSF, Organisation for Economic Cooperation and Development, International Monetary Fund, and national sources

Figure 9. International comparisons of total and nondefense R&D as a percentage of GDP

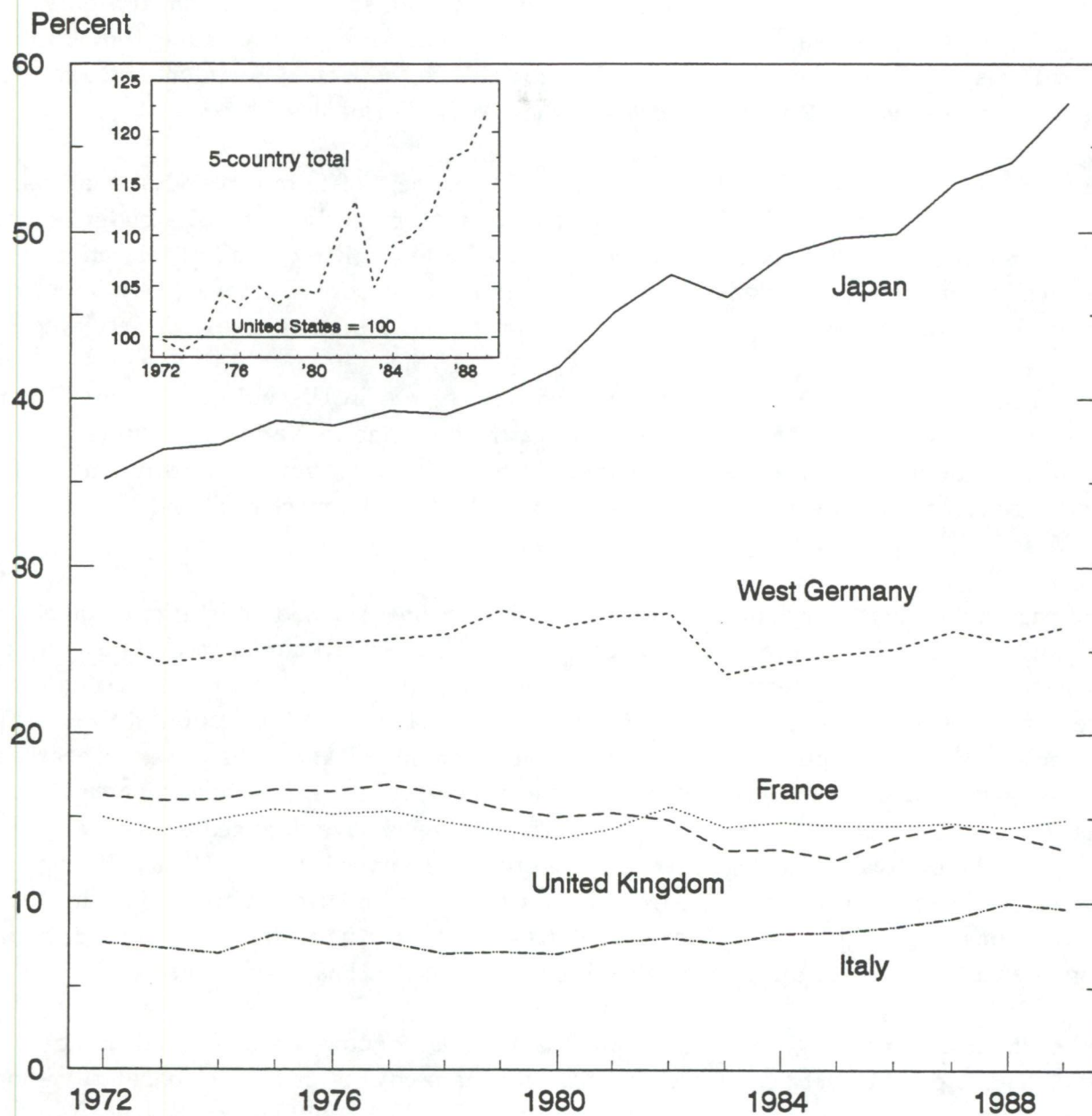


The U.S. trails Japan and Germany in nondefense R&D/GDP.

Note: See table A-10.

Sources: NSF, Organisation for Economic Cooperation and Development, International Monetary Fund, and national sources

Figure 10. International comparisons of growth in nondefense R&D



Japan's investment in nondefense R&D has been growing at a much faster pace than U.S. investment in nondefense R&D

Note: See Appendix Table 1-10.

Sources: NSF, Organisation for Economic Cooperation and Development, International Monetary Fund, and national sources

in France, 42 percent; and in the United Kingdom, 55 percent. (See figure 11 and table A-11.) Thirteen percent of the U.S. Government R&D budget is directed at health (compared to between 4 and 6 percent for the trading partners); 7 percent to civilian space applications (roughly comparable to [West] Germany and France, and higher than the United Kingdom, but lower than Japan's 11 percent); and 4 percent to energy (comparable to the United Kingdom and France, but much lower than Japan's 39 percent and lower than [West] Germany's 9.5 percent).

Except for a few programs—including some in the Department of Commerce's National Institute for Standards and Technology (NIST) and arguably, a small proportion of NSF's budget—almost none (0.2 percent) of the U.S. Federal R&D budget is directed at R&D of direct relevance to commercial technology. In the other countries, government support of commercially oriented R&D is considerably higher, ranging from 8 percent in Japan¹³ to 19 percent in (West) Germany.

Government-sponsored R&D has, however, played a major role in U.S. industrial competitiveness in some instances. The billions of dollars for research conducted in National Institutes of Health laboratories, although not specifically earmarked to help U.S. firms build competitive advantage, nevertheless contributed to the leadership position of the U.S. pharmaceutical and biotechnology industries.

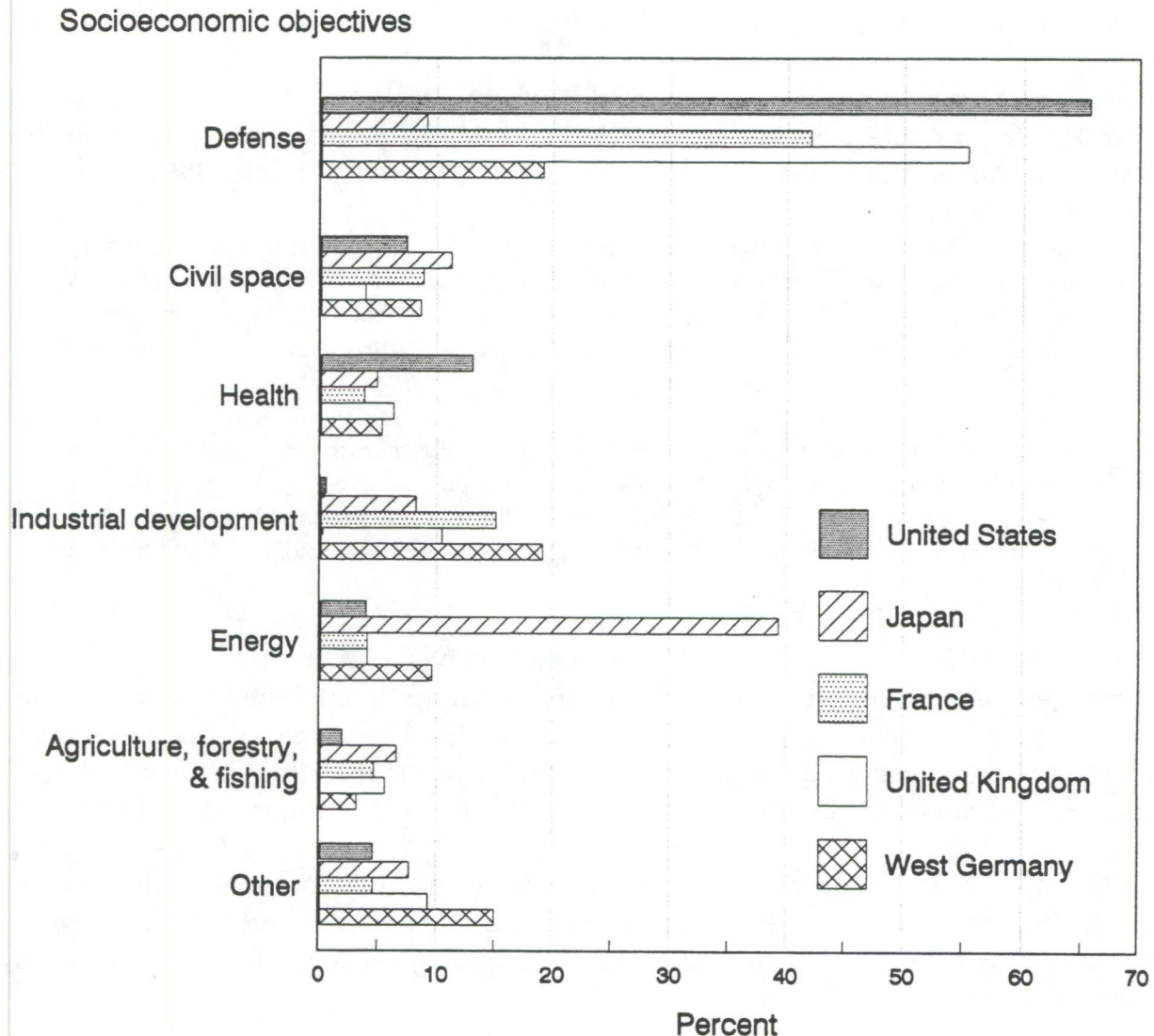
In the past, byproducts or spinoffs from government mission R&D had a significant impact on U.S. industrial technology. The jet engine, computer, and integrated circuit received a jumpstart in the United States precisely because R&D funding was linked to defense missions. Defense needs drove development of these technologies that then found widespread application in the commercial sphere. But spillover benefits from defense-oriented R&D no longer seem nearly as strong as they used to be (Nelson 1990 and Alic et al. 1992). In many technology areas, performance requirements of military and commercial systems have diverged dramatically since the days of the postwar technology spinoffs. According to Kenneth Flamm (1988), "Relying on accidental spillover from military R&D may have worked out just fine in an era in which the U.S. had no serious technological competitors. That was also a time when the sums the U.S. spent on technology vastly exceeded all foreign expenditures, a time that has clearly passed."

Whether the heavy role of government in R&D is, on balance, now a source of advantage or disadvantage is open to debate. In fact, an opposite perspective is gaining in popularity—many are now claiming that "the military sector increasingly builds on civilian [technological] development[s], rather than the other way around" (Bloch 1991).¹⁴

¹³ Although direct government support of commercial technology development appears to be relatively low in Japan, the Japanese Government provides extensive indirect support, including various tax incentives and low-interest loans to industrial firms to encourage them to invest in R&D and commercialize new technology.

¹⁴ See Council on Competitiveness (1991), table 4, "The Defense Department's Changing Role in Technology Development." The advantages of DOD-supported technology in the 1950s, contrasted with the disadvantages apparent in today's DOD-supported technology development, are listed in this table.

Figure 11. International comparisons of governmental R&D budget priorities



U.S. R&D budget priorities differ from those of its trading partners.

Note: See table A-11.

Sources: NSF, Organisation for Economic Cooperation and Development, and national sources for Japan

In general then, the U.S. R&D system exhibits a strong presence by the Federal Government in industrial R&D, but that R&D is oriented toward government rather than commercial objectives. For example, in manufacturing, "many of the DOD- and NASA-funded efforts in robotics deal with mobility and navigation, the areas deemed least important in a recent Robot Industries Association survey of American manufacturers" (Hanifin 1988).

This issue was also addressed by a Presidential Advisory Panel formed to assess the Nation's effort in high-temperature superconductivity. In late 1988, the panel concluded the following (Committee to Advise the President on High Temperature Superconductivity 1988, p. 8).

While there is a high level of activity in U.S. industry today, much of it is scattered and in monitoring groups and is unlikely to survive in what we believe will be a long distance race. And while there is a high level of activity by the U.S. government today both in government labs and in support of universities, the work is primarily structured around government rather than commercial applications.

In contrast the Japanese government laboratories have a long tradition of materials work done closely with industry, and the Japanese government has put in place . . . a structure that will support, coordinate and sustain the various individual industrial efforts in Japan as the Japanese companies work their way through the early stages of this new technology and look for applications.

U.S. industry's inability to commercialize technology rapidly and effectively is the focus of almost all recent literature on competitiveness. This failing is frequently attributed to a lack of attention to improvements in process technology. Studies on individual industries conducted by the MIT Commission on Industrial Productivity revealed "that the lax attitude toward process improvement is widespread in U.S. companies but not universal" (Detouzos et al. 1989, p. 76).

Edwin Mansfield of the University of Pennsylvania found that U.S. companies differ significantly from their Japanese counterparts in R&D organization and mix of activities. In particular, Mansfield's research revealed striking differences in emphasis on process technology between U.S. and Japanese firms (Mansfield 1988b).

The American firms . . . devote about two-thirds of their R&D expenditures to improved product technology (new products and product changes) and about one-third to improved process technology (new process and process changes). Among the Japanese firms . . . the proportions are reversed, two-thirds going for improved process technology and one-third going for improved product technology.

Results from another study show U.S. companies devoting only 19 percent of their R&D budgets to process innovation (Caravatti 1991).

Mansfield's research provides evidence of another significant difference between U.S. and Japanese R&D investment. He found that nearly one out of every two dollars spent on R&D by U.S. companies is used to support projects seeking new products and processes. In contrast, a smaller percentage—approximately one-third—of Japanese R&D expenditures is devoted to discovering

new products and processes, while the remainder is directed toward perfecting existing technologies (Mansfield 1988a, table 4).

How Are U.S. Firms Adjusting to Meet Increasing Foreign Competition?

Alden S. Bean's 1988 survey of R&D executives from 140 firms affiliated with the Industrial Research Institute (IRI)¹⁵ provides some insight into this issue (Bean 1989).

The survey results showed that the distribution of effort between relatively centralized corporate laboratories and technical centers and relatively decentralized division and group labs changed markedly during the 1980s. According to the survey respondents, there was a shift away from centralized R&D and toward more divisional R&D. This trend implies a change in lead times as well as the mix of R&D actually undertaken by U.S. firms.

The survey revealed a shift in emphasis toward the "customer" end of the pipeline in all industrial R&D laboratories—the distinction between central and division work has been fading. A strong drive is under way to make central laboratories more responsive to business units. Thus, a greater emphasis is being placed on risk minimization; R&D has a more short-term focus to meet the needs of today's customers.

Two important changes appear to have occurred in the 1980s, both of which are consistent with the trend away from corporate, central labs.

1. In the 1970s, exploratory research and research aimed at complying with government regulations were emphasized. In the 1980s, these two types of research, while still viewed as significant, were considered less important than research aimed directly at product and process innovations for commercial advantage.
2. Among corporate or central R&D labs, new product and process development was emphasized during both the 1970s and the 1980s. Where there has been a change is in the relative emphasis on existing markets as opposed to new markets. "Central labs appear to have become more involved in some form of applications development research for existing markets in the 1980s. This appears to be a striking contrast to their role in the 1970s, when they emphasized diversification and programs for new markets over programs for existing markets" (Bean 1989).

The survey also found that:

1. Cost-based factors and efficiency considerations determine whether R&D is performed in central or other research facilities. For example, the high cost of using supercomputing

¹⁵U.S.-based firms in the IRI fund roughly 85 percent of total U.S. industrial R&D. See IRI (1992).

facilities requires performing work using a supercomputer in a central research laboratory.¹⁶

2. The advantages of centralization include intellectual synergy and cost-effective use of facilities; the disadvantages are management difficulties in transferring research technology from the central laboratory to other parts of the company.
3. Companies under less competitive pressure are able to devote more resources to central research laboratories than those facing intense foreign and domestic competition.

Data from NSF's annual industry R&D survey appear to confirm the findings from Bean's survey; they show basic research, as a percentage of total R&D expenditures, declining in the late 1980s from 5.8 percent in 1986 to 4.3 percent in 1990, applied research staying about the same (around 25 percent of the total), and development rising slightly.¹⁷ In addition, a recent survey of chief executive officers (CEOs) representing electronics companies revealed a shift in that industry from basic to applied research. According to the respondents, the change is largely attributable to an increasing emphasis on accommodating customers' needs in product development (*Electronic Business* 1991).

R&D Output

Several recent studies have yielded information helpful in examining and evaluating the quality and effectiveness of U.S. industrial R&D and in comparing U.S. research, applications, and commercialization of new technologies with those of other countries. Unfortunately, there has been only a scattering of attempts to quantify output indicators—e.g., degree of innovation and speed of product development—and the feasibility of collecting such data has yet to be established.¹⁸ Thus, almost all of the information available on R&D output is derived from the observations of industrial, government, and academic experts.

¹⁶This situation is changing rapidly because of improved network access to supercomputers.

¹⁷Two problems seriously affect the quality of NSF's data on industry-performed basic research, applied research, and development: (1) lack of response to the item on the survey questionnaire, and (2) respondents' varying interpretations of the definitions of the three categories. The first problem is far more serious than the second. Until 1986, NSF estimated that industry spent 3 to 4 percent of its own funds on basic research and slightly over 20 percent on applied research; about three-fourths of the monies supported development of new products and processes. NSF and Census staff refined the methodology used for estimating nonresponse beginning with the 1986 data. These revisions resulted in basic research accounting for 4 to 5 percent, applied research about 25 percent, and development about 70 percent of industry's R&D expenditures. See NSF (1990a and 1990b).

¹⁸One such attempt was made several years ago; the results appeared in an unpublished report, "A Survey of Industrial Innovation in the United States," prepared by Audits and Surveys for NSF's Division of Science Resources Studies.

Deterioration of U.S. Technology Leadership Position

There have been at least three recent efforts to evaluate and rate the quality of other nations' research and advancement in selected technologies vis-a-vis those of the United States: (1) the Japanese Technology Evaluation Center;¹⁹ (2) a Commerce Department evaluation, *Emerging Technologies: A Survey of Technical and Economic Opportunities*; and (3) a Council on Competitiveness report, *Gaining New Ground: Technology Priorities for America's Future*. The Committee did not independently assess the U.S. position relative to other nations in technologies so it cannot substantiate the validity of these assessments. Moreover, the studies differ slightly in some details. Nevertheless, the general conclusion emerges strongly and repeatedly: a decline in relative strength of U.S. industrial technology.

The purpose of the JTEC project is to bring together experts from industry, universities, and the government to evaluate the strengths and weaknesses of both the Japanese and U.S. systems that facilitate and hinder the exploration and commercialization of technology. Findings of these studies are based on the experts' perceptions of performance in each of the examined technologies.

The Japanese and U.S. approaches to the performance of research and development have traditionally differed in several major respects. In the United States there has been greater emphasis on basic research, while in Japan the emphasis tends to be on focused development work with specific commercial applications. Also, academic institutions have different functions within the scientific and technological apparatus of each country.

Factors responsible for the high quality of science and technology in Japan appear to be the practices of sending students and professionals to other countries for study, Japan's longer time horizon, lower capital costs due to higher savings rates, Japanese manufacturing excellence and attention to engineering, and—in some industries—the role of the Ministry of International Trade and Industry (MITI). MITI has been particularly successful in inducing companies to translate generic into proprietary research, thus facilitating the development of new and/or improved products (Gamota and Frieman 1988, pp. 5-9).

One of the weaknesses of the Japanese system is that because it is customary to employ workers for life, Japanese companies have difficulty acquiring outside expertise. Existing staff must be used to gain access to new developments.

Another conclusion from these studies is that numbers on Japanese investment in certain technologies often understate the actual amount of investment, because several costs (which are included in U.S. calculations) may be excluded from the figures compiled in Japan.

¹⁹J-TECH became JTEC in February 1989 when management of the program was transferred from Science Applications International Corporation to Loyola College in Maryland. J-TECH stood for Japan Technology; JTEC stands for the Japanese Technology Evaluation Center.

Completed and ongoing JTEC studies are listed in table 2. These studies cover a large number of technologies including computer sciences, advanced computing, opto- and microelectronics, mechatronics, telecommunications, biotechnology, advanced materials, advanced sensors, superconductivity, space propulsion, space robotics, and nuclear power.

Table 2. Japanese technology evaluation reports

Report title	Date
JTECH Panel Report on Computer Science in Japan	Dec. 1984
JTECH Panel Report on Opto- and Microelectronics	May 1985
JTECH Panel Report on Mechatronics in Japan	May 1986
JTECH Panel Report on Biotechnology in Japan	May 1986
JTECH Panel Report on Telecommunications Technology in Japan	May 1986
JTECH Panel Report on Advanced Materials	May 1986
JTECH Panel Report on Advanced Computing in Japan	Dec. 1987
JTECH Panel Report on CIM and CAD for the Semiconductor Industry in Japan	Dec. 1988
JTECH Panel Report on the Japanese Exploratory Research for Advanced Technology (ERATO) Program	Dec. 1988
JTECH Panel Report on Advanced Sensors in Japan	Jan. 1989
JTECH Panel Report on High Temperature Superconductivity	Nov. 1989
JTECH Panel Report on Space Propulsion in Japan	Aug. 1990
JTECH Panel Report on Nuclear Power in Japan	Oct. 1990
JTECH Panel Report on Advanced Computing in Japan	Oct. 1990
JTECH Panel Report on Space Robotics in Japan	Jan. 1991
JTECH Panel Report on High Definition Systems in Japan	Feb. 1991
JTECH Panel Report on Advanced Composites in Japan	March 1991
JTECH Panel Report on Construction Technologies in Japan	June 1991
JTECH Panel Report on X-Ray Lithography in Japan	Oct. 1991
JTECH Panel Report on Machine Translation in Japan	Jan. 1992
JTECH Panel Report on Database Use and Technology in Japan	April 1992
JTECH Panel Report on Bioprocess Engineering in Japan	May 1992
JTECH Panel Report on Flat Panel Display Technology in Japan	June 1992

The evaluations have revealed that in a significant number of technology-intensive industries, U.S. firms

- are losing, or have lost, their edge in research;
- continue to lose ground in the transition from research to product development/diffusion; and
- are losing still more ground in transition from product development to product implementation.

For example, a JTEC evaluation of factory automation showed that the United States was behind in development and product implementation of most of the technologies crucial to the industry. (See table 3.)

Table 3. Comparison of United States and Japan in development and implementation of factory automation technologies

	Research	Adv. Development	Product implementation
U.S. AHEAD	Software Vision	Software	Software
U.S. EVEN	Flexible mfg systems Non-vision Assembly Intelligent mechs. Standards Manipulators Precision mechanism		Intelligent mechs. Non-vision
U.S. BEHIND		Vision Manipulators Precision mechanism Intelligent mechs. Assembly	Manipulators Flexible mfg system Precision mechanism Assembly, vision

Source: Prepared by J. Morone from the JTECH Panel Report on Mechatronics in Japan, June 1985

In another recently released study on the construction industry, the JTEC panel reported that

Japanese construction companies have well-established, in house research and development programs, generously funded mainly from their own internal sources, and including well-equipped laboratories, on a level that is almost absent in U.S. construction companies. Partly through the application of their research findings, they have moved ahead of their U.S. counterparts in many areas.

Recent figures from the Construction Industry Institute (1988) indicate that U.S. construction companies have been losing their share of the global market; they show U.S. companies holding one-quarter of the worldwide major construction contracts in 1988, down from one-half in 1980.

A Federal study on the semiconductor industry described a similar situation. U.S. firms are lagging behind Japanese companies in the development of most semiconductor products. (See figure 12) For example, in advanced processing of electronic materials in the United States and Japan, the experts found that "At present, the Japanese are ahead of the United States in the development and application of advanced process technologies. At least ten of the major semiconductor companies in Japan have vigorous programs targeted for projects with an expected payoff 7 to 10 years later. There are only a few, perhaps two, U.S. firms similarly involved" (NSF 1987).

The panel also found that the United States has lost the lead in more than three-fourths of the critical semiconductor technologies included in the study.²⁰

As noted by the MIT Commission on Industrial Productivity study (Detouzos et al. 1989, p. 250):

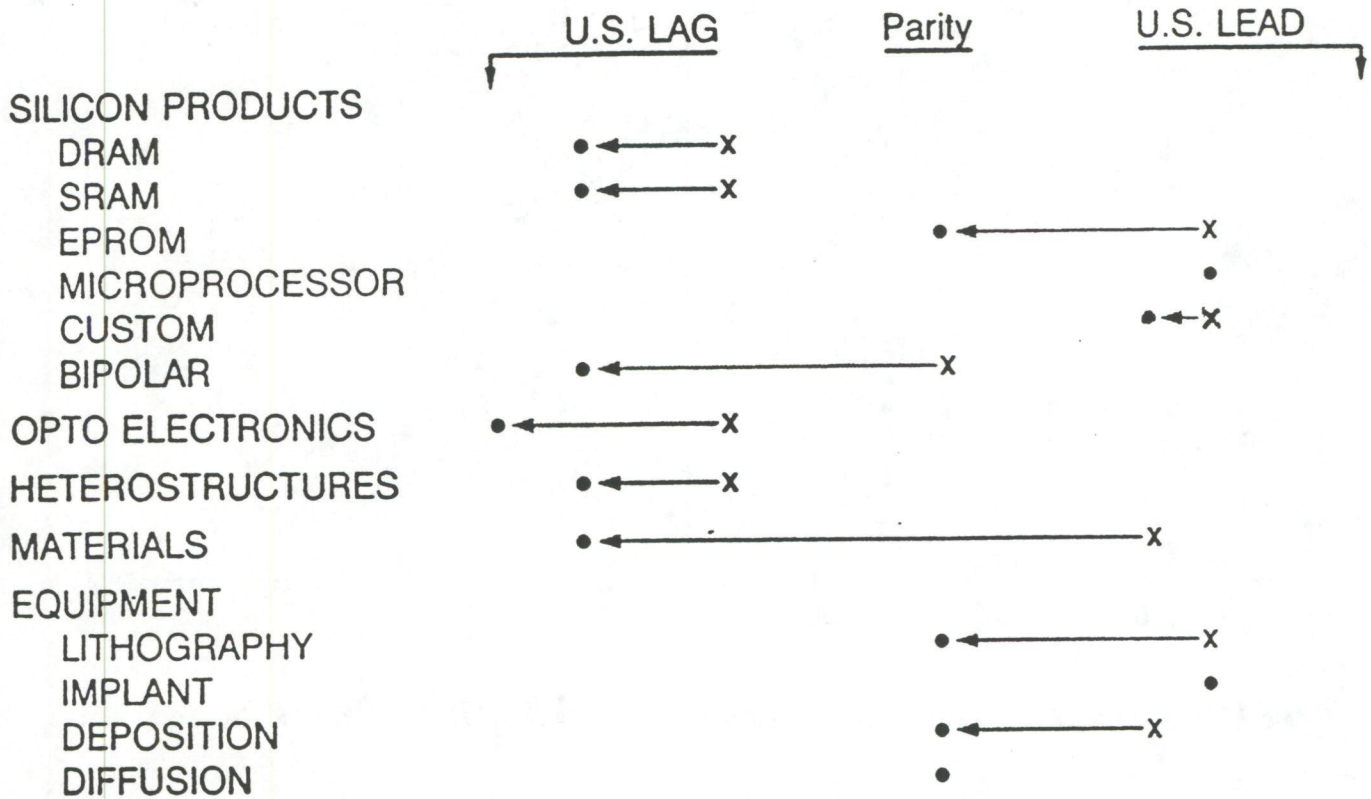
The loss of U.S. leadership across a wide range of semiconductor technologies in the short span of about a decade has enormous implications. Semiconductors are the basic building blocks for a rapidly expanding spectrum of high-growth, high-technology industries that touch every market sector: business, industry, consumer products, and defense. They are the most critical components for computers, telecommunications, factory automation and robotics, aerospace, radar, and many consumer products. They provide controls for still more products, including automobiles, appliances, machine tools, and military equipment.

The consumer electronics industry is probably the best example of a high-technology industry that has been almost completely annihilated by foreign competition. Data compiled by the Council on Competitiveness and presented in figure 13 show a dramatic contraction in U.S. consumer electronics companies' share of the domestic market.

Fortune magazine recently used a group of experts to put out a "scorecard" for 13 key industries. Five of these industries were given a grade of C or lower, with a C "connot[ing] vulnerability and the risk of continued decline, [and a] D mean[ing] a business is basically on its back."

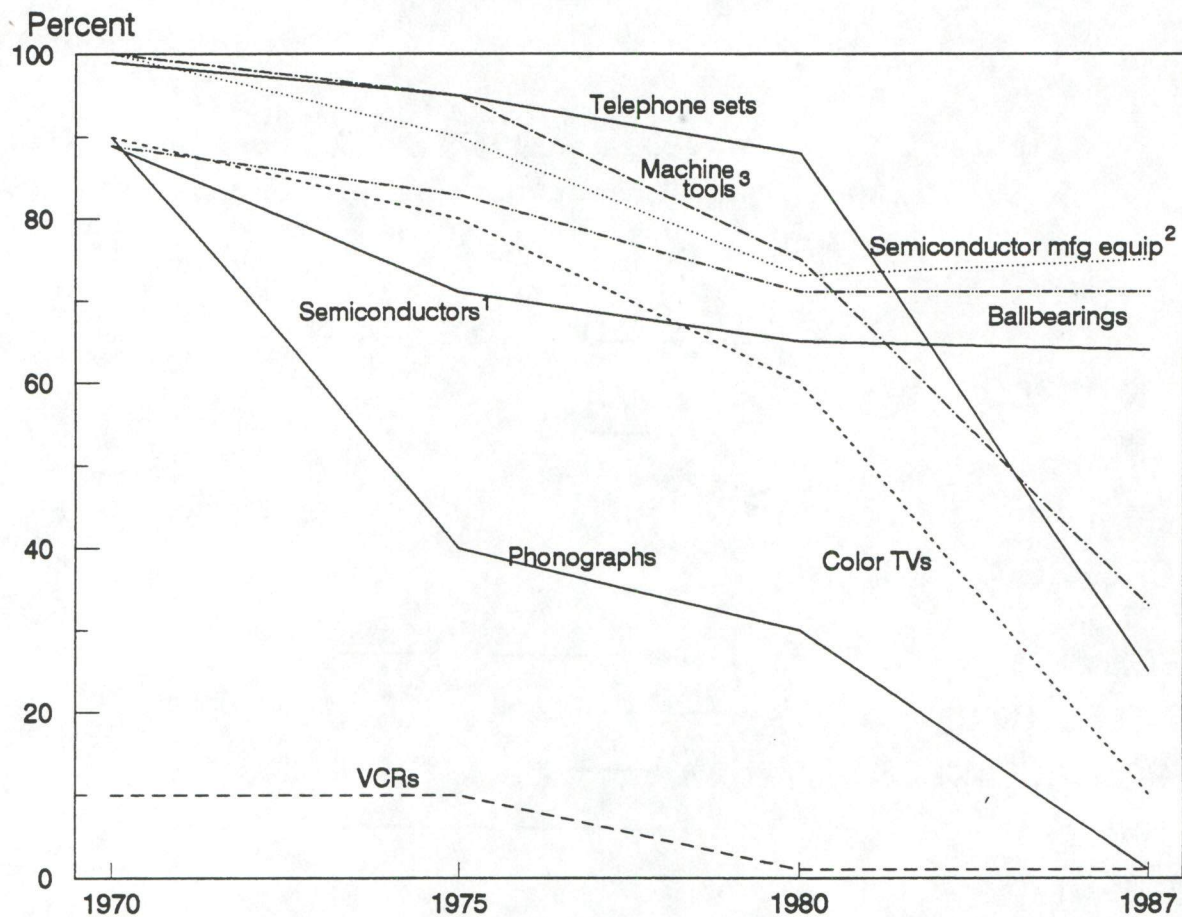
²⁰See NSF (1987). For a national strategy that would benefit not only the semiconductor industry but also a broad set of industries that depend on technology for a competitive edge in the marketplace, see National Advisory Committee on Semiconductors (1992).

Figure 12. Between 1980 and 1987, the U.S. lost the lead to Japan in most semiconductor technologies



SOURCE: Federal Interagency Staff Working Group on the Semiconductor Industry

Figure 13. U.S. share of selected technology markets



The U.S. share of several technology markets eroded during the 1970s and 1980

¹Data are for semiconductor merchant companies only. U.S. company share includes production of foreign subsidiaries operating in the United States.

²Estimates only. No official data exist.

³Includes horizontal, numerically, controlled lathes and machining centers.

Source: Council on Competitiveness

The computer, industrial and farm equipment, motor vehicles, and metals industries all received grades in the C range; the electronics industry received a D (*Fortune* 1992).

Recently, three agencies of the U.S. Government (Commerce, Defense, and the Office of Science and Technology Policy [OSTP] in the White House), several private organizations (e.g., the Council on Competitiveness, the Aerospace Industries Association, and the Computer Systems Policy Project), the Japanese Ministry of International Trade and Industry, and the European Community all identified similar sets of critical technologies that currently, and will continue to, foster economic growth during the decade. Although Federal agencies, including NSF and Commerce, are supporting research programs that focus on most of these critical technologies, the amount of money going into these programs is small, and there is currently no systematic tracking of the levels of funding and the results of investment in each of the technologies. A limited amount of information has been prepared on an ad hoc basis to respond to congressional and other requests. For example, table 4 contains a few dollar figures for investment in critical technologies at NSF's Engineering Research Centers and Industry/University Cooperative Research Centers. Table 5 lists the first and second year awardees of Commerce's Advanced Technology Program.

Table 4. NSF support of critical technologies at Engineering Research Centers and Industry/University Cooperative Research Centers: 1992

Technology	Funding (in millions)
Materials	\$12
Manufacturing	12
Information and communications technologies	20
Biotechnology and medical technology	6
Energy and the environment	5

Source: National Science Foundation, Directorate for Engineering

Table 5. 1991 and 1992 Advanced Technology Program awards

<i>1991 Single Applicants (6)</i>
Precision Optics for XRL, AT&T Bell Laboratories Computer Interface—Cursive Handwriting Recognition, Communication Intelligence Corp. Nonvolatile MRAM Semiconductors, Nonvolatile Electronics, Inc. Tunable UV/VUV Solid State Laser, Light Age, Inc. Machine Tool Compensation Techniques, Saginaw Machine Systems, Inc. Thallium Superconductor Thin Film Processing, E.I. du Pont de Nemours & Co.
<i>1991 Joint Ventures (5)</i>
PWB Interconnect, National Center for Manufacturing Sciences Holographic Mass Storage, Microelectronics and Computer Technology Corporation (MCC) FPD Manufacturing, American Display Consortium Solid State Laser—Point Source XRL, Hampshire, Inc. & McDonnell Douglas Electronic Systems Company Short Wavelength Sources—Optical Recording, National Storage Industry Consortium
<i>1992 Single Applicants (18)</i>
Polymeric Switches for Optical Interconnects, IBM Corporation Thermal Insulation Materials—Morphology Control and Processes for the Next Generation of Performance, Armstrong World Industries, Inc. Autonomous Navigation in Quasi-Structured Environments, Transitions Research Corporation Synthesis and Processing of Nanocrystalline Ceramics on a Commercial Scale, Nonphase Technologies Corporation High Fidelity Digital Image Compression, Iterated Systems, Inc. U.S. Self-Sufficiency in High-Quality Pyrethrin Production, AgriDyne Technologies, Inc. Development of Cost-Effective Routes to Compatibilize Polymers in a Commingled Waste Stream, Michigan Molecular Institute X-Ray and Neutron Focusing and Collimating Optics, X-Ray Optical Systems, Inc. Low-Temperature Viral Inactivation, Bio-Eng, Inc. Manufacturing Technology for High Performance Optoelectronic Devices Based on Liquid Phase Electro-Epitaxy, AstroPower, Inc. High-Temperature Superconducting Racetrack Magnets for Electric Motor Applications, American Superconductor Corp. A Three-Dimensional Database for Visualization of Human Physiology, Engineering Animation, Inc.

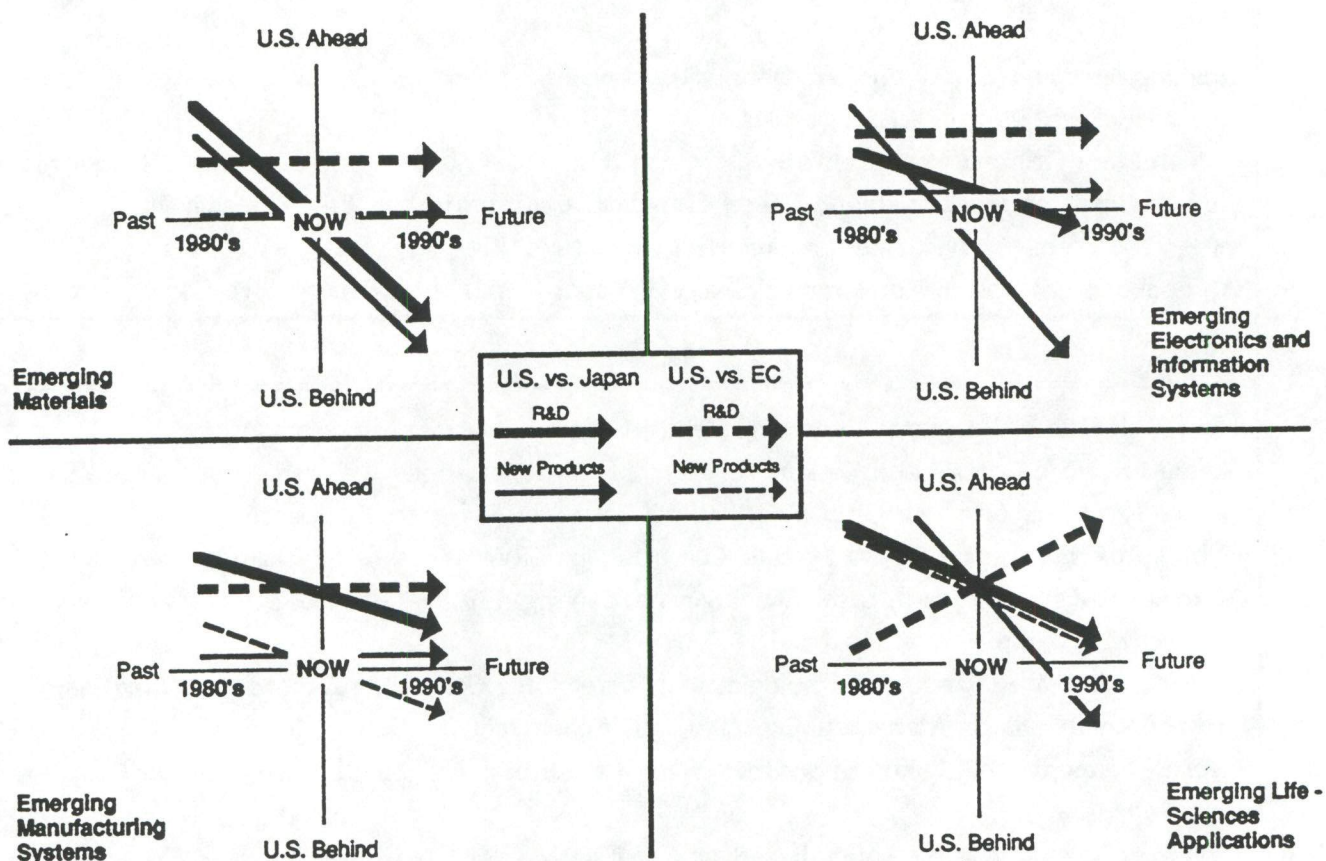
Table 5. 1991 and 1992 Advanced Technology Program awards
(Continued)

<i>1992 Single Applicants (continued)</i>
Novel Near-Net-Shape Processing of Engineered Ceramics , Carret Ceramic Components, a unit of Allied-Signal Aerospace Development and Applications of Density Functional Software for Chemical and Biomolecular Modelings , Biosym Technologies, Inc. Human Stem Cell and Hematopoietic Expansion Systems , Aastrom Biosciences, Inc. Advancement of Monocrystalline Silicon Carbide Growth Processes , Cree Research, Inc. Integrated Force Array , Center for Microelectronics at MCNC A Feedback-Controlled Metalorganic Chemical Vapor Deposition Reactor , Spire Corporation
<i>1992 Joint Ventures (9)</i>
Ultra-High Density Magnetic Recording Heads , National Storage Industry Consortium Neural Network Control and Sensors for Complex Materials , Honeywell/Hercules Aerospace/Sheldahl/3M NCMS Rapid Response Manufacturing , National Center for Manufacturing Sciences Hybrid Superconducting Digital System , Conductus, Inc./TRW Inc./Hewlett-Packard/Stanford U./U.C. Berkeley Monolithic Multiwavelength Laser Diode Array Spanning 430 to 1100 nm , Spectra Diode Laboratories, Inc./Xerox Corp. Development of Advanced Technologies and Systems for Controlling Dimensional Variation in Automobile Body Manufacturing , Auto Body Consortium Cyclic Thermoplastic Liquid Composite Molding for Automotive Structures , Ford Motor Co./General Electric Scalable High-Density Electronics Based on MultiFilm Modules , The American Scaled-Electronics Consortium PREAMP—Pre-Competitive Advances Manufacturing of Electrical Products , South Carolina Research Authority

Source: U.S. Department of Commerce, NIST

The Commerce Department (1990) issued a report containing a diagram and some "report cards" that depict where the United States stands, vis-à-vis Japan and the European Community, in the research and exploitation of emerging technologies. Figure 14 and tables 6 and 7 are taken from this report. The outlook these experts predict is not particularly favorable for U.S. competitiveness. For example, table 7 shows the United States falling behind Japan in all but 3 of the 13 critical technologies addressed in the report. The authors concluded that, "If current trends continue . . . before the year 2000, the United States could lag behind Japan in most emerging technologies and trail the European Community in several of them."

Figure 14. A Commerce Department evaluation revealed an erosion in U.S. technology leadership



SOURCE: U.S. Department of Commerce, Technology Administration

Table 6. Relative performance of the United States in several critical technologies

	Versus Japan	Versus Europe
Behind	Advanced materials Advanced semiconductor devices Digital imaging technology High-density data storage Optoelectronics	Digital imaging technology
Even	Superconductors	Flexible computer-integrated mfg Semiconductors
Ahead	Artificial intelligence Biotechnology Flexible computer-integrated mfg High-performance computing Medical devices and diagnostics Sensor technology	Advanced materials Advanced semiconductor devices Artificial intelligence Biotechnology High-density data storage High-performance computing Medical devices and diagnostics Optoelectronics Sensor technology

Source: U.S. Department of Commerce, Technology Administration

Table 7. Future trends for United States in several critical technologies

	Versus Japan	Versus Europe
Losing Badly	Advanced materials Biotechnology Digital technology Superconductors	Digital imaging technology Flexible computer-integrated mfg
Losing	Advanced semiconductor devices High-density data storage High-performance computing Medical devices and diagnostics Optoelectronics Sensor technology	Medical devices and diagnostics
Holding	Artificial intelligence Flexible computer-integrated mfg	Advanced materials Advanced semiconductor devices High-density data storage Optoelectronics Sensor technology Superconductors
Gaining		Artificial intelligence Biotechnology High-performance computing

Source: U.S. Department of Commerce, Technology Administration

The National Critical Technologies Panel (1991), sponsored by OSTP, issued a report on the results of its work. In this document, the panel identified and defined 22 critical technologies, gave the reasons each was selected, evaluated their status in the United States vis-à-vis other countries, and reported on international trends. Table 8 shows a list prepared by the panel comparing its 22 critical technologies with those identified by the Departments of Commerce and Defense.

Table 8. Comparison of national critical technologies with Department of Commerce emerging technologies and Department of Defense critical technologies

National critical technologies	Commerce emerging technologies	Defense critical technologies
Materials		
Materials synthesis and processing Electronic and photonic materials Ceramics Composites High-performance metals and alloys	Advanced materials Advanced semiconductor devices Superconductors Advanced materials	Composite materials Semiconductor materials & microelectronic circuits Superconductors Composite materials
Manufacturing		
Flexible computer integrated mfg Intelligent processing equipment Micro- and nanofabrication Systems management technologies	Flexible computer integrated mfg Artificial intelligence	Machine intelligence and robotics
Information and communications		
Software Micro- and optoelectronics High-perf. computing & networking High-definition imaging & displays Sensors and signal processing Data storage and peripherals Computer simulation & modeling	High-performance computing Advanced semiconductor devices Optoelectronics High-performance computing Digital imaging Sensor technology High-density data storage High-performance computing	Software producibility Semiconductor materials and microelectronic circuits Photonics Parallel computer architecture Data fusion Data fusion Signal processing Passive sensors Sensitive radars Machine intelligence and robotics Photonics Simulation and modeling Computational fluid dynamics
Biotechnology and life sciences		
Applied molecular biology Medical technology	Biotechnology Medical device and diagnostics	Biotech materials and processes

Table 8. Comparison of national critical technologies with Department of Commerce emerging technologies and Department of Defense critical technologies
(continued)

Aeronautics and surface transportation		
Aeronautics		Air-breathing propulsion
Surface transportation technologies		
Energy and environment		
Energy technologies		
Pollution minimization, remediation, and waste management		
		No national critical technologies counterpart: high-energy density materials, hypervelocity projectiles, pulsed power, signature control, weapon system environment

Note: National critical technologies were designated by the National Critical Technologies Panel; emerging technologies were designated by the Department of Commerce; defense critical technologies were designated by the Department of Defense.

Source: *Report of the National Critical Technologies Panel*, Office of Science and Technology Policy, March 1991

The recently released Council on Competitiveness (1991) report contains

- a list of critical generic technologies and assessments of the U.S. competitive position in each technology;²¹
- a comparison of critical technologies lists prepared by the Department of Defense, the Department of Commerce, the Japanese Ministry of International Trade and Industry, and the European community; and
- recommendations for government, academia, and industry.

²¹The Council has also published "competitive profiles" providing detailed evaluations of the competitive strengths and weaknesses of nine industries: aerospace, chemical and allied products, computers and software, construction, drugs and pharmaceuticals, electronic components and equipment, machine tools, motor vehicles, and telecommunications.

The Council's categorization of technologies in which the United States is either strong, competitive, weak, or losing (or has lost) is shown in table 9. The authors emphasize that even in technologies where the United States is strong or competitive, its position has been eroding, and there are no technologies in which the United States is gaining on its competitors. According to the Council, "Many of the areas where the United States is weak reflect the effects of high capital costs; the lack of cooperative relations between equipment, materials and components suppliers and their customers; and an underemphasis on manufacturing" (Council on Competitiveness 1991, p. 33).

These various panels comprised of government and nongovernment experts assembled to evaluate the status of the United States, vis-à-vis other countries, in technology advancement and application agreed that the preeminent technology leadership position enjoyed by the United States for decades has been eroding. To identify the factors adversely affecting U.S. industry's ability to compete in global markets for high-tech products, the Committee requested the assistance of the Industrial Research Institute²² to secure input from leading industrial R&D officials.

Potential Causes for the Erosion in U.S. Technology Leadership

Based on its own discussions and review of external contributions, the Committee was able to identify five major categories and 6 to 10 factors under each of the five categories that may be responsible for the erosion in U.S. technology leadership. The list prepared by the Committee was used by IRI to conduct a survey of its membership to gauge how industry officials perceive and rate the categories and factors. IRI agreed to share the results with the Committee. The five major categories were

- general management practices,
- external financial pressures,
- changing global technological environment,
- technology management practices, and
- Federal technology policy.

The survey was mailed to the 237 members of IRI with U.S. mailing addresses. Completed questionnaires were received from 139 members. Survey recipients were asked to rank both the five categories and the factors under each of the categories from highest to lowest in

²²IRI is an association of more than 250 companies. Its major function is to coordinate the study of problems confronting managers of industrial research and development. A company may join IRI if it (1) maintains a technical staff and research laboratory in the United States, and (2) engages primarily in industrial production. The IRI membership includes R&D directors from most large U.S. R&D-performing companies. IRI member companies account for approximately 85 percent of industry-funded R&D in the United States.

Table 9. Council on Competitiveness' assessment of the U.S. competitive position in critical technologies

TECHNOLOGIES IN WHICH THE UNITED STATES IS STRONG	TECHNOLOGIES IN WHICH THE UNITED STATES IS COMPETITIVE	TECHNOLOGIES IN WHICH THE UNITED STATES IS WEAK	TECHNOLOGIES IN WHICH THE UNITED STATES IS LOSING BADLY OR HAS LOST
Materials and Associated Processing Technologies Bioprocessing Bioactive/Biocompatible Materials Drug Discovery Techniques Emissions Reduction Genetic Engineering Recycling/Waste Processing Engineering and Production Technologies Computer-Aided Engineering Systems Engineering Electronic Components Magnetic Information Storage Microprocessors Information Technologies Animation and Full Motion Video Applications Software Artificial Intelligence Computer Modeling and Simulation Data Representation Data Retrieval and Update Expert Systems Graphics Hardware and Software Handwriting and Speech Recognition High-Level Software Languages Natural Language Neural Networks Operating Systems Optical Character Recognition Processor Architecture Semantic Modeling and Interpretation Software Engineering Transmitters and Receivers Powertrain and Propulsion Airbreathing Propulsion Low Emission Engines Rocket Propulsion	Materials and Associated Processing Technologies Catalysis Chemical Synthesis Magnetic Materials Metal Matrix Composites Net Shape Forming Optical Materials Photoreists Polymers Polymer Matrix Composites Process Controls Superconductors Engineering and Production Technologies Advanced Welding Computer Integrated Manufacturing Human Factors Engineering Joining and Fastening Technologies Measurement Techniques Structural Dynamics Electronic Components Logic Chips Sensors Submicron Technology Information Technologies Broadband Switching Digital Infrastructure Digital Signal Processing Fiber Optic Systems Hardware Integration Multiplexing Spectrum Technologies Powertrain and Propulsion Alternative Fuel Engines Electrical Storage Technologies Electric Motors and Drives	Materials and Associated Processing Technologies Advanced Metals Membranes Precision Coating Engineering and Production Technologies Design for Manufacturing Flexible Manufacturing High-Speed Machining Integration of Research, Design and Manufacturing Leading-Edge Scientific Instruments Precision Bearings Precision Machining and Forming Total Quality Management Electronic Components Actuators Electro Photography Electrostatics Laser Devices Photonics Powertrain and Propulsion High Fuel Economy/Power Density Engines	Materials and Associated Processing Technologies Display Materials Electronic Ceramics Electronic Packaging Materials Gallium Arsenide Silicon Structural Ceramics Engineering and Production Technologies Integrated Circuit Fabrication and Test Equipment Robotics and Automated Equipment Electronic Components Electroluminescent Displays Liquid Crystal Displays Memory Chips Multichip Packaging Systems Optical Information Storage Plasma and Vacuum Fluorescent Displays Printed Circuit Board Technology

SOURCE: Council on Competitiveness, *Gaining New Ground: Technology Priorities for America's Future*, pp. 31-34.

importance.²³ In addition, they were provided space to add other factors they felt were important but may have been omitted from the Committee's list. They were also asked to provide recommendations for addressing the problems responsible for the erosion in U.S. technology leadership and to identify their companies' major industry (or industries) and domestic employment size group.

According to the industrial R&D officials who participated in the survey, *general management practices* and *external financial pressures* are more at fault for the erosion in U.S. technology leadership than are the other three categories. *Federal technology policy* was ranked last (closely behind *technology management practices*). Although *Federal technology policy* was ranked below the other categories, it cannot be inferred that the R&D directors consider it to be unimportant in contributing to the decline in U.S. technology leadership, only less important than the other four categories.

Nevertheless, it would appear that there is a strong consensus among industrial R&D officials that *general management practices* and *external financial pressures* are more to blame for the erosion in U.S. technology leadership than *Federal technology policy*. This finding, however, does not lead to the conclusion that increasing Federal support of technology development or other new Federal policies and programs would be ineffectual in strengthening U.S. industrial competitiveness. The issue is far too complex and multifaceted to downplay the role of any sector. As stated in the recent Council on Competitiveness (1991, p. 44) report, "Each sector has a responsibility. Government must work with the private sector to make the development and application of technology a new national priority. Industry must improve its ability to commercialize technology. And universities must make sure that their research and education programs adequately address the technology needs of industry."

It is also important to emphasize that the survey results reflect the views of a single set of industry representatives. Although this group of leading R&D officials is a particularly relevant and appropriate group for this study, their opinions may not represent the composite views of other industry leaders. For example, the rankings might have been quite different had the respondents been CEOs, chief financial officers, or manufacturing leaders. Also, with respect to the role of Federal technology policy, many CEOs of major high-technology companies have voiced their support for a larger role for the Federal Government in fostering industrial competitiveness; their views are reflected in reports such as *Gaining New Ground: Technology Priorities for America's Future* (Council on Competitiveness 1991).

The industry R&D officials' ranking of the five categories, however, is consistent with the observations of leading experts. For example, Rosenbloom and Abernathy (1982) contend that *general management practices* are at least partially to blame for some of the difficulties U.S. consumer electronics companies encountered in competing successfully with their foreign

²³Not all respondents ranked every category; some did not rank all factors within a category; and a few gave identical rankings to some of the factors. Missing and duplicative rankings were imputed using statistical procedures designed to maximize respondents' ordinal placement of categories and factors and minimize bias.

counterparts. It should be acknowledged, of course (and several IRI officials noted this) that the two categories of *general management practices* and *external financial pressures* are closely linked: external financial pressures constrict, to a great extent, general management decision-making.

Under the category *general management practices*, survey respondents placed greatest emphasis on "short time horizons" and "management by the numbers rather than by strategic vision." "Failure and/or inability to integrate technology into business strategy" and "corporate executives' lack of scientific and technical insight and lack of experience in the management of science and technology" were also frequently mentioned. A common theme of numerous studies is that "U.S. firms [are] less willing than their rivals to live through a period of heavy investment and meager returns in order to secure a foothold in a growing market" (Detouzos et al. 1989, p. 53). For example, "The short-term orientation of U.S. firms and their unwillingness to commit resources to the development and commercialization of new technologies is a critical factor in explaining the failure of U.S. firms to compete in the fast changing electronics industry" (Sanderson 1989, p. 44). Japanese companies' success in developing and manufacturing a videocassette recorder for the consumer market is frequently cited as an example of how perseverance eventually paid off. In contrast, U.S. companies failed to capitalize (on what was initially a U.S. invention) because they were unwilling to make the long-term commitment of resources necessary to perfect a product for the consumer market.²⁴ The need for financial incentives that would induce management to adopt a longer term perspective was mentioned by one-third of those IRI members who added recommendations to their questionnaires.

Survey respondents overwhelmingly selected "growing dominance of institutional investors in equity markets and their demand for short-term returns on their investments" as the most important factor in the category, *external financial pressures*. "High cost of capital" finished a distant second in the ranking of factors under this category.

Although it is widely assumed, and several studies have suggested, that Japanese companies' greater propensity to invest in long-term R&D, process technology, and capital equipment can be attributed to a lower cost of capital, the issue—whether there is truly a significant difference in the cost of capital between the United States and Japan—is still being debated. In addition, there is disagreement over how much this difference, if it exists, is responsible for the longer time horizons of Japanese companies compared to those of U.S. firms. In a recent study conducted for the National Academy of Engineering's Committee on Time Horizons and Technology Investment, Joseph Morone and A.S. Paulson (1991) assert that "While there is heated dispute about whether or not the cost of capital in the United States is higher than it is in Japan, there is a growing consensus that Japanese firms behave *as if* their cost of capital is lower."

²⁴ A clarification is needed at this point. The Committee is not here advocating more investment in long-term research. Rather, the point being made is that because of their short time horizons, companies are more willing to spend their earnings on, for example, paying out large dividends or acquiring other companies, rather than on developing and, more importantly, applying technology to perfect and create new products and processes. Indeed, long-term research is not the issue in the U.S. electronics industry; what is lacking is perseverance, the patience needed to tinker with available technology, and speed of commercialization.

Their interviews with 15 corporate executives revealed widely differing opinions on whether the cost of capital is having a significant impact on U.S. competitiveness. Officials who felt that the cost of capital was having a minimal effect on their firms' ability to compete tended to represent companies in better financial condition and at the forefront of technology leadership in their respective industries than those who contended that the cost of capital was a major handicap, limiting their companies' ability to take on more risky investments in capital equipment and R&D.

There was less consensus in the IRI members' ranking of factors under *global technological environment* than was displayed in their ordering of the factors under *general management practices* and *external financial pressures*. "Growing difficulty of controlling enough technological competitive advantage to sustain an entry barrier" was ranked highest, marginally ahead of the factor ranked second, "declining lead times and faster product turnover cycles." These two factors received almost the same number of first and second place rankings and are closely related. Both are prominent characteristics of the electronics industry where rapid advancements in technology are continuously shortening product and process cycles, thus increasing the risk that companies will be unable to fully recover their investments and make a profit before their products become obsolete.

Several of the experts invited to discuss their recent research with the Committee spoke about the contrast between U.S. free market policies and the protectionist policies of competitor nations and emphasized the negative effect that this difference was having on U.S. companies' ability to compete in global markets. For example, Candace Howes (forthcoming) stressed that Japan's export-based development strategy, a key component of which is the export of motor vehicles, precludes U.S. automobile manufacturers from competing on a "level playing field."

In a recent article, Edward Steinmueller (1988) described how the Japanese Government's policies were successful in protecting the domestic computer industry.

A major factor in the rapid growth of Japanese computer manufacture has been the support of the Japanese government for this industry . . . The prohibition of direct investment may have been the most effective means of isolating the Japanese market from the competitive influences prevailing in international markets. This prohibition prevented U.S. and European companies from setting up the coordinated manufacturing, distribution, and support systems in Japan that have been shown to be important to competitive success in the international computer industry.

"Relative slowness in product development and commercialization" was ranked first in the *technology management practices* category and "reluctance to invest in new enabling technologies because the R&D may be too expensive, long-term, multi-industry, and interdisciplinary" was ranked second, although it received the highest number of first place rankings.

A standard conclusion of recent studies on competitiveness is that U.S. companies trail their foreign rivals in the commercialization of new technologies. They fall short of their foreign competitors by being slow to digest and respond to market information and by missing crucial opportunities to be first on the market with low-cost, high-quality products. As stated in a

Council on Competitiveness report (1988, pp. 1, 9), "The speed with which firms are able to translate innovations into commercial products and processes often spells the difference between success and failure . . . By rapidly translating new technology into new products and processes, firms in other countries have gained access to new markets and reaped considerable commercial rewards."

In many U.S. industries, development of new products proceeds at a much slower pace than in other countries. For example, a study of the automobile industry revealed that Japanese companies required on average only half the number of engineering hours and two-thirds the time of U.S. companies to transform a concept into a product ready for the sales floor (Clark and Fujimoto 1986). The need for more rapid commercialization of new technology was cited by ten of the IRI officials in their recommendations.

The need for speedy conversion of ideas into products requires firms to have access to an ever-expanding, relevant engineering knowledge base and the techniques of translating that base quickly into practice. Two of the primary reasons U.S. companies are relatively slow in translating innovation to products and processes are (1) the lack of a sufficiently broad and deep fundamental engineering research base, and (2) inadequate fundamental engineering research. In addition, "reluctance to invest in new enabling technologies . . ." is linked to underinvestment by industry in engineering research.²⁵ The level of Federal support for basic engineering research actually declined in constant dollars from 1989 to 1991 and the Federal support for applied engineering research declined gradually over the decade (see NSB 1991, figure 4-6, p. 97).

Two-thirds of the respondents gave first or second place rankings to "lack of long-term strategies for expanding the economy (and tax revenues) through technological competitiveness" under the *Federal technology policy* category. The importance attributed to this factor can be interpreted as a statement (from most respondents) in favor of a comprehensive national technology strategy aimed at improving industrial competitiveness. Twenty-five of the IRI members mentioned the need for such a strategy in their recommendations. The two factors that refer to education, "too little attention to the training of future scientists and engineers" and "too little attention to pre-college education," were ranked second and fourth, respectively. The need to strengthen the U.S. educational system was mentioned more frequently than any other in respondents' recommendations.

The results of the IRI survey are discussed in greater detail in appendix B.

²⁵These concerns were addressed in detail in NRC (1987).

Part II

Recommendations

Introduction

The Committee related its recommendations to its four major findings. The recommendations focus on areas in which the Federal Government, and especially the National Science Foundation (NSF), may be able to contribute to strengthening U.S. industrial competitiveness. Although NSF can play a key innovative role—and one in which its skills in building partnerships can be particularly used—its support of relevant research is but a small fraction of the total R&D industrial enterprise. The most important contribution NSF can make, in fact, is to continue to concentrate on what it does best and for which it is especially qualified—the support of basic research and education. Investment in these two areas is critical to successfully maintaining U.S. technological leadership, even though, unlike other Federal programs and policies aimed at bolstering U.S. competitiveness, the benefits may not be visible for several years.

In addition to making general recommendations, the Committee also made several specific recommendations—some directed to individual Federal agencies, others to the government in general. Both the general recommendations and those specific ones not directly related to NSF are listed below under each of the four findings. Following these general and specific recommendations, NSF programs and policies are discussed, with particular emphasis on those that now affect—or have the potential to affect—industrial competitiveness; specific recommendations to the Foundation are also included in this discussion.

General Recommendations

1. *The real rate of growth in U.S. industrial R&D spending has declined since the late 1970s and early 1980s. In addition, there has been a deterioration in the U.S. position relative to that of its major international competitors, whose investment in nondefense R&D has been growing at a much faster pace than U.S. nondefense R&D since the mid-1980s.*

General Recommendation: Although industry must take the lead in the resumption of more rapid growth of industrial R&D to match that of U.S. competitors, the Federal Government has a direct, crucial role in establishing a healthy economic environment conducive to R&D investment. Monetary, fiscal, and regulatory policies are important determinants of the climate for investment, and therefore can enhance or impede U.S. industry's ability to compete successfully in the global marketplace. Presidential and congressional action should include adoption of fiscal and monetary policies that encourage strategic investment in both tangible (e.g., plant and equipment) and

intangible (e.g., training) assets for R&D and changes in Federal regulations and the regulatory process to promote and facilitate technological innovation.

Organizations such as the Council on Competitiveness and the Competitiveness Policy Council have issued recommendations addressing these factors. Although the Committee has nothing significant to add to their lists, it strongly endorses such recommendations, including urging the President and Congress to do the following (Council on Competitiveness 1991, p. 4).

Make the cost of capital . . . competitive with that of America's major competitors by accelerating depreciation schedules for manufacturing equipment, making the R&D tax credit permanent and broadening it to include manufacturing engineering and process R&D, and placing a permanent moratorium on Treasury Regulation 1.861-8, which creates a tax benefit for U.S. corporations that move their R&D facilities to a foreign country [and] promote capital formation, antitrust reforms, regulatory guidelines, export policies and foreign market-opening measures that are conducive to U.S. manufacturing, investment in technology and quality of life.

2. The allocation of U.S. R&D expenditures is not optimal.

- *The balance between defense and nondefense expenditures is disadvantageous compared to that of foreign competitors.*
- *Too little is spent on process-oriented rather than product-oriented R&D.*
- *Inadequate effort is devoted to fundamental engineering research.*
- *There is insufficient emphasis on emerging and precompetitive technologies.*
- *The United States faces an emerging risk of losing its traditional strength in pioneering discoveries and inventions.*

General Recommendation: Federal support of R&D directly relevant to industrial competitiveness should be increased. The primary need is to reorient Federal R&D budgets away from noncivilian government missions and toward the needs of industry. More programs should be created that encourage the interaction of scientists and engineers in universities and industry in exploring joint research interests that hold the promise of pioneering discoveries and inventions. In addition, traditional and nontraditional education programs that motivate creativity, innovation, and entrepreneurship should be supported.

The Committee is not alone in making this type of recommendation. Others have noted, for example, that "when it comes to technology, U.S. public policy can no longer afford to be preoccupied with basic research and military issues; economic security and industrial competitiveness are also vital considerations" (Inman and Burton 1991). The recent reports on the deteriorating position of the U.S. industrial sector vis-à-vis other countries emphasize the need to

elevate technological competitiveness to an equal footing and integrate it with other national priorities such as improving the state of the economy, national security, and health care.

An appropriate first step would be for the President and Congress to implement the national technology policy that was set forth by the President's Office of Science and Technology Policy (OSTP) in a document entitled *U.S. Technology Policy*. A key component of the OSTP statement is the advocacy of Federal participation "with the private sector in precompetitive research on generic, enabling technologies that have the potential to contribute to a broad range of government and commercial applications" (OSTP 1990). Several Federal programs that contribute to this goal—e.g., NSF's Engineering Research Centers and Commerce's Advanced Technology Program and Manufacturing Technology Centers—have already been established. The Committee believes, however, that more needs to be done by strengthening and fine-tuning these and other ongoing activities and by creating selected new programs.

U.S. industry's relative slowness in product development and commercialization is clearly a related issue in the debate on competitiveness. The Japanese Technology Evaluation Center and critical technologies assessments and the results of the Industrial Research Institute (IRI) survey, all of which were discussed in part I of this report, document the magnitude and seriousness of the problem. Many IRI members and other corporate leaders, as well as government legislators and policymakers, advocate increased Federal support of programs and policies designed to promote the rapid commercialization of technology. Their agenda includes the provision of incentives and assistance to companies to

- integrate their approach to research, design, manufacturing, and maintenance;
- maximize the use of concurrent engineering, total quality management, just-in-time production, and other modern techniques;
- invest in more process and manufacturing R&D; and
- identify and acquire technology from outside sources.

A related issue, and one that the Committee believes to be a pervasive problem in the United States today (although a lack of systematic data has precluded detailed discussion of this topic to this point) is the insufficient attention given to fundamental engineering research in industry, government, and universities. Every firm must have an ever-expanding, relevant engineering knowledge base—and the hardware and software techniques for translating that base quickly into practice—in order to convert ideas into products rapidly and efficiently. The often-cited lack of emphasis on process improvement and manufacturing, along with excessive time delays from concept to available product, attest to a pervasive lack of understanding of, appreciation for, and sufficient attention to the vital role of fundamental engineering research by U.S. industry, government, and universities. Yet there is no sufficiently broad and deep fundamental engineering research base on which to build; furthermore, there are an inadequate number of engineering researchers in U.S. industry who are equipped to, and called upon to, extend that base as needed. The greater the storehouse of fundamental engineering research, and the greater

the ability in industry and government to extend it as needed for proprietary or national reasons, the better able the qualified engineer is to innovate in an integrated system of design, manufacture, and maintenance.

The Committee makes the following recommendations:

- Several fledgling programs within the Department of Commerce's National Institute of Standards and Technology (NIST)—including the Advanced Technology Program, the Manufacturing Technology Centers Program, and the State Technology Extension Program—should be expanded. In addition, the strong NIST budget proposal by the Administration, which calls for doubling the agency's budget by 1996, should be supported. Such an increase is needed to "allow NIST to conduct research and provide laboratory support for manufacturing technologies, information technologies, and other emerging technologies that are extremely important to the U.S. economy" (U.S. Congress 1991).
- Federal agencies, where appropriate, should incorporate the following elements as either primary or secondary criteria in evaluations for awarding R&D support: (1) relevance to the critical technologies in which the U.S. lead is slipping, and (2) relevance to U.S. industrial competitiveness.
- New programs should be established that stimulate the redirection of government resources from defense to nondefense R&D.
- Activities that directly support technology transfer activities in Federal laboratories should be expanded.

3. *U.S. expenditures are not as effective as they should be in producing needed results.*

- *The U.S. competitive position in important, technologically based industries is deteriorating.*
- *The U.S. time horizon has become too short, and the Nation's business decisions tend not to be based on strategic technological considerations.*
- *U.S. R&D is not translated into beneficial economic and social results quickly enough.*

General Recommendation: Traditionally, Federal R&D agencies have played no role with respect to factors that influence the managerial context for technology. This report suggests that the business context for technology is such an important determinant of the strength of U.S. industrial technology that it may be time to reexamine this traditional isolation from business issues. The Committee also believes that support should be increased for science and engineering research and education programs that emphasize production systems engineering and the integration of product design and manufacturing. Activities should also be encouraged that lead to faster dissemination of research results among researchers in academia, industry, and other sectors.

Some U.S. companies have managed to succeed in the high-technology arena despite inherent disadvantages. These companies have made the adjustments necessary to thrive within the prevailing financial investment climate. Operating under the same financial pressures as other companies to produce quick profits to satisfy impatient stockholders, their leaders continue to have long-range vision and to support risky projects in which returns may not be realized for a relatively long time.

Why are some U.S. firms successful in the global marketplace, when others have not been? According to Morone and others, these firms share a "style of general managerial decision making that is driven by strategic imperatives . . . rather than by financial objectives"¹ (Morone forthcoming). There is now a considerable body of evidence (including the IRI survey results) suggesting that general management bears much of the responsibility for the United States' lackluster performance in high-technology markets. More research is needed to determine how some companies have mitigated the constraints imposed by external financial pressures.

4. *The current information base on industrial science and technology is inadequate. The current knowledge base has gaps, is questionable in parts, and often does not provide enough detail to meet the needs of policymakers.*

General Recommendation: Although policymakers could use more informative, integrated, and better quality, data on industrial technology and the role of R&D investment in economic activity than are currently available, the feasibility and/or the costs of collecting such data are frequently not known. The Committee recommends that a systematic assessment be carried out that examines the feasibility and cost of developing and tracking a set of industrial science and technology indicators that would be of value to policymakers concerned with technology policy, U.S. industry's involvement in high-technology markets, and R&D investment in emerging technologies.

In the course of its investigation, the Committee discovered gaps in the government's databases, including a lack of, or incomplete, information on

- international comparisons of industrial R&D performance;
- R&D investment in narrowly defined product areas and emerging technologies;
- comparisons of the content and allocation of R&D resources;
- the R&D performance and achievements of nonprofit organizations, including R&D consortia;

¹Dr. Morone's list of "strategic imperatives" includes "striving to be first to market, with the best performing products, at the lowest costs, and with the highest quality, in every market segment and price tier, in every region of the globe."

- R&D contracted to or sourced from outside organizations;
- foreign companies' R&D investment in the United States;
- independent research and development; and
- R&D performed in the service sector.

The Committee recognizes that it may not be possible or feasible to collect data in all of the areas noted above. For example, companies may be unwilling, or perhaps unable, to compile and provide more disaggregated data; nonresponse to NSF (and other) surveys has been a major problem for many years. Also, collection of data on some topics of interest, including emerging technologies, is likely to prove especially difficult because survey respondents sometimes use varying definitions when supplying the requested data (even though NSF provides detailed instructions and definitions along with its questionnaires).

NSF Recommendations

What NSF Is Currently Doing

NSF contributes in many ways to U.S. scientific and technological leadership. It contributes through its science and engineering basic research and education programs and through programs specifically focused on industry competitiveness. Fundamental research in science and engineering has made important contributions to the competitive strength of U.S. industry. In recent months, there has been a major effort throughout the Foundation to enhance industrial participation in NSF programs.² One of the principal outcomes of this outreach effort should be an increase in the amount of NSF-supported research providing a foundation for the most important and immediate industrial needs.

Many NSF programs and projects have high rates of industry involvement:

- The Industry/University Cooperative Research Centers Program provides "seed" support for more than 50 centers to work in collaboration with industry on research relevant to industrial needs.

²NSF is already demonstrating serious commitment in addressing the question of how it can increase interaction between academia and industry to speed the deployment of new knowledge and technologies to industry. The NSF Director recently established an internal NSF Committee—the Industrial Programs Coordinating Committee—to (1) coordinate programs that focus on industrial collaboration; (2) provide recommendations for a substantive long-term program of activities to strengthen NSF's interactions with industry and the latter's interactions with academia; (3) develop a brochure focused on industry, especially smaller firms, depicting the benefits of industry-university collaboration; and (4) develop a strategy for improved outreach to industrial organizations.

- The **Engineering Research Centers Program** is designed to focus cross-disciplinary teams on research and education on engineering systems important for competitiveness.
- The **Science and Technology Centers Program** is designed to team scientists and engineers to focus on research with a long-term technological horizon and promote linkages with industry and other sectors.

Other center programs also foster industry-university collaboration. The **Supercomputer Centers** have close links with industry to facilitate the use of supercomputers. The **Materials Research Laboratories**, because of their focus on interdisciplinary programs in materials research, have proven attractive to industry. The **National Center for Atmospheric Research** has developed an active program of research in atmospheric phenomena relevant to aviation technology that receives considerable industrial support. The new **State University/Industry Cooperative Research Centers** program aims to enhance local economic development and actively focuses on technology transfer and knowledge deployment, especially with regard to small firms.

A number of programs under the jurisdiction of NSF's Engineering Directorate support research aimed at developing and/or perfecting manufacturing technologies and/or improving the speed and efficiency by which the results of NSF-sponsored (and other) research and technology are transferred to the marketplace. Included in this group (in addition to the already noted Engineering Research Centers program) are the **Industrial Innovation Interface Programs**, **Design and Manufacturing Systems Programs**, the **Strategic Manufacturing Initiative**, the **Small Business Innovation Research (SBIR) Program**, and a newly revived **Management of Technology Program**. The SBIR program, which originated in NSF, has served as a model for the national congressionally mandated program. Many SBIR awards utilize academic personnel and have generated process and product advances having considerable market impact.

NSF also funds small groups of investigators collaborating across disciplines. For example, participants in the Biotechnology Group and the Strategic Manufacturing Group perform research likely to produce technological advancements important to industry. There are also four relatively new initiatives in the single-investigator programs which focus on industry-university collaboration at the individual investigator level. Two of these programs—the Management of Technology Program and the Strategic Manufacturing Initiative—were identified above. The other programs are the **Decision, Risk, and Management Science Program** in the Social, Behavioral, and Economic Sciences Directorate (SBE) and the **Environmentally Benign Chemical Synthesis and Processing Initiative** between the Chemistry and the Chemical and Thermal Systems Divisions.

The Decision, Risk, and Management Science Program supports research aimed at improving decision-making under conditions of risk and uncertainty. Within this program is a **Joint NSF/Private Sector Research Initiative** wherein matching funding is available to investigators with private sector support to conduct research in the areas of operational control, management systems, and strategic planning. The Economics Program within SBE also supports research on corporate behavior.

The Division of Science Resources Studies in SBE sponsors several surveys that produce both funding and personnel data on industrial science and technology. Part I of this report contains information collected with these surveys.

In addition, SBE divisions fund and support the dissemination of research

- in the economics, public policy development, social impact, and management of technological change, and the building and testing of theories, models, and methodologies; and
- on the interrelationships among industry R&D and competitiveness, international technology transfer, international interdependencies, and the development of additional critical science and engineering indicators.

Recent examples of these programs are **Research on Methods to Estimate the Supply and Demand of U.S. Scientists and Engineers**, a new **Center for Survey Methods**, and a new program on **Research on Science and Technology**. The latter will support studies of particular interest to the industrial community, including studies of processes, inputs, outputs, and impacts in areas such as industrial research, university-industry interactions, the payoff to industrial innovation from academic research, knowledge/know-how/technology transfer, utilization, and diffusion.

NSF also participates in the **Federal Coordinating Council for Science, Engineering, and Technology (FCCSET)**. A number of the interagency initiatives coordinated through FCCSET target technologies of key interest to industry, including high-performance computing and communications, advanced materials and processing, biotechnology, and a soon-to-be-started initiative, **Advanced Manufacturing Technologies**.

In addition, NSF will be monitoring the new **Critical Technologies Institute** that will be responsible for identifying near- and long-term R&D objectives and for providing options for achieving those objectives.

What More Needs to Be Done

As the above examples indicate, within its mandate to support science and engineering education and academic basic research, NSF includes a broad range of programs and initiatives that contribute both directly and indirectly to industrial needs. The Committee fully endorses this broad range of programs and initiatives and NSF's recent efforts to further enhance industrial participation in its programs.

The Committee believes that NSF can further strengthen the direct impact of academic research on industrial competitiveness through the following actions.

- **Creating new fundamental science and engineering research initiatives that contribute to emerging and precompetitive technologies.** While the Directorates of Engineering and of Computer and Information Science and Engineering will be the likely home of many such new initiatives, other Directorates—including Education and Human Resources, the new Social, Behavioral, and Economic Sciences Directorate, and the traditional research directorates—are also likely candidates for programs that would benefit the development of emerging and precompetitive technologies.
- **Increasing support for strategic scientific and engineering research programs and initiatives, particularly for activities that attract industrial cosupport.** These include centers, cooperative multi-user facilities, consortia, and individual investigator projects with coparticipation by industry.
- **Following through on the recommendations of a National Academy of Engineering (NAE) evaluation of the NSF Engineering Research Centers Program, especially “a renewed effort to achieve original funding targets of the program.”** According to the evaluation, “if the Federal Government is to assist industry in its fight to remain competitive, this is precisely the kind of program that it should support” (NAE 1989).
- **Significantly expanding and enhancing the effectiveness, scope, and outreach of its Engineering Research Centers, Science and Technology Centers, Industry/University Cooperative Research Centers, and other industry-related programs and coupling these even more closely with future industry needs.**
- **Promoting activities that specifically encourage more rapid knowledge transfer among researchers in academia, industry, and other sectors.** Efforts could be made to advance the capabilities of NSFNET (the Foundation’s nationwide computer network) for scientific and technical information exchange.
- **Increasing support of research and education on engineering design, manufacturing processes, and programs that emphasize systems integration in engineering education.**
- **Encouraging and assisting in the expansion of Federal support of fundamental engineering research.**

While the managerial context for technology has not been a subject within the traditional realm of NSF responsibilities, NSF has identified a new Management of Technology Program as an area where it can make a meaningful contribution. In the context of this new program, NSF may want to broaden its traditional focus on the education of future scientists and engineers to include the education of future corporate leaders of both high-technology and traditional industries. NSF could support business and engineering schools in expanding their curricula to include integrated instruction in technology and management that would provide students with a better understanding of the R&D process and the importance of skillful technology planning and management to commercial success. A program also could be established to encourage and

facilitate the introduction of courses tailored to meet the needs of recent engineering and business graduates by providing them with the management skills necessary to lead technology-based companies. NSF could also assist corporate leaders by supporting and disseminating research conducted to determine how some companies have mitigated the constraints imposed by external financial pressures.

The Committee therefore recommends that

- The Director examine NSF's role with respect to the managerial context for technology. For example, should NSF encourage the development of new kinds of university programs that integrate engineering and management education programs? Any significant changes in this direction would represent a substantial departure from NSF's traditional role, and thus should be given careful examination.

Both NSF and the Department of Commerce should anticipate increased demand for information on science- and technology-related subjects from policymakers in the Office of Management and Budget, OSTP, and other executive branch agencies and from Congress, and should begin developing and instituting procedures and mechanisms for responding to such requests as expeditiously as possible.

The Committee therefore recommends that

- NSF should develop an integrated program to
 - explore ways of correcting existing deficiencies in ongoing data collection activities;
 - identify missing information of value to policymakers and develop valid indicators of that information; and
 - determine the feasibility of collecting, analyzing, and disseminating the information.

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Appendix A

Statistical Tables

Table A-1. Trends in industrial R&D performance, by source of funds: 1953-90 and 1991-92 (est.)

Year	[Dollars in millions]					
	Total R&D		Federal		Company(1)	
	Current dollars	Constant 1987 dollars	Current dollars	Constant 1987 dollars	Current dollars	Constant 1987 dollars
1953.....	\$3,630	NA	\$1,430	NA	\$2,200	NA
1954.....	4,070	NA	1,750	NA	2,320	NA
1955.....	4,640	NA	2,180	NA	2,460	NA
1956.....	6,605	NA	3,328	NA	3,277	NA
1957.....	7,731	NA	4,335	NA	3,396	NA
1958.....	8,389	NA	4,759	NA	3,630	NA
1959.....	9,618	37,585	5,635	22,020	3,983	15,565
1960.....	10,509	40,388	6,081	23,370	4,428	17,018
1961.....	10,908	41,554	6,240	23,771	4,668	17,783
1962.....	11,464	42,712	6,434	23,972	5,029	18,737
1963.....	12,630	46,451	7,270	26,738	5,360	19,713
1964.....	13,512	48,868	7,720	27,920	5,792	20,948
1965.....	14,185	49,930	7,740	27,244	6,445	22,686
1966.....	15,548	52,974	8,332	28,388	7,216	24,586
1967.....	16,385	54,130	8,365	27,635	8,020	26,495
1968.....	17,429	54,894	8,560	26,961	8,869	27,934
1969.....	18,308	54,897	8,451	25,340	9,857	29,556
1970.....	18,067	51,429	7,779	22,143	10,288	29,286
1971.....	18,320	49,527	7,666	20,725	10,654	28,802
1972.....	19,552	50,353	8,017	20,646	11,535	29,706
1973.....	21,249	51,488	8,145	19,736	13,104	31,752
1974.....	22,887	50,996	8,220	18,316	14,667	32,680
1975.....	24,187	49,171	8,605	17,493	15,582	31,677
1976.....	26,997	51,649	9,561	18,292	17,436	33,358
1977.....	29,825	53,383	10,485	18,767	19,340	34,616
1978.....	33,304	55,240	11,189	18,559	22,115	36,681
1979.....	38,226	58,316	12,518	19,097	25,708	39,219
1980.....	44,505	62,062	14,029	19,564	30,476	42,499
1981.....	51,810	65,699	16,382	20,774	35,428	44,925
1982.....	58,650	70,021	18,545	22,141	40,105	47,881
1983.....	65,268	74,883	20,680	23,726	44,588	51,156
1984.....	74,800	82,153	23,396	25,696	51,404	56,457
1985.....	84,239	89,265	27,196	28,818	57,043	60,446
1986.....	87,823	90,614	27,891	28,777	59,932	61,837
1987.....	92,155	92,155	30,752	30,752	61,403	61,403
1988.....	97,889	94,260	32,117	30,926	65,772	63,334
1989.....	101,854	93,944	31,292	28,862	70,562	65,082
1990.....	104,344	92,446	30,580	27,093	73,764	65,353
1991 (NSF est.).....	106,750	91,161	30,400	25,961	76,350	65,201
1992 (NSF est.).....	110,300	91,346	31,300	25,921	79,000	65,424

(1) Company funds include funds for industrial R&D work performed within company facilities in the U.S. from all sources except the Federal Government. These sources may include other companies, research institutions, colleges and universities, other nonprofit organizations, and state and local governments, as well as companies' own funds. Company-financed R&D not performed within the company is excluded.

NA = Not available

NOTE: The 1987 GDP implicit price deflator was used to convert current dollars to constant dollars.

SOURCES: National Science Foundation, Survey of Industrial Research and Development and NSF Panel on Industrial Science and Technology

Table A-2. National expenditures for R&D, by performing sectors and sources of funds: 1953-92 (page 1 of 2)
 [In millions of dollars]

Year	Industry (2)			Universities & colleges				Other nonprofit institutions (2)			
	Federal Govt.	Sources			Sources			Sources			U&C FRDCs
		Total used	Fed. Govt.	Indus-try (3)	Total used	Fed. Govt.	Indus-try (4)	U&Cs (4)	Non-profits	Total used	
	United States (1)										
1953.....	\$5,124	\$3,630	\$1,430	\$2,200	\$255	\$138	\$19	\$72	\$26	\$121	
1954.....	5,644	4,070	1,750	2,320	290	160	22	80	28	141	
1955.....	6,172	4,640	2,180	2,460	312	169	25	88	30	180	
1956.....	8,364	6,605	3,328	3,277	372	213	29	96	34	194	
1957.....	9,775	7,731	4,335	3,396	410	229	34	109	38	240	
1958.....	10,711	8,389	4,759	3,630	456	254	39	121	42	293	
1959.....	12,357	9,618	5,635	3,983	526	306	39	134	47	338	
1960.....	13,520	10,509	6,081	4,428	646	405	40	149	52	360	
1961.....	14,320	10,908	6,240	4,668	763	500	40	165	58	410	
1962.....	15,392	11,464	6,435	5,029	904	613	40	185	66	470	
1963.....	17,059	12,630	7,270	5,360	1,081	760	41	207	73	530	
1964.....	18,854	13,512	7,720	5,792	1,275	917	40	235	83	629	
1965.....	20,044	14,185	7,740	6,445	1,474	1,073	41	267	93	629	
1966.....	21,846	15,548	8,332	7,216	1,715	1,261	42	304	108	630	
1967.....	23,146	16,385	8,365	8,020	1,921	1,409	48	345	119	673	
1968.....	24,605	17,429	8,560	8,869	2,149	1,572	55	390	132	719	
1969.....	25,629	18,308	8,451	9,857	2,225	1,600	60	420	145	725	
1970.....	26,134	18,067	7,779	10,288	2,335	1,647	61	462	165	737	
1971.....	26,676	18,320	7,666	10,654	2,500	1,724	70	529	177	716	
1972.....	28,476	19,552	8,017	11,535	2,630	1,795	74	574	187	753	
1973.....	30,718	21,249	8,145	13,104	2,884	1,985	84	613	202	817	
1974.....	32,863	22,887	8,220	14,667	3,022	2,032	95	676	219	865	
1975.....	35,213	24,187	8,605	15,582	3,409	2,288	113	749	259	987	
1976.....	39,018	26,997	9,561	17,436	3,729	2,512	123	809	285	1,147	
1977.....	42,783	29,825	10,485	19,340	4,067	2,726	139	888	314	1,384	
1978.....	48,128	33,304	11,189	22,115	4,625	3,059	170	1,037	359	1,717	
1979.....	54,953	38,226	12,518	25,708	5,380	3,604	194	1,214	368	1,935	
1980.....	62,610	44,505	14,029	30,476	6,077	4,104	236	1,334	403	2,246	

Table A-2. National expenditures for R&D, by performing sectors and sources of funds: 1953-92 (page 2 of 2)
[In millions of dollars]

Year	Industry (2)			Universities & colleges				U&C FFRDCs			Other nonprofit institutions (2)				
	Federal Govt.	Sources			Sources				Sources			Sources			
		Total used (1)	Fed. Govt. (2)	Indus-try (3)	Total used (4)	Fed. Govt. (5)	Indus-try (6)	U&Cs (7)	Non-profits (8)	Total used (9)	Fed. Govt. (10)	Indus-try (11)	Nonprof-its (12)		
1981.....	\$71,868	\$8,426	\$51,810	\$16,382	\$35,428	\$6,846	\$4,565	\$291	\$1,554	\$436	\$2,486	\$2,300	\$1,550	\$225	\$525
1982.....	80,018	9,141	58,650	18,545	40,105	7,323	4,763	337	1,731	492	2,479	2,425	1,650	250	525
1983.....	89,139	10,582	65,268	20,680	44,588	7,877	4,983	388	1,929	577	2,737	2,675	1,850	275	550
1984.....	101,139	11,572	74,800	23,396	51,404	8,617	5,424	475	2,103	615	3,150	3,000	2,100	325	575
1985.....	113,819	12,945	84,239	27,196	57,043	9,687	6,057	559	2,376	695	3,523	3,425	2,400	375	650
1986.....	119,529	13,535	87,823	27,891	59,932	10,926	6,703	699	2,789	735	3,895	3,350	2,250	425	675
1987.....	125,353	13,413	92,155	30,752	61,403	12,154	7,333	789	3,201	831	4,206	3,425	2,200	450	775
1988.....	133,740	14,281	97,889	32,117	65,772	13,464	8,181	871	3,471	941	4,531	3,575	2,200	500	875
1989.....	140,763	15,121	101,854	31,292	70,562	15,009	8,984	998	3,946	1,081	4,729	4,050	2,500	550	1,000
1990.....	146,152	16,002	104,344	30,580	73,764	16,325	9,611	1,135	4,356	1,223	4,831	4,650	2,900	600	1,150
1991.....	150,800	16,500	106,750	30,400	76,350	17,450	10,100	1,250	4,750	1,350	5,000	5,100	3,200	650	1,250
1992.....	157,400	17,600	110,300	31,300	79,000	19,000	10,900	1,350	5,250	1,500	5,100	5,400	3,300	700	1,400

(1) Total funds used by Federal Government are from Federal sources.

(2) Expenditures for FFRDCs administered by industry and nonprofit institutions are included in the totals of the respective sectors.

(3) Industry R&D expenditures include all non-Federal sources of funds.

(4) Includes R&D funds from state and local government sources.

(5) Includes R&D expenditures only of FFRDCs administered by individual universities and colleges and by university consortia.
In 1990, 99 percent of total funds used were from Federal sources.

NOTES: Data are based on annual reports by performers except for the nonprofit sector; R&D expenditures by nonprofit sector performers have been estimated since 1973 on the basis of a survey conducted in that year. Data are preliminary for 1991 and estimated for 1992.
Data available to NSF's Division of Science Resources Studies as of May 14, 1992, have been incorporated.

KEY: FFRDCs = Federally funded research and development centers
U&Cs = Universities and colleges

SOURCES: National Science Foundation, "National Patterns of R&D Resources: 1992." Reported data were derived from "Research and Development in Industry: 1990"; "Academic Science/Engineering: R&D Expenditures, Fiscal Year 1990"; "Federal Funds for Research and Development: Fiscal Years 1990, 1991, and 1992"; and Aspen Systems Corporation prepared for NSF "Planned R&D Expenditures of Major U.S. Firms: 1991-1992"

Table A-3. Company and other (except Federal) funds for industrial R&D performance, by industry and size of company: 1980-90 (page 1 of 2)

[Dollars in millions]

Industry and size of company	SIC code	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Total.....		\$30,476	\$35,428	\$40,105	\$44,588	\$51,404	\$57,043	\$59,932	\$61,403	\$65,772	\$70,562	\$73,764
Distribution by industry												
Food, kindred, and tobacco products (1).....	20,21	(D)	636	777	824	1,081	1,136	1,280	1,204	1,192	1,284	1,376
Textiles and apparel.....	22,23	(D)	116	136	150	182	218	246	243	210	(S)	(S)
Rubber products.....	24,25	(D)	161	159	152	143	147	144	137	156	172	180
Lumber, wood products, and furniture.....	26	(D)	566	566	552	594	576	538	604	664	686	736
Paper and allied products.....	28	4,264	5,205	6,197	6,792	7,736	8,310	8,664	9,445	10,573	11,383	12,498
Chemicals and allied products.....												
Industrial chemicals.....	281-82,286	1,856	2,393	2,810	2,828	3,057	3,281	3,374	3,531	3,763	3,960	4,280
Drugs and medicines.....	283	(D)	2,064	2,473	2,896	3,310	3,481	3,657	4,095	4,743	5,164	5,651
Other chemicals.....	284-85,287-89	653	747	914	1,068	1,369	1,548	1,633	1,819	2,067	2,259	2,567
Petroleum refining and extraction.....	13,29	1,401	1,780	2,003	2,074	2,245	2,194	1,971	1,883	1,923	2,050	2,083
Rubber products.....	30	(D)	598	617	638	671	659	655	596	635	678	732
Stone, clay, and glass products.....	32	(D)	472	472	586	705	825	941	985	826	863	893
Primary metals.....	33	594	702	711	701	683	730	786	711	642	715	774
Ferrous metals and products.....	331-32,3398-99	338	415	426	396	357	323	336	249	257	254	240
Nonferrous metals and products.....	333-36	256	287	285	305	326	407	450	462	385	461	534
Fabricated metal products.....	34	501	545	565	634	773	780	800	633	687	664	675
Machinery.....	35	5,254	6,124	7,227	7,911	9,312	10,721	10,701	10,577	11,992	13,478	13,804
Office, computing, and accounting machines.....	357	(D)	3,847	4,944	5,634	7,011	8,418	8,380	8,193	9,371	10,780	11,050
Other machinery, except electrical.....	351-56,358-59	(D)	2,277	2,283	2,277	2,301	2,303	2,321	2,384	2,621	2,698	2,754
Electrical equipment.....	36	5,431	6,409	6,682	8,158	9,037	9,271	9,767	10,449	11,061	11,641	11,768
Radio and TV receiving equipment.....	365	346	358	364	324	362	350	133	139	139	84	93
Communication equipment.....	366	2,367	2,975	3,555	4,500	5,147	5,174	5,117	5,455	5,675	5,820	5,533
Electronic components.....	367	1,165	1,212	1,342	1,810	2,354	2,826	3,357	3,630	4,068	4,458	4,747
Other electrical equipment.....	361-64,369	1,553	1,864	1,421	1,524	1,174	921	1,160	1,225	1,179	1,279	1,395
Transportation equipment.....	37	6,958	7,739	8,621	8,991	10,406	12,092	13,567	13,462	14,162	15,083	14,992
Motor vehicles and motor vehicles equipment.....	371	4,300	4,219	4,321	4,754	5,384	6,164	7,171	7,167	7,769	8,725	8,550
Other transportation equipment.....	373-75,379	(D)	80	114	227	258	279	330	356	370	353	302
Aircraft and missiles.....	372,376	2,570	3,440	4,186	4,010	4,764	5,649	6,066	5,939	6,023	6,005	6,140

Table A-3. Company and other (except Federal) funds for industrial R&D performance, by industry and size of company: 1980-90 (page 2 of 2)

[Dollars in millions]

Industry and size of company	SIC code	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Distribution by industry												
Professional and scientific instruments.....	38	\$2,456	\$2,978	\$3,407	\$3,816	\$4,211	\$4,622	\$4,752	\$4,950	\$5,306	5,630	\$6,064
Scientific and mechanical measuring instruments.....	381-82	1,001	1,235	1,363	1,605	1,671	1,596	1,521	1,598	1,710	1,858	2,076
Optical, surgical, photographic, and other instruments.....	383-87	1,454	1,743	2,044	2,211	2,540	3,026	3,231	3,352	3,596	3,772	3,988
Other manufacturing industries (1).....	27,31,39	339	411	493	525	373	361	380	380	383	400	445
Nonmanufacturing industries.....	10-11,14-17,40-42,44-51,53-54,56,60,62-63,72-73,78,806-07,87	1,037	1,048	1,472	2,084	3,252	4,401	4,740	5,144	5,360	5,620	6,515
Distribution by size of company [Based on number of employees]												
Less than 500.....		1,711	1,880	2,411	3,781	3,781	5,127	6,203	6,200	(S)	(S)	(S)
500 to 999.....		2,257	2,586	3,241	3,438	4,618	5,249	6,243	6,281	1,517	1,660	1,817
1,000 to 4,999.....		1,596	2,369	2,224	2,080	2,764	3,350	3,455	3,753	6,441	6,646	6,538
5,000 to 9,999.....		4,867	5,537	6,448	7,228	8,546	8,366	8,489	9,681	4,322	4,815	5,867
10,000 to 24,999.....		20,045	23,056	25,781	28,061	30,354	33,421	33,778	33,878	37,438	41,860	42,137
25,000 or more.....												

(1) Until 1984, tobacco products (SIC 21) were included with "other manufacturing industries."

(D) Data have been withheld to avoid disclosing operations of individual companies.

(S) Data have been withheld due to imputation of more than 50 percent.

NOTE: Company funds include funds for industrial R&D work performed within company facilities in the U.S. from all sources except the Federal Government. These sources may include other companies, research institutions, colleges and universities, other nonprofit organizations, and state and local governments, as well as companies' own funds. Company-financed R&D not performed within the company is excluded.

SOURCE: National Science Foundation, Survey of Industrial Research and Development

Table A-4. Rates of change in industrial R&D spending: 1975-80, 1980-85, 1985-90, and 1990-92

Industry	SIC code	Average annual real change in industrial R&D spending			
		[percent]			
		1975-80	1980-85	1985-90	1990-92 (est.)
Total.....		6.1 %	7.3 %	1.6 %	0.1 %
Chemicals and allied products.....	28	3.3	8.2	4.7	3.2
Industrial and other chemicals.....	281-82,284-89	2.4 (1)	7.9	3.5	-0.8
Drugs and medicines.....	283	4.2 (1)	8.5	6.3	7.8
Petroleum refining and extraction.....	13,29	6.8 (1)	3.5	-4.5	-1.7
Machinery.....	35	6.0	9.2	1.5	-0.2
Office, computing, and accounting machines.....	357	6.3	13.2	1.9	-0.4
Other machinery, except electrical.....	351-56,358-59	5.5	-0.8	0.0	0.4
Electrical equipment.....	36	5.9	5.3	1.2	-1.8
Communication equipment.....	366	4.1	10.7	-2.2	NA
Electronic components.....	367	17.4 (2)	13.0	7.0	NA
Other electrical equipment.....	361-65,369	2.7 (2)	-12.6	-0.4	NA
Transportation equipment.....	37	7.3	5.7	0.7	NA
Motor vehicles and motor vehicles equipment.....	371	7.8	1.7	3.0	-0.5
Aircraft and missiles.....	372,376	6.5	10.8	-1.9	-1.0
Professional and scientific instruments.....	38	11.0	7.4	1.9	NA
Scientific and mechanical measuring instruments....	381-82	22.3	3.9	1.7	-1.0
Optical, surgical, photographic, and other instruments.....	383-87	5.9	9.6	2.0	NA
Nonmanufacturing industries.....	08,10-12,14-17, 40-67,72-73, 806-07,891	10.9	26.4	4.4	NA

(1) Estimated by NSF staff.

(2) Average annual real change for 1974-80.

NA = Not available

NOTE: The 1987 GDP implicit price deflator was used to convert current dollars to constant dollars.

SOURCES: National Science Foundation, Survey of Industrial Research and Development and NSF Panel on Industrial Science and Technology

Table A-5. Company and other (except Federal) R&D funds as a percentage of net sales in R&D-performing manufacturing companies, by industry and size of company: 1980-90 (page 1 of 2)

Industry and size of company	SIC code	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Total.....		2.1 %	2.2 %	2.6 %	2.6 %	2.6 %	3.0 %	3.2 %	3.1 %	3.1 %	3.2 %	3.2
Distribution by industry												
Food, kindred, and tobacco products (1).....	20,21	(D)	0.4	0.4	0.4	0.4	0.6	0.6	0.6	0.5	0.5	0.5
Textiles and apparel.....	22,23	(D)	0.4	0.5	0.4	0.5	0.5	0.5	0.4	0.4	0.4	0.4
Lumber, wood products, and furniture.....	24,25	0.8	0.8	0.8	0.8	0.7	0.8	0.6	0.6	0.7	0.7	0.7
Paper and allied products.....	26	1.0	1.0	1.1	0.9	0.8	0.8	0.7	0.6	0.7	0.7	0.8
Chemicals and allied products.....	28	3.3	3.4	4.0	4.2	4.6	4.9	5.1	5.2	5.3	5.3	5.7
Industrial chemicals.....	281-82,286	2.8	2.8	3.5	3.4	3.8	4.2	4.4	4.4	4.3	4.3	4.5
Drugs and medicines.....	283	6.1	6.3	7.0	7.7	8.2	8.0	8.4	8.7	9.0	9.1	9.8
Other chemicals.....	284-85,287-89	1.9	2.1	2.3	2.5	2.9	3.1	3.3	3.3	3.5	3.4	3.9
Petroleum refining and extraction.....	13,29	0.5	0.6	0.8	0.7	0.7	0.9	1.1	1.0	1.0	1.0	0.8
Rubber products.....	30	(D)	1.9	1.7	1.7	1.9	1.8	1.7	1.6	1.6	1.7	1.8
Stone, clay, and glass products.....	32	1.3	1.4	1.7	1.9	1.9	2.3	2.4	2.5	2.2	2.3	2.3
Primary metals.....	33	0.5	0.7	0.8	0.8	0.9	0.9	1.0	0.9	0.8	0.9	1.0
Ferrous metals and products.....	331-32,3398-99	0.5	0.6	0.6	0.6	0.6	0.5	0.7	0.6	0.6	0.6	0.6
Nonferrous metals and products.....	333-36	0.6	1.0	1.3	1.2	1.2	1.4	1.5	1.3	1.1	1.2	1.5
Fabricated metal products.....	34	1.2	1.2	1.2	1.3	1.4	1.4	1.4	1.2	1.0	1.0	1.0
Machinery.....	35	4.5	4.4	5.0	5.4	5.8	6.7	7.3	7.1	7.2	8.0	8.4
Office, computing, and accounting machines.....	357	10.4	9.7	10.4	10.0	10.5	12.4	12.4	12.3	11.5	13.5	15.4
Other machinery, except electrical.....	351-56,358-59	2.2	2.3	2.4	2.4	2.5	2.6	2.9	3.0	3.1	3.0	3.0
Electrical equipment.....	36	3.9	4.2	4.4	5.0	4.5	4.8	5.1	5.4	5.2	4.9	4.9
Radio and TV receiving equipment.....	365	2.7	2.6	3.3	2.9	3.7	4.3	3.6	3.2	3.0	2.8	3.1
Communication equipment.....	366	5.4	6.0	6.7	7.2	5.1	5.4	5.2	5.5	5.4	5.3	4.9
Electronic components.....	367	5.9	5.7	5.2	6.6	6.6	8.2	9.2	8.5	8.0	8.0	8.6
Other electrical equipment.....	361-64,369	2.5	2.8	2.3	2.6	2.2	2.0	2.2	2.6	2.4	2.0	2.2
Transportation equipment	37					3.3	3.4	3.6	3.4	3.5	3.7	3.7
Motor vehicles and motor vehicles equipment.....	371	4.2	3.9	4.0	3.5	3.0	3.1	3.3	3.4	3.4	3.8	3.9
Other transportation equipment.....	373-75,379	0.3 %	0.3 %	0.7 %	1.7 %	2.0 %	2.3 %	2.7 %	2.5 %	2.5 %	2.3 %	1.9
Aircraft and missiles.....	372,376	3.8	4.6	5.1	4.1	4.0	3.9	4.0	3.6	3.6	3.6	3.5

Table A-5. Company and other (except Federal) R&D funds as a percentage of net sales in R&D-performing manufacturing companies, by industry and size of company: 1980-90 (page 2 of 2)

Industry and size of company	SIC code	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Professional and scientific instruments.....	38	6.1	6.7	7.3	7.7	7.6	8.3	8.2	7.5	7.3	7.3	7.6
Scientific and mechanical measuring instruments... Optical, surgical, photographic, and other instruments.....	381-82 383-87	6.2 6.0	6.9 6.6	7.6 7.1	8.8 7.1	8.3 7.3	8.4 8.1	8.4 8.0	8.1 7.2	8.4 6.9	8.5 6.9	9.4 6.9
Other manufacturing industries (1).....	27,31,39	0.4	0.4	0.8	1.0	1.1	1.0	1.2	1.1	1.1	1.0	1.1
Distribution by size of company [Based on number of employees]												
Less than 500.....		1.2	1.4	1.6	2.2	2.8	3.4	4.0	3.8	3.6	3.6	3.6
500 to 999.....						2.2	2.2	2.2	2.2	2.1	1.6	1.8
1,000 to 4,999.....		1.4	1.5	1.7	2.0	2.0	2.4	2.4	2.4	2.1	2.0	2.1
5,000 to 9,999.....		1.1	1.7	1.5	1.3	1.6	1.8	2.0	2.0	2.3	2.5	2.7
10,000 to 24,999.....		1.4	1.6	2.0	2.3	2.5	2.5	2.6	2.5	2.6	2.4	2.7
25,000 or more.....		2.5	2.7	3.3	3.4	3.2	3.5	3.7	3.8	3.8	3.7	3.8

(1) Until 1984, tobacco products, SIC 21, were included with "other manufacturing industries."

(D) Data have been withheld to avoid disclosing operations of individual companies.

SOURCE: National Science Foundation, Survey of Industrial Research and Development

Table A-6. R&D scientists and engineers per 1,000 employees in manufacturing companies, by industry and size of company: 1980-90 (page 1 of 2)

Industry and size of company	SIC code	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Distribution by industry												
Total.....		27	29	33	34	40	43	45	45	47	49	49
Food, kindred, and tobacco products (1).....	20,21	5	6	6	6	7	8	7	7	7	7	7
Textiles and apparel.....	22,23	3	3	4	4	5	5	4	4	(S)	4	4
Lumber, wood products, and furniture.....	24,25	6	(S)	(S)	(S)	6	6	5	5	5	5	5
Paper and allied products.....	26	14	16	14	12	13	13	11	11	11	11	12
Chemicals and allied products.....	28	42	44	51	54	57	57	70	68	70	72	73
Industrial chemicals.....	281-82,286	36	37	44	45	41	39	56	52	55	56	57
Drugs and medicines.....	283	60	66	74	(S)	89	81	98	98	99	98	104
Other chemicals.....	284-85,287-89	30	33	37	39	51	62	63	61	61	63	64
Petroleum refining and extraction.....	13,29	17	20	22	22	22	21	19	20	24	25	25
Rubber products.....	30	(S)	25	(S)	(S)	27	26	25	19	(S)	17	17
Stone, clay, and glass products.....	32	13	13	15	16	17	20	20	24	27	29	29
Primary metals.....	33	7	8	10	11	12	12	11	12	13	12	13
Ferrous metals and products.....	331-32,3398-99	6	6	8	11	11	11	7	9	9	9	10
Nonferrous metals and products.....	333-36	12	13	13	13	16	16	17	16	17	16	16
Fabricated metal products.....	34	14	15	(S)	(S)	(S)	(S)	(S)	17	17	18	18
Machinery.....	35	36	35	48	57	56	60	64	67	68	76	81
Office, computing, and accounting machines.....	357	72	71	80	88	90	99	107	115	116	133	143
Other machinery, except electrical.....	351-56,358-59	18	19	26	30	32	29	26	29	29	30	32
Electrical equipment.....	36	44	48	55	51	49	53	59	65	70	70	73
Radio and TV receiving equipment.....	365	35	51	(S)	(S)	(S)	23	55	45	48	45	29
Communication equipment.....	366	55	56	74	61	56	62	68	73	83	77	80
Electronic components.....	367	55	66	66	(S)	(S)	81	82	86	102	105	111
Other electrical equipment.....	361-64,369	32	34	(S)	(S)	30	30	26	28	26	26	30
Transportation equipment.....	37					(S)	71	69	68	73	73	72
Motor vehicles and motor vehicles equipment.....	371	30	30	31	30	27	28	38	42	41	43	45
Other transportation equipment.....	373-75,379	9	9	12	(S)	(S)	8	23	38	39	47	49
Aircraft and missiles.....	372,376	92	98	94	102	110	116	99	91	101	100	96

Table A-6. R&D scientists and engineers per 1,000 employees in manufacturing companies, by industry and size of company: 1980-90 (page 2 of 2)

Industry and size of company	SIC code	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Distribution by industry												
Professional and scientific instruments.....	38	39	46	(S)	(S)	(S)	(S)	(S)	71	70	76	71
Scientific and mechanical measuring instruments....	381-82	(S)	(S)	(S)	(S)	(S)	(S)	(S)	85	94	106	106
Optical, surgical, photographic, and other instruments.....	383-87	48	47	(S)	(S)	(S)	70	61	63	58	60	53
Other manufacturing industries (1).....	27,31,39	7	7	9	(S)	(S)	(S)	(S)	18	18	16	13
Distribution by size of company [Based on number of employees]												
Less than 500.....		25	28	30	34	42	50	59	59	58	59	55
500 to 999.....						21	21	23	27	26	27	28
1,000 to 4,999.....		19	21	22	25	24	26	32	30	31	30	31
5,000 to 9,999.....		19	18	23	22	19	19	28	29	29	39	36
10,000 to 24,999.....		20	23	26	26	29	30	33	32	34	31	33
25,000 or more.....		34	36	43	42	47	49	56	57	58	62	62

(1) Until 1984, tobacco products, SIC 21, were included with "other manufacturing industries."

(S) Data have been withheld due to imputation of 50 percent or more.

NOTE: The number of R&D scientists and engineers per 1,000 employees for 1989 is derived by dividing the arithmetic mean of scientists and engineers employed in January 1989 and January 1990 by the number of employees in all activities in March 1989. Similar procedures were used for earlier years. Nonmanufacturing industries are included in pre-1983 calculations.

SOURCE: National Science Foundation, Survey of Industrial Research and Development

Table A-7. Share of global exports of high-technology products

Ranking	Microelectronics			Computers			Telecommunications Equipment			Aerospace		
	1980	1989		1980	1989		1980	1989		1980	1989	
1	United States (18.3)	Japan (22.1)		United States (38.6)	United States (24.0)		West Germany (16.7)	Japan (29.7)		United States (47.6)	United States (45.8)	
2	Japan (13.2)	United States (21.9)		West Germany (11.5)	Japan (17.5)		Sweden (15.3)	West Germany (9.5)		United Kingdom (19.7)	West Germany (12.5)	
3	Singapore (10.1)	Malaysia (8.9)		United Kingdom (10.4)	United Kingdom (9.0)		United States (10.9)	United States (8.8)		West Germany (9.1)	United Kingdom (10.9)	
4	Malaysia (8.9)	South Korea (7.4)		France (8.6)	West Germany (6.9)		Japan (10.3)	Sweden (8.1)		France (6.0)	France (10.2)	
5	West Germany (8.4)	West Germany (5.8)		Italy (6.6)	Taiwan (5.8)		Netherlands (9.3)	Hong Kong (6.3)		Canada (4.4)	Canada (4.4)	
6	France (4.9)	Singapore (5.6)		Japan (4.3)	Singapore (4.6)		Belgium (7.4)	United Kingdom (5.1)		Netherlands (2.5)	Italy (3.3)	
7	Hong Kong (4.8)	United Kingdom (4.5)		Canada (3.4)	France (4.2)		France (6.5)	France (4.5)		Italy (2.1)	Netherlands (2.9)	
8	United Kingdom (4.5)	Hong Kong (4.2)		Sweden (2.9)	Hong Kong (4.0)		Canada (5.1)	Canada (4.1)		Belgium (1.2)	Japan (1.1)	
9	South Korea (4.2)	Taiwan (3.5)		Hong Kong (1.9)	Italy (3.7)		United Kingdom (4.1)	Taiwan (3.5)		Switzerland (0.8)	Belgium (1.0)	
10	Philippines (3.8)	France (3.1)		Netherlands (1.6)	Netherlands (3.6)		Italy (2.7)	South Korea (3.2)		Japan (0.6)	Sweden (1.0)	

Ranking	Machine Tools and Robotics			Scientific/Precision Equipment			Medicine and Biologicals			Organic Chemicals		
	1980	1989		1980	1989		1980	1989		1980	1989	
1	West Germany (25.8)	Japan (23.8)		United States (28.3)	United States (25.2)		West Germany (16.7)	West Germany (15.6)		West Germany (19.1)	West Germany (17.0)	
2	United States (14.1)	West Germany (20.8)		West Germany (18.1)	West Germany (18.5)		Switzerland (12.5)	Switzerland (12.2)		United States (13.9)	United States (15.5)	
3	Japan (11.3)	United States (12.1)		United Kingdom (9.4)	Japan (12.9)		United Kingdom (12.0)	United States (12.2)		Netherlands (10.9)	France (8.7)	
4	Switzerland (9.1)	Italy (10.0)		France (8.0)	United Kingdom (9.6)		France (11.9)	United Kingdom (11.8)		France (10.7)	Netherlands (8.1)	
5	Italy (8.7)	Switzerland (8.4)		Japan (7.1)	France (5.6)		United States (11.4)	France (10.3)		United Kingdom (8.4)	United Kingdom (7.2)	
6	United Kingdom (6.9)	United Kingdom (4.2)		Switzerland (5.5)	Switzerland (4.1)		Italy (5.4)	Italy (5.5)		Japan (6.3)	Japan (7.0)	
7	France (6.3)	France (3.2)		Netherlands (4.2)	Netherlands (3.1)		Belgium (5.2)	Belgium (4.5)		Belgium (6.1)	Belgium (5.7)	
8	Sweden (2.4)	Taiwan (2.3)		Italy (3.0)	Italy (3.1)		Netherlands (4.7)	Sweden (3.7)		Italy (4.6)	Italy (4.6)	
9	Canada (1.8)	Sweden (2.0)		Belgium (2.7)	Sweden (2.4)		Sweden (2.5)	Netherlands (3.6)		Switzerland (3.3)	Switzerland (3.0)	
10	Netherlands (1.8)	Belgium (1.9)		Sweden (2.7)	Canada (1.9)		Japan (2.2)	Japan (2.8)		Canada (2.5)	Canada (2.4)	

Table A-8. Worldwide sales of information systems, by producer base region: 1984 and 1988

Information system	1984				1988					
	World sales (dollars in billions)	Regional distribution			World sales (dollars in billions)	Regional distribution				
		N. Amer.	Europe	Japan		N. Amer.	Europe	Japan	Korea	Taiwan
All products	137	77	11	12	261	61	16	21	1	1
Mainframe	22.6	77	6	16	30.4	53	9	37	0	0
Mini	16	79	13	8	25.5	72	13	15	0	0
Micro	14.8	86	7	7	31.3	64	12	16	4	4
Datacomm	9.1	52	32	16	17	42	21	36	1	0
Peripherals	37.3	75	10	14	65.9	53	15	29	2	1
Software	10.3	76	14	10	23.1	70	17	13	0	0
Services	9	86	7	7	24	78	14	8	0	0
Maintenance	14.4	81	10	9	29.8	72	18	10	0	0
Other revenues	3.4	68	14	18	13.2	48	43	9	0	0

Notes: Compilation is from Datamation 100 and was supplemented by other industry sources. "0" means < 1 percent after rounding. Distribution of information system revenues by product segment has occasionally used 1987 data when 1988 data were unavailable. Compilations were based on data for 151 largest information systems companies. Workstations were counted as minicomputer sales. Amdahl, NAS, Zenith, and Wyse were counted as U.S. firms. Nihon Univac was counted as a Japanese firm. 1984 data cover 104 largest U.S. companies, 33 European companies, and 14 Japanese companies. 1988 data cover 100 largest U.S. companies plus Northern Telecom (Canada); 30 largest European; 19 largest Japanese; Acer & Mitec (Taiwan); and Samsung (Korea). The remainder of Taiwan and Korean computer industries were estimated and added in.

Source: Kenneth Flamm, *Globalisation in the Computer Industry*, Organisation for Economic Cooperation and Development, Paris, December 1990.

Table A-9. International R&D expenditures and R&D as a percentage of GDP: 1961-90

	R&D expenditures (1)							R&D expenditures as a percentage of GNP						
	United States	Japan	Germany	France	United Kingdom	Italy	Sweden	United States	Japan	Germany	France	United Kingdom	Italy	Sweden
	-----Billions of constant 1987 dollars-----							-----Percent-----						
1961....	54.6	NA	NA	NA	NA	NA	NA	2.7	1.4	NA	1.4	2.5	NA	NA
1962....	57.3	NA	NA	NA	NA	NA	NA	2.7	1.5	1.2	1.5	NA	NA	NA
1963....	62.7	6.2	NA	5.7	NA	2.0	NA	2.8	1.5	1.4	1.6	NA	0.6	NA
1964....	68.2	7.0	7.3	7.1	10.5	NA	0.9	2.9	1.5	1.6	1.8	2.3	NA	1.2
1965....	70.6	7.7	8.7	8.2	NA	2.2	NA	2.8	1.6	1.7	2.0	NA	0.7	NA
1966....	74.4	8.4	9.5	8.8	11.2	NA	NA	2.8	1.5	1.8	2.1	2.3	NA	NA
1967....	76.5	9.7	10.1	9.7	11.5	2.8	1.0	2.8	1.6	2.0	2.2	2.3	0.7	1.3
1968....	77.5	11.5	10.9	9.9	11.7	3.2	NA	2.8	1.7	2.0	2.1	2.2	0.8	NA
1969....	76.8	13.4	11.7	10.1	11.8	3.5	1.1	2.7	1.7	1.8	2.0	2.3	0.8	1.2
1970....	74.4	16.0	13.8	10.1	NA	3.9	NA	2.6	1.9	2.1	1.9	NA	0.8	NA
1971....	72.1	17.1	15.2	10.5	NA	4.1	1.4	2.4	1.9	2.2	1.9	NA	0.9	1.5
1972....	73.3	18.8	15.8	10.7	11.6	4.3	NA	2.4	1.9	2.2	1.9	2.1	0.9	NA
1973....	74.4	20.7	15.8	10.7	NA	4.3	1.6	2.3	2.0	2.1	1.8	NA	0.8	1.6
1974....	73.2	21.2	16.2	11.2	NA	4.2	NA	2.2	2.0	2.1	1.8	NA	0.8	NA
1975....	71.6	21.6	16.7	11.3	12.2	4.6	1.9	2.2	2.0	2.2	1.8	2.2	0.8	1.7
1976....	74.6	22.4	17.0	11.5	NA	4.5	NA	2.2	2.0	2.2	1.8	NA	0.8	NA
1977....	76.6	23.1	17.4	11.8	NA	4.7	1.9	2.2	2.0	2.2	1.8	NA	0.8	1.8
1978....	79.8	24.3	18.7	12.1	13.5	4.6	NA	2.1	2.0	2.3	1.8	2.2	0.7	NA
1979....	83.8	26.8	20.5	12.9	NA	4.9	2.1	2.2	2.1	2.4	1.8	NA	0.7	1.9
1980....	87.3	29.3	21.4	13.3	NA	5.1	NA	2.3	2.2	2.5	1.8	NA	0.8	NA
1981....	91.1	32.0	21.1	14.6	15.4	6.0	2.5	2.4	2.3	2.4	2.0	2.4	0.9	2.3
1982....	95.5	34.5	21.8	15.6	NA	6.2	NA	2.5	2.4	2.5	2.1	NA	0.9	NA
1983....	102.3	37.1	22.0	16.0	15.0	6.6	2.9	2.6	2.6	2.5	2.1	2.3	1.0	2.6
1984....	111.1	39.6	22.4	16.8	NA	7.1	NA	2.7	2.6	2.5	2.2	NA	1.0	NA
1985....	120.6	43.5	24.4	17.3	15.9	8.1	3.4	2.8	2.8	2.7	2.3	2.3	1.1	2.9
1986....	123.3	43.9	24.9	17.5	16.8	8.3	NA	2.8	2.8	2.7	2.2	2.3	1.1	NA
1987....	125.4	46.9	26.5	18.1	16.9	9.0	3.7	2.8	2.8	2.9	2.3	2.3	1.2	3.0
1988....	128.8	50.3	27.2	18.8	17.4	9.5	NA	2.7	2.9	2.9	2.3	2.2	1.2	NA
1989....	129.8	54.5	28.2	19.9	18.0	10.0	3.6	2.7	3.0	2.9	2.3	2.3	1.2	2.9
1990....	129.5	59.2	28.8	20.9	NA	11.1	NA	2.7	3.1	2.8	2.4	NA	1.4	NA

(1) Conversions of foreign currencies to U.S. dollars are calculated with OECD purchasing power parity exchange rates. Constant 1987 dollars are based on U.S. Department of Commerce GDP implicit price deflators.

NA = Not available

SOURCES: NSF, Division of Science Resources Studies; Organisation for Economic Cooperation and Development (OECD); International Monetary Fund; and national sources

Table A-10. International nondefense R&D expenditures and nondefense R&D as a percentage of GDP: 1971-90

	Nondefense R&D expenditures (1)							Nondefense R&D expenditures as a percentage of GNP						
	United States	Japan	Germany	France	United Kingdom	Italy	Sweden	United States	Japan	Germany	France	United Kingdom	Italy	Sweden
	-----Billions of constant 1987 dollars-----							-----Percent-----						
1971....	50.2	17.0	14.1	8.0	NA	4.0	NA	1.7	1.9	2.1	1.4	NA	0.8	NA
1972....	50.4	18.7	15.0	8.4	8.5	4.2	NA	1.6	1.9	2.1	1.5	1.5	0.8	NA
1973....	52.6	20.5	14.7	8.4	NA	4.2	NA	1.6	2.0	2.0	1.4	NA	0.8	NA
1974....	53.1	21.0	15.1	8.9	NA	4.1	NA	1.6	2.0	2.0	1.4	NA	0.8	NA
1975....	51.9	21.5	15.7	9.1	8.5	4.6	1.6	1.6	2.0	2.1	1.4	1.4	0.8	1.4
1976....	54.7	22.3	15.9	9.4	NA	4.4	NA	1.6	2.0	2.0	1.4	NA	0.8	NA
1977....	55.3	23.0	16.4	9.6	NA	4.7	1.6	1.6	2.0	2.0	1.4	NA	0.8	1.5
1978....	58.4	24.1	17.6	9.7	9.6	4.5	NA	1.6	2.0	2.1	1.4	1.5	0.7	NA
1979....	62.8	26.6	19.3	10.1	NA	4.8	1.8	1.6	2.1	2.2	1.4	NA	0.7	1.6
1980....	66.5	29.1	20.4	10.3	NA	5.1	NA	1.7	2.2	2.3	1.4	NA	0.7	NA
1981....	67.8	31.9	20.2	10.9	11.4	5.8	2.3	1.8	2.3	2.3	1.5	1.8	0.8	2.1
1982....	69.2	34.3	20.9	12.0	NA	6.1	NA	1.8	2.4	2.4	1.6	NA	0.9	NA
1983....	73.7	36.9	21.0	12.6	11.1	6.4	2.6	1.9	2.5	2.4	1.7	1.7	0.9	2.3
1984....	78.9	39.3	21.4	13.3	NA	6.7	NA	1.9	2.6	2.4	1.7	NA	1.0	NA
1985....	84.9	43.2	23.2	13.7	11.8	7.6	3.0	2.0	2.8	2.6	1.8	1.7	1.1	2.6
1986....	85.2	43.6	23.6	13.7	13.0	7.9	NA	1.9	2.7	2.6	1.8	1.8	1.1	NA
1987....	86.2	46.6	25.2	14.2	13.3	8.6	3.3	1.9	2.8	2.7	1.8	1.8	1.1	2.7
1988....	90.2	49.9	26.0	14.6	14.1	8.9	NA	1.9	2.8	2.7	1.8	1.8	1.1	NA
1989....	92.3	54.1	26.9	15.6	14.7	9.4	3.2	1.9	3.0	2.7	1.8	1.9	1.2	2.6
1990....	94.1	58.8	27.3	16.0	NA	10.7	NA	1.9	3.0	2.7	1.8	NA	1.3	NA

NA = Not available

(1) Nondefense expenditures estimated here as total R&D expenditures, generally reported by the R&D performers, minus government R&D funds for defense purposes, generally taken from national budget documents; that is, as reported by the R&D funders. Conversions of foreign currencies to U.S. dollars are calculated with OECD purchasing power parity exchange rates. Constant 1987 dollars are based on U.S. Department of Commerce GDP implicit price deflator.

SOURCES: NSF, Division of Science Resources Studies; Organisation for Economic Cooperation and Development (OECD); International Monetary Fund; and national sources

Table A-11. Government R&D support by socioeconomic objective: 1989

	United States	Japan	Germany	France	United Kingdom
	-----Percent-----				
Total.....	100.0	100.0	100.0	100.0	100.0
Defense.....	65.5	9.0	19.0	41.9	55.2
Civil space.....	7.3	11.1	8.5	8.7	3.8
Advancement of research.....	3.8	13.8	20.7	17.5	5.8
Health.....	12.9	4.8	5.2	3.7	6.2
Industrial development.....	0.2	8.1	19.0	15.0	10.3
Energy.....	3.9	39.2	9.5	4.0	4.0
Agriculture, forestry, and fishing.....	1.9	6.5	3.1	4.6	5.5
Other.....	4.5	7.6	14.9	4.5	9.2

NOTE: Data adjusted to exclude general university funds for Japan (43 percent of the government-funded R&D total), West Germany (33 percent), the United Kingdom (18 percent), and France (12 percent).

SOURCES: Organisation for Economic Cooperation and Development, NSF, and national sources for Japan

Appendix B

IRI Survey: Questionnaire and Results

IRI Survey Purpose and Design

To identify the factors adversely affecting U.S. industry's ability to compete in global markets for high-tech products, the Committee needed input from leading industrial R&D officials.¹

Preparatory to receiving this input, the Committee first identified potential factors in the erosion of U.S. technology leadership. It identified these factors based on

- presentations by Dr. Arden Bement, Dr. Joseph Morone, and others;²
- discussions among Committee members; and
- a review of recent literature.

Subsequently, the Committee identified five major categories with 6 to 10 factors under each that may be responsible for the erosion in U.S. technology leadership.

The Industrial Research Institute (IRI) was contacted, and it agreed to work with the Committee.³ The Committee and IRI were interested in determining the relative importance of each of these categories and factors in maintaining U.S. technology leadership. IRI used the list prepared by the Committee to survey its membership; it agreed to share the survey results with the Committee.

The survey questionnaire, entitled "Potential Causes for the Erosion in U.S. Technology Leadership," was mailed in June 1990 to the 237 members of IRI with U.S. mailing addresses. (A copy of the questionnaire appears at the end of this appendix.) Completed questionnaires were received from 139 members.⁴

¹The information the Committee obtained is thus limited by the fact that it is based on the opinions of industrial R&D officials only; chief executive officers and other industry officials may perceive the problems differently.

²Dr. Bement prepared a list, "Potential Root Causes for the Decline in Technology Leadership of U.S. Industry." Dr. Morone, Assistant Professor, School of Management, Rensselaer Polytechnic Institute, was a consultant to the Committee.

³IRI is an association of more than 250 companies. Its major function is to coordinate the study of problems confronting managers of industrial research and development. A company may join IRI if it (1) maintains a technical staff and research laboratory in the United States, and (2) engages primarily in industrial production. IRI membership includes R&D directors from most large U.S. R&D-performing companies. IRI member companies account for approximately 85 percent of industry-funded R&D in the United States.

⁴Instead of returning the survey forms, two IRI members wrote letters. One member wrote that his company was based in another country and he didn't think it appropriate for him to complete the questionnaire. (Other IRI members representing foreign-owned companies did respond to the survey, however.) Another IRI member, representing a company in the petroleum

IRI members were asked to rank both the five categories and the factors under each of the categories from highest to lowest in importance.⁵ In addition, they were provided space to add other factors they felt were important but may have been omitted from the Committee's list. They were also asked to provide recommendations for addressing the problems responsible for the erosion in U.S. technology leadership and to identify their companies' major industry (or industries) and domestic employment size group. The main survey results are described below.

The Five Categories

The five major categories identified by the Committee that may be responsible for the erosion in U.S. technology leadership were

- general management practices,
- external financial pressures,
- changing global technological environment,
- technology management practices, and
- Federal technology policy.

General management practices and *external financial pressures* are more at fault for the erosion in U.S. technology leadership than are the other three factors, according to the industrial R&D officials who participated in the survey. *General management practices* and *external financial pressures* received 91 and 86 first and second place rankings, respectively, and 61—or 44 percent—of the respondents ranked these two categories first and second. (See table B-1.)

Table B-1. Ranking of the five major categories

Rank	Category	Average rank	No. of 1st places	No. of 2nd places	No. of last places
1	General management practices	2.0	50	41	1
2	External financial pressures	2.2	45	41	9
3	Changing global technological environment	3.4	18	11	31
4	Technology management practices	3.8	5	18	44
5	Federal technology policy	3.8	6	14	46

Sources: Industrial Research Institute and NSB Committee on Industrial Support for R&D

industry, wrote that his industry was not losing technology leadership.

⁵Not all respondents ranked every category, some did not rank all factors within a category, and a few gave identical rankings to some of the factors. Missing and duplicative rankings were imputed using statistical procedures designed to maximize respondents' ordinal placement of categories and factors and minimize bias.

Federal technology policy, which received only 6 first and 14 second place "votes," was ranked last (closely behind *technology management practices*). Although *Federal technology policy* was ranked below the other categories, it cannot be inferred that the R&D directors consider this category to be unimportant in contributing to the decline in U.S. technology leadership; they only consider it less important than the other four categories.

One respondent suggested that the reason *Federal technology policy* was ranked last is because the United States lacks a national technology policy. According to this R&D official, it is not surprising that the IRI members gave less consideration to something that has never existed and therefore has never influenced their decision-making.

Response by Industry and by Size of Company

There was relatively little variation in response by industry and by size of company. (See tables B-2 and B-3.)

General management practices and *external financial pressures* were ranked first and second, respectively, by all but three industries. Respondents from the transportation equipment and instruments industries gave first place rankings to *changing global technological environment* (ranked third overall); those from the computer industry ranked *technology management practices* first.

No industry ranked *Federal technology policy* first. It received one second place ranking—from the communication services industry. This relatively high ranking is probably attributable to judicially imposed restrictions on companies in this industry. One respondent stated that his company was "precluded from major R&D investment" because the Modified Final Judgment imposed by the Federal judiciary prohibited his company's access to certain markets. (The ban was recently lifted.) *Federal technology policy* received third place rankings from the drug; other machinery; instruments; and research, development, and testing services industries.

Table B-2. Ranking of the five major categories by industry

Industry	No. of responses*	Gen'l mgmt practices	External financial pressures	Changing global tech. environment	Tech. mgmt practices	Federal tech. policy
All industries	127	1	2	3	4	5
Food, tobacco	11	1	2	4	3	5
Lumber, paper	6	1	2	3	4	5
Industrial chemicals	27	1	2	3	5	4
Drugs	10	2	1	4	5	3
Other chemicals	8	1	2	3	3	5
Petroleum	8	1	2	3	4	5
Rubber	4	1	2	5	3	4
Ferrous metals	5	1	2	3	5	4
Fabr. metal prod.	7	1	1	5	3	4
Other machinery	3	1	2	4	5	3
Computers	4	2	2	4	1	5
Electrical equip.	8	2	1	3	5	4
Transport. equip.	8	2	3	1	4	5
Instruments	3	2	4	1	4	3
Comm. svcs	4	2	1	5	4	2
Research, devel., and testing	3	2	1	5	3	2

*Two respondents did not identify their industries; six other respondents represent industries having fewer than three respondents.

Sources: Industrial Research Institute and NSB Committee on Industrial Support for R&D

Size of company made little difference in the ranking of the five categories. Almost all size groups gave *general management practices* and *external financial pressures* first and second place rankings.

Table B-3. Ranking of the five major categories by size of company

No. of domestic employees	No. of responses*	Gen'l mgmt practices	External financial pressures	Changing global tech. environment	Tech. mgmt practices	Federal tech. policy
All companies	127	1	2	3	4	5
Less than 1,000	5	1	2	3	4	5
1,000 - 4,999	21	1	2	4	3	5
5,000 - 9,999	14	2	1	4	5	3
10,000 - 24,999	36	1	1	3	4	5
25,000 - 49,000	26	1	3	2	4	4
More than 50,000	24	1	2	3	4	5

*One respondent did not select a company-size group.

Sources: Industrial Research Institute and NSB Committee on Industrial Support for R&D

General Management Practices

Survey respondents placed greatest emphasis on "short time horizons" and "management by the numbers rather than by strategic vision," ranking these two factors first and second, respectively, under the *general management practices* category. (See table B-4.) "Short time horizons" received 89 first and second place rankings, and "management by the numbers" received 81; 51—or 37 percent—of the respondents gave first and second place rankings to these two management practices that are usually associated with external financial pressures.

Several factors—e.g., "over-concern for shareholder value"—added to this category by the respondents allude to the interrelationship between this category and the *external financial pressures* category. Institutional investors' large and growing dominance in equity markets (and their impatience for quick returns), the high cost of capital, and the threat of unwelcome takeovers all create a financial environment in which long-term strategic investments in technology are likely to be sacrificed when there is an exaggerated emphasis on short-term profitability. The need for financial incentives that would induce management to adopt a longer term perspective was mentioned by one-third of those IRI members who added recommendations to their questionnaires.

"Failure and/or inability to integrate technology into business strategy" and "corporate executives' lack of scientific and technical insight and lack of experience in the management of science and

technology" were fairly consistently ranked third and fourth.⁶ Other factors cited by the respondents are closely related to these. These other factors are as follows:

- inability of marketing and top management to recognize opportunities based on new technology,
- domestic myopia—do not see the "globe" as a marketplace,
- too many lawyers and finance people in management positions, and
- "MBA syndrome" which encourages going for the top job—with little or no apprenticeship in understanding the nature of the company business and products.

Table B-4. Ranking of *general management practices*

Rank	Factor	Average rank	No. of 1st places	No. of 2nd places
1	Short time horizons	2.3	47	42
2	Management by the numbers rather than by strategic vision	2.3	47	34
3	Failure and/or inability to integrate technology into business strategy	3.0	22	30
4	Corporate executives' lack of scientific and technical insight and lack of experience in the management of science and technology	3.5	18	21
5	Executive talent reward structure	4.6	6	9
6	High rates of executive turnover	5.6	0	0

Sources: Industrial Research Institute and NSB Committee on Industrial Support for R&D

External Financial Pressures

Survey respondents overwhelmingly selected "growing dominance of institutional investors in equity markets and their demand for short term returns on their investments" as the most

⁶Several respondents added factors similar to these under the *technology management practices* category.

important factor in the category of *external financial pressures*. (See table B-5.) More than four out of five of the IRI members ranked this factor first or second.

Institutional investors—e.g., mutual funds and pension funds—have become a large and growing source of financing for U.S. firms. Their interest in maximizing the current value of their portfolios usually takes precedence over their interest in the long-term investment needs of the companies they are financing. The need for tax and other financial incentives to induce long-term holding by U.S. investors was frequently mentioned by the respondents in their recommendations.

"High cost of capital" finished a distant second in the ranking of factors under *external financial pressures*. Twelve IRI members addressed the cost of capital issue in their recommendations; most of these mentioned that reducing the budget deficit and increasing the savings rate would lower the cost of capital in the United States.

"Pressure to reduce debt accrued through leveraged buyouts and hostile takeovers," ranked fourth overall, was given high rankings by IRI members from companies that had experienced or were threatened by unwelcome raiders. This factor received 17 first place rankings, more than "growing costs of compliance with environmental, OSHA [Occupational Safety and Health Administration], and other Federal and state regulations," which was ranked third overall.

Table B-5. Ranking of *external financial pressures*

Rank	Factor	Average rank	No. of 1st places	No. of 2nd places
1	Growing dominance of institutional investors in equity markets and their demand for short term returns on their investments	1.7	80	33
2	High cost of capital	2.9	26	35
3	Growing costs of compliance with environmental, OSHA, and other Federal and state regulations that compete with and displace R&D investment	3.4	10	30
4	Pressures to reduce debt accrued through leveraged buyouts and hostile takeovers	3.5	17	22
5	Investment of "patient" capital inhibited by statutory separation of the managements of industrial and financial corporations (Glass-Steagal Act)	4.6	3	10
6	High cost of U.S. labor relative to that of other countries	4.9	4	2

Sources: Industrial Research Institute and NSB Committee on Industrial Support for R&D

Changing Global Technological Environment

There was less consensus in the IRI members' ranking of factors under *global technological environment* than was displayed in their ordering of the factors under the two previously discussed factors. Table B-6 shows a relatively small difference in the "average" rankings of the factors in this category. "Growing difficulty of controlling enough technological competitive advantage to sustain an entry barrier" was ranked highest, marginally ahead of the second-ranked factor, "declining lead times and faster product turnover cycles." These two factors received almost the same number of first and second place rankings and are closely related. Both are prominent characteristics of the electronics industry where rapid advancements in technology are continuously shortening product and process cycles, thus increasing the risk that companies will be unable to recover their investments fully and make a profit before their products become obsolete.

"Increasing number of skilled workers, including scientists and engineers, in other countries," ranked third overall, was considered to be the leading contributor to the *changing global technological environment* by 29 of the IRI officials. Several respondents added a factor referring to the "increasingly effective collaboration between other countries' governments and industries to foster national economic growth."

Table B-6. Ranking of *changing global technological environment*

Rank	Factor	Average rank	No. of 1st places	No. of 2nd places
1	Growing difficulty of controlling enough technological competitive advantage to sustain an entry barrier	2.9	36	27
2	Declining lead times and faster product turnover cycles	3.0	35	27
3	Increasing number of skilled workers, including scientists and engineers, in other countries	3.4	29	23
4	Fragmented structure of some U.S. industries (e.g., semiconductor equipment manufacturing) not conducive to efficient and effective R&D and its commercialization	3.4	20	25
5	Shifts from leadership to fast-follower technology development strategies	3.7	13	18
6	Intensifying efforts of foreign companies to derive income from the licensing of intellectual properties	4.9	6	6

Sources: Industrial Research Institute and NSB Committee on Industrial Support for R&D

Technology Management Practices

"Relative slowness in product development and commercialization" was ranked first overall in the *technology management practices* category. (See table B-7.) This factor received 68 first, second, and third place rankings—less than the 74 received by "reluctance to invest in new enabling technologies because R&D may be too expensive, long-term, multi-industry, and interdisciplinary," which was ranked second overall.

"Failure to integrate R&D and marketing" was ranked third overall; it received 57 first, second, and third place votes. Nine respondents gave identical rankings to this factor, "failure to integrate R&D and manufacturing," and "failure to integrate design and manufacturing"; these three were listed sequentially on the questionnaire. (Five of the nine respondents gave first place rankings to these three factors.) Overall, "failure to integrate R&D and manufacturing" and "failure to integrate design and manufacturing" were ranked fourth and seventh, respectively. Respondents recommended that "general and technology managers demand a closer linkage between design and manufacturing using techniques such as concurrent engineering and design for assembly."

A recurrent theme of recent literature on the erosion of the U.S. position in high-technology markets is "weakness in process technology." Apparently, however, the IRI officials do not perceive this as a major problem, compared to the other factors, because it was ranked sixth overall. Only 37 respondents gave this factor first, second, or third place rankings, and 13 of the 69 respondents who assigned rankings to all factors in this category ranked "weakness in process technology" last. Only three respondents mentioned the need to invest more in process R&D in their recommendations. "Weakness in process technology" may have been ranked higher if the survey had included a larger number of R&D officials representing electronics companies.⁷ According to Steinmueller, continuous improvements in process technology are crucial in the integrated circuit industry where companies must be quick to implement state-of-the-art manufacturing innovations to remain competitive.

"Reluctance to commit significant resources to cooperative research for acquiring new technology" was ranked eighth overall. Only 33 respondents thought it was a major factor, ranking it first, second, or third. Also, 13 of those who ranked all 10 factors put it in last place. It can be inferred from the relatively low ranking of this factor that few major barriers prevent companies from participating in consortia, "centers of excellence," engineering research centers, joint ventures, and other cooperative activities to further the development of new technologies. The relatively low ranking of this factor is not surprising, because in the last few years (after passage of the National Cooperative Research Act of 1984), the number of joint ventures between domestic firms and with foreign partners has increased dramatically.⁸ About one-fifth of the respondents recommended the establishment of more mechanisms to facilitate—and greater opportunities for—cooperation between industry, the government, and the academic sector. Several respondents recommended elimination of the "us versus them" attitude between government and the business community.

⁷Also, more IRI members represent central corporate laboratories; process technology and R&D are seldom undertaken at such locations.

⁸The Office of Technology Administration of the U.S. Department of Commerce maintains a Research and Development Consortia Register under the National Cooperative Research Act of 1984.

Table B-7. Ranking of *technology management practices*

Rank	Factor	Average rank	No. of 1st places	No. of 2nd places	No. of 3rd places	No. of last places
1	Relative slowness in product development and commercialization	3.9	24	26	18	2
2	Reluctance to invest in new enabling technologies because the R&D may be too expensive, long-term, multi-industry, and interdisciplinary	3.9	47	14	13	3
3	Failure to integrate R&D and marketing	4.7	21	22	14	1
4	Failure to integrate R&D and manufacturing	5.5	12	11	10	0
5	"Big hit" mentality instead of focused, incremental development	5.8	10	14	12	5
6	Weakness in process technology	5.8	8	13	16	13
7	Failure to integrate design and manufacturing	5.9	8	10	11	3
8	Reluctance to commit significant resources to cooperative research for acquiring new technology	6.1	3	18	12	13
9	Bias toward internal development	6.9	4	4	11	16
10	High-performance/high-cost mentality	7.0	2	1	7	13

Sources: Industrial Research Institute and NSB Committee on Industrial Support for R&D

Federal Technology Policy

Two-thirds of the respondents gave first or second place rankings to "lack of long-term strategies for expanding the economy (and tax revenues) through technological competitiveness." (See table B-8.) The importance assigned to this factor can be interpreted as a statement (from most respondents) in favor of a comprehensive national technology strategy aimed at improving industrial competitiveness. Twenty-five of the IRI members mentioned the need for such a strategy in their recommendations.

The two factors that refer to education, "too little attention to the training of future scientists and engineers" and "too little attention to pre-college education," were ranked second and fourth, respectively. The need to strengthen the U.S. educational system was mentioned more frequently than any other respondent recommendation.

Two factors frequently included in discussions of competitiveness issues—"too much investment in defense, too little investment in civilian R&D activities" and "hands-off attitudes of government officials"—were ranked third and fifth, respectively. Eleven respondents mentioned the need to channel the revenue saved from any cutbacks in defense spending into the educational system and/or nondefense R&D. Twenty-eight respondents thought the Federal Government should take a more active role in arresting the decline in technology leadership by providing (1) support for emerging technologies or critical industries and (2) more financial incentives and opportunities for cooperative research by government, industry, and the academic sector. (Two respondents explicitly stated that the government had no role in industrial research and development.)

Table B-8. Ranking of *Federal technology policy*

Rank	Factor	Average rank	No. of 1st places	No. of 2nd places	No. of last places
1	Lack of long-term strategies for expanding the economy (and tax revenues) through technological competitiveness	2.4	58	31	3
2	Too little attention to the training of future scientists and engineers	3.8	16	23	5
3	Too much investment in defense, too little investment in civilian R&D activities	4.0	23	17	15
4	Too little attention to pre-college education	4.0	15	21	15
5	Hands-off attitudes of government officials toward joint government-industry investments in emerging or endangered technologies and/or lack of sufficient funding for newly created mechanisms, e.g., the National Institute of Standards and Technology's Advanced Technology Program	4.2	23	14	11
6	Inability to support emerging technology areas that cut across government agencies	4.8	0	15	15
7	Lengthy, ineffective enforcement of Federal laws against patent infringement and dumping	5.2	5	7	31

Sources: Industrial Research Institute and NSB Committee on Industrial Support for R&D

The respondents added more factors to this category than to any of the others, as follows:

- ineffective enforcement of reciprocal free and fair international trade practices;
- regulatory laws that slow technology commercialization and new product clearance;
- laws that permit high product liability exposure;

- lack of state and local strategies for expanding the economy through the technological infrastructure;
- tax laws that discourage investment in capital-intensive industries (in other countries, companies can write off their investments faster and install new technology sooner);
- lack of tax incentives for research;
- instability of Federal funding and increased insistence on annual funding such that too much time is spent in winning and reporting on contracts and not enough on doing creative R&D;
- antitrust laws; and
- Modified Final Judgment restrictions on Bell operating companies.

Summary

The overwhelming majority of IRI member officials participating in the survey held *general management practices* and *external financial pressures* responsible for the erosion in U.S. technology leadership. *Changing global technological environment* and *technology management practices* were ranked third and fourth, respectively. *Federal technology policy* was judged to have the least impact on maintaining U.S. technological supremacy compared to the other four categories.

"Short time horizons" and "management by the numbers rather than by strategic vision" received far more first and second place rankings than any of the other four factors listed under the *general management practices* category. Under *external financial pressures*, "growing dominance of institutional investors in equity markets and their demand for short term returns on their investments" was ranked first by most respondents; "high cost of capital" finished a distant second. Compared to the categories ranked first and second, there was a weaker consensus in the ranking of factors under the categories *changing global technological environment* and *technology management practices*. "Growing difficulty of controlling enough technological competitive advantage to sustain an entry barrier" and "relative slowness in product development and commercialization" were ranked first under each of these two categories, respectively. "Lack of long-term strategies for expanding the economy (and tax revenues through technological competitiveness)" was an easy winner under the *Federal technology policy* category.

There was little variation in response by industry and size of company, with the following exceptions:

- Based on the ranking of factors under *Federal technology policy*, it would appear that respondents from the largest companies are more likely than those from smaller companies

to believe that the U.S. Government's hands-off policy toward investment in emerging technologies is a major impediment in the race to develop and commercialize new technologies.

- Similarly, respondents from several of the major R&D-performing industries—i.e., electrical equipment, computers, instruments, and communication services—were more likely than those from less R&D-intensive industries to favor an expanded role for the Federal Government in assisting industrial science and technology.



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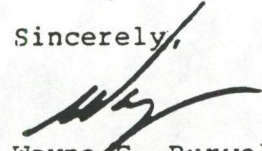
Concern is growing over the threat to U.S. technology leadership from other industrialized nations. Unfortunately, instead of increasing investment in R&D to meet this challenge, the rate of growth in U.S. industrial R&D spending slowed considerably during the late 1980s (according to National Science Foundation data). Although there has been extensive coverage of this issue, no one to my knowledge has attempted to identify and rank the crucial factors responsible for the deceleration of R&D spending and gradual erosion in U.S. technology leadership.

The enclosed questionnaire was developed as a quick, painless way of gathering your opinions on this important issue. I urge you to take a few minutes to respond by ranking the listed factors in Part A and/or by adding others you feel may be more important. In addition, in Part B you have an opportunity to provide your recommendations on how the problem could best be tackled by those of us in industry and/or by government policymakers.

IRI has agreed to share the information from this survey with the National Science Board's (NSB) Committee on Industrial Support for R&D which, in conjunction with Commerce Department officials, has been exploring this issue. The NSB Committee will include the results of this survey and issue recommendations for NSF, other executive agencies, Congress, and the private sector in its final report on this subject. The Committee's Co-chairmen, Dr. Roland Schmitt and Dr. Arden Bement, are looking forward to having your input before the recommendations are finalized. Therefore, it is important that you return your questionnaire as soon as possible, but no later than July 15th.

Your cooperation on this project is important for IRI and the NSB to obtain a thorough understanding of the factors behind the erosion in U.S. technology leadership. Thank you in advance for your response.

Sincerely,


Wayne G. Burwell
President
Industrial Research
Institute

Enclosure

POTENTIAL CAUSES FOR THE EROSION IN U.S. TECHNOLOGY LEADERSHIP

The purpose of this survey is to identify the most important factors responsible for the erosion in technology leadership of U.S. industry. We would greatly appreciate your contributing to this project by

1. ranking the 5 major factors in Part A, using #1 for the factor you believe is most important
(You may include others you feel are important that may have been omitted from this list.) Please rank them:

_____ General management practices
_____ Technology management practices
_____ External financial pressures
_____ Federal technology policy
_____ Changing global technological environment
_____ Other
2. ranking the items (using the blanks next to the items) under each of the 5 categories
(Please use the "other" category, if necessary.)
3. commenting on the implications and consequences of continued erosion in U.S. technological leadership and listing your recommendations to improve the situation in Part B
4. identifying the industry classification(s) and domestic employment size-group of your company in Part C.

PART A

I. GENERAL MANAGEMENT PRACTICES

- _____ failure and/or inability to integrate technology into business strategy
- _____ management by the numbers rather than by strategic vision
- _____ short time horizons
- _____ high rates of executive turnover
- _____ executive talent reward structure
- _____ corporate executives' lack of scientific and technical insight and lack of experience in the management of science and technology
- _____ other _____

II. TECHNOLOGY MANAGEMENT PRACTICES

- _____ weakness in process technology
- _____ relative slowness in product development and commercialization
- _____ failure to integrate R&D and manufacturing
- _____ failure to integrate design and manufacturing
- _____ failure to integrate R&D and marketing
- _____ "big hit" mentality instead of focused, incremental development
- _____ high performance/high cost mentality
- _____ bias toward internal development
- _____ reluctance to commit significant resources to cooperative research for acquiring new technology
- _____ reluctance to invest in new enabling technologies because the R&D may be too expensive, long-term, multi-industry, and interdisciplinary
- _____ other _____

III. EXTERNAL FINANCIAL PRESSURES

- _____ growing dominance of institutional investors in equity markets and their demand for short term returns on their investments
- _____ investment of "patient" capital inhibited by statutory separation of the managements of industrial and financial corporations (Glass-Steagal Act)
- _____ pressures to reduce debt accrued through leveraged buy-outs and hostile takeovers
- _____ growing costs of compliance with environmental, OSHA, and other federal and state regulations that compete with and displace R&D investment
- _____ high cost of capital
- _____ high cost of U.S. labor relative to that of other countries
- _____ other _____

IV. FEDERAL TECHNOLOGY POLICY

lengthy, ineffective enforcement of federal laws against patent infringement and dumping

hands-off attitudes of government officials toward joint government-industry investments in emerging or endangered technologies and/or lack of sufficient funding for newly created mechanisms, e.g. the National Institute of Standards and Technology's Advanced Technology Program

too much investment in defense, too little investment in civilian R&D activities

lack of long-term strategies for expanding the economy (and tax revenues) through technological competitiveness

inability to support emerging technology areas that cut across government agencies

too little attention to the training of future scientists and engineers

too little attention to pre-college education

other _____

V. CHANGING GLOBAL TECHNOLOGICAL ENVIRONMENT

increasing number of skilled workers, including scientists and engineers, in other countries

intensifying efforts of foreign companies to derive income from the licensing of intellectual properties

shifts from leadership to fast-follower technology development strategies

declining lead times and faster product turnover cycles

fragmented structure of some U.S. industries (e.g., semiconductor equipment manufacturing) not conducive to efficient and effective R&D and its commercialization

growing difficulty of controlling enough technological competitive advantage to sustain an entry barrier against competing companies around the world

other _____

PART B

IMPLICATIONS AND CONSEQUENCES

Please comment on what you think may be the implications and consequences of continued erosion in U.S. technological leadership and prioritize some specific recommendations (say, 4-6) to improve the situation. If you need more space, please attach an additional sheet.

Please comment:

Please list your recommendations in order of importance:

U.S. Panel Urges Bolstering Scientific Research in Industry

U.S. Panel Asks More For Science Research in Industry Said to Be Declining

By WILLIAM J. BROAD

A Federal panel said yesterday that scientific research by American business was in a perilous state of stagnation and recommended tough steps to strengthen industry against foreign rivals, including a series of actions by the Federal Government.

While many experts have issued such calls to action, this one is unusual for its breadth and authority. Its author, the National Science Board, is the policy-making arm of the National Science Foundation, a Federal agency that supports general science research in the United States and is responsible for monitoring the nation's overall scientific health.

Without saying so explicitly, the panel's report seems to repudiate the laissez-faire approach of the Reagan and Bush Administrations, which disdained Government involvement in industry research in favor of reliance on market forces. Lately the Bush Administration has softened its stance on this issue, and Gov. Bill Clinton has strongly backed new Federal policies to increase industrial innovation.

The National Science Board in its report, released yesterday in Washington, detailed American declines in research spending by business and setbacks in high-technology markets and called for a plan in which Government would play a leading role in riding to industry's rescue.

Art of Fostering Innovation

Among the proposed Federal steps were increasing the money for industrial research; changing tax, fiscal and monetary policies to promote scientific investment; and creating Federal education programs to train future corporate leaders in the art of fostering innovation.

The report "paints a grim picture," Dr. Roland W. Schmitt, the president of Rensselaer Polytechnic Institute, in Troy, N.Y., and co-chairman of the report panel, said in a statement, adding that stronger Federal leadership was needed. "Implementation of a national technology policy, establishing a rationale and guidelines for Federal action, should receive the highest priority," he said.

The situation was especially dangerous, he said at a news conference, because the erosion of America's industrial edge was steady rather than precipitous, leading to insufficient alarm being given to the issues and markets at stake.

"We're waving a warning flag," he said. "There's an emerging risk" that the United States is losing its inventive and competitive edge, threatening a series of significant losses and setbacks.

The report, "The Competitive Strength of U.S. Industrial Science

"Whoever is in the White House is eventually going to see the light and realize that industry and government have to work together on this as a team," he said.

From Teflon to Transistors

Traditionally, America's main source of innovation and technological leadership has been scientific research by private industry. People in corporate research invented nylon, Teflon, the transistor, the computer chip, fiber optics and instant color film. But now industry faces rising competition from abroad. In 1991, top honors in the award of sheer numbers of United States patents went to three Japanese companies: Toshiba, Mitsubishi and Hitachi.

In its report, the National Science Board panel, echoing past alarms, found that American spending on industrial research and development had stagnated in the 1980's and early 1990's, even as foreign rivals increased their investments.

In the last three years, it said, six competitors — Japan, Germany, France, Italy, Sweden and Britain — significantly increased their support of civilian research so that it cumulatively rose from being 25 percent larger than similar work in the United States to being 34 percent greater.

The report noted that American spending on industrial research slowed from an annual average growth of 7.5 percent in constant dollars from 1960 to 1985, to only four-tenths of 1 percent from 1985 to 1991.

At Risk of Decline

As a result, it said, many American industries were at risk of decline, including computers, factory automation, motor vehicles, metals and electronics.

The report, citing a survey of 136 leading high-technology companies, said the main cause of the financial pullback was not Federal policy, technology management or the changing global economy. It was, the report found, general management practices and external financial pressures.

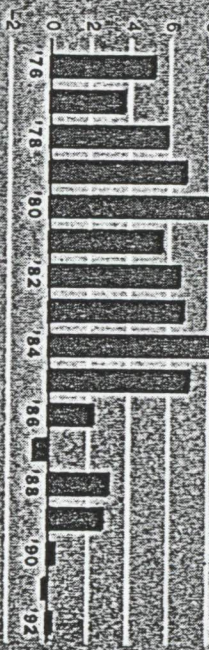
Corporate laboratories, it said, were under severe financial stress and were being forced to shift to shorter-term research for existing markets. It found that the mountain of corporate debt accumulated during the takeovers, mergers and acquisitions in the 1980's had squeezed research to some extent, but that the top financial pressure was the "growing dominance of institutional investors in equity markets and their demand for short-term returns on their investments."

It added that many top corporate managers lacked the skills and insights to the technology into business strategy. In summary, the report said the United States "spends too few dollars" on industrial research and

Stagnation in Industrial Labs

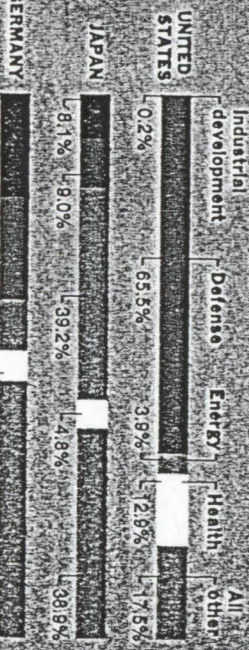
INDUSTRY'S SPENDING HAS LEVELLED OFF...

Percentage growth or decline of industry-funded research and development from the previous year, in constant dollars



...AND GOVERNMENT'S FOCUS IS ELSEWHERE

Percentage of government-funded research spending devoted to each category of research in 1989



Excludes general funding to universities.

Source: National Science Foundation

The New York Times

makes poor use of the ones it does.

It called for a tax credit for research and development to be made permanent and a moratorium on a Treasury regulation that induces American corporations to move research overseas.

Perhaps most important, it called for a sharp reversal of priorities in the overall Federal research budget, shifting the focus from the military to the commercial. Currently, some 60 percent of the \$70 billion or so Washington is spending this year on science research goes to the Defense Department and other agencies engaged in military research.

Industry research sponsored by the Federal Government should be a team effort with business that focuses on generic, precompetitive technologies that have a broad range of commercial applications, the report said.

In a recommendation likely to provoke controversy, the report also called for Federal efforts to improve how industry performs its own re-

search. For instance, it called on the National Science Foundation, the Government's main sponsor of general scientific research and education programs, to consider broadening its mission to include "the education of future corporate leaders of both high-technology and traditional industries."

Copies of the report can be obtained from the National Science Board, 1800 G Street N.W., Washington, D.C. 20550.

Kohlberg Buys Stake

By Bloomberg Business News

STERLING, Ill., Aug. 12 — Kohlberg & Company, the investment firm run by the buyout specialist J.C. Kohlberg, has bought a 52 percent stake in the Northwestern Steel and Wire Company for about \$35 million. The transaction marks a financial restructuring for the 113-year-old Northwestern, a closely held maker of steel products.

INDUSTRIAL R&D

National Science Board Sounds a Wake-Up Call

The U.S. economy as a whole may still be struggling to lift itself out of a recession-induced funk, but one industry, at least, has experienced remarkable growth: the publishing of reports that predict dire consequences for economic competitiveness if domestic firms don't invest more in research and development. Over the past 3 to 4 years, groups as varied as the Carnegie Commission, the National Academy of Sciences, the Council on Competitiveness, the Office of Science and Technology Policy, and several congressional committees have produced a pile of literature on the subject that a strong man would be hard-pressed to lift. Now comes a new report,* this time from the National Science Board, warning that without concerted government action the United States risks losing its technological leadership.

While this report echoes the concerns of many of its predecessors, it is unusual in at least two respects. First, it forthrightly lays part of the blame for U.S. industrial decline at the door of industry itself, although its authors also argue that corporate CEOs are merely responding rationally to hostile financial conditions. Second, while the report recommends a stepped-up federal role in supporting industrial technology, it does not call for the creation of a civilian agency analogous to the Defense Advanced Research Projects Agency to coordinate this work, as have a number of other reports.

Furthermore, the report highlights the generally poor quality of statistics on industrial R&D, particularly in terms of assessing the quality and commercial results of R&D spending, and explicitly recommends upgrading the collection of such data. As a result of these data gaps, the report's authors are reduced to arguing that trends in aggregate R&D spending translate directly into trends in innovation—an assumption that several R&D analysts have criticized. Still, members of the science board committee—co-chaired by Rensselaer Polytechnic Institute president Roland Schmitt and TRW vice president for science and technology Arthur Bement—say their report is an important wake-up call to the policy establishment. "We are spending too little, not spending it the right way, and getting too little for our money," Schmitt says.

Shrinking investment. The new report cites an array of statistics to support that

notion. For instance, while U.S. industrial R&D expenditures grew at an average, inflation-adjusted rate of 7.5% a year from 1980 to 1985, such investments tapered off in the late 1980s, growing by only 0.4% a year from 1986 to 1991. The report doesn't directly compare U.S. industrial R&D with industrial R&D in other Western nations. But it notes that growth in total U.S. R&D spending—that is, research performed in the United States by industry, government, and academia—has been slower than in many of the nation's major industrial competitors. Japan, in particular, has increased spending on total nondefense-related R&D much faster than the United States: In 1990, the United States spent only 1.9% of GDP on nondefense R&D and Japan spent 3.0%, whereas in 1980 the United States spent 1.7% compared with Japan's 2.2%.

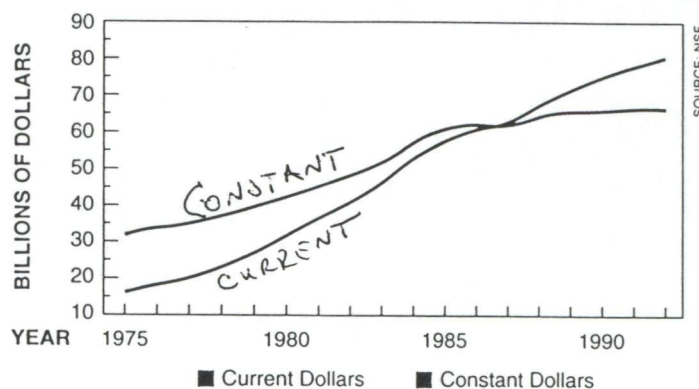
What's worse, the report argues, is that U.S. firms haven't been investing wisely. For instance, the report notes that U.S. firms allocate a much smaller fraction of their R&D budgets to process technology than do their Japanese counterparts, a trend that has slowed the conversion of innovations into products and widened the Japanese lead in a variety of industrial technologies. Similarly, it cites a recent survey of corporate R&D managers as evidence that U.S. corporations have overly short time horizons that hinder the development of technologies with long-term payoffs.

"Our overriding concern was that these trends are fatal to the technological competitiveness of the United States in the long run," Bement says. To reverse them, the report endorses a national technology policy that would: Offer a grab bag of tax incentives to improve the financial investment climate and consequently boost corporate R&D; reorient defense research toward industrial needs; and provide direct government support for the development of process technology, basic engineering research, and generic technologies. "The private sector can be nudged [into increasing R&D investment] by fine-tuning existing programs and through fiscal policies," says Bement.

Where direct federal spending is necessary,

the report recommends expanding existing programs such as the Commerce Department's Advanced Technology Program, which provides federal assistance for technology development at small and medium-sized companies. Many of these programs were resisted by the Reagan Administration and have only recently won the support of the Bush Administration (*Science*, 20 March, p. 1500).

Sour notes. While some in Congress and academia were quick to applaud the report, others have given it mixed reviews. Arno Penzias, director of research at AT&T Bell Labs, faults it for emphasizing an apparent shortfall in corporate R&D and for blaming the failures of management on the investment climate. "The problem is not one of not inventing enough stuff, it's how we invent stuff, how we use it, and how we get it to the market," Penzias says. Furthermore, he says, it makes no sense to argue that a hostile financial climate



Cause for alarm? R&D expenditures by corporations in the United States have barely grown since the mid-1980s.

forces managers to make "rational" decisions that slight R&D. "If people don't know how to drive and they run their car off the road, you can't say they're irrational—they just don't know how to drive."

Harvard political economist Robert Reich also argues that the report misses the point in focusing on a perceived gap in R&D expenditures. "Two measurements are more appropriate [than levels of R&D funding]—the speed of new innovations and the speed at which they're utilized.... There we do have a problem, and not one that's necessarily rectified by throwing more money into R&D."

But Harvard professor of science and technology Lewis Branscomb says the report is remarkable as a watershed in the evolution of technology policy. When he was director of the National Bureau of Standards more than 20 years ago, he says, he tried to get the National Science Board to consider funding applied research with industrial potential. "They didn't want anything to do with the idea." Whether or not the new report has a major influence on national policy, its release by that same National Science Board is a clear sign that those days are long gone.

—David P. Hamilton

**The Competitive Strength of U.S. Industrial Science and Technology: Strategic Issues*, NSF-92-138, August 1992.

Sematech's Critical Juncture

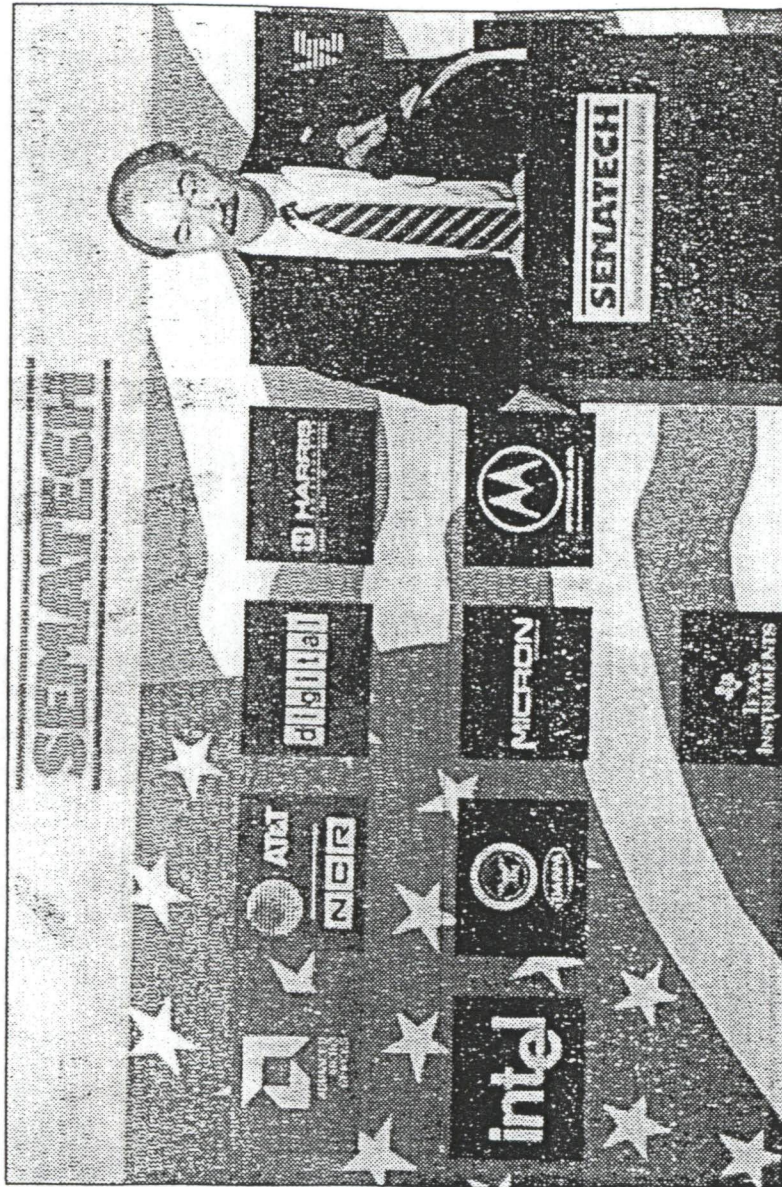
Hailed as Success,
Chip Consortium
Faces Budget Cuts

By Daniel Southerland
Washington Post Staff Writer

Since it was set up five years ago to boost the competitiveness of the beleaguered U.S. semiconductor industry, the Texas-based research consortium known as Sematech has been hailed by some as a model of enlightened partnership between government and industry, and criticized by others as an intrusion by Washington in the private sector.

This summer, the debate has been joined once again as the Defense Department proposes to cut funding for the 12-company consortium by \$20 million, even as Congress's General Accounting Office (GAO) is circulating a report saying that Sematech "appears to be on schedule for achieving its overall technological objectives."

The funding fight reflects long-



Sematech CEO William J. Spencer says of its budget prospects: "We think we've got strong support in Washington..."

standing differences between the Democratic-controlled Congress and the Bush administration over the role of government in supporting American high-technology industries.

In general, Democrats have been more enthusiastic about government helping companies keep their lead in critical civilian technologies. In a position paper issued earlier this summer, Democratic

presidential nominee Bill Clinton called for the "creation of a civilian research and development agency to bring together businesses and universities to develop cutting-edge products and technologies."

But senior Bush administration officials, while going along with federal funding of Sematech in the defense budget because of the potential importance of its work to the military, have repeatedly ex-

pressed reservations about what they see as the dangers of violating free-market principles.

Congress created Sematech in 1987 in response to Japan's success in becoming the leading seller of semiconductor chips and equipment in world markets.

The understanding was that it would receive \$100 million a year through Oct. 1 of this year, with

See SEMATECH, B2, Col. 1

Computer Chip Consortium Faces a Budget Crossroads

SEMATECH, From B1

the federal contribution matched by companies joining the research consortium.

American semiconductor companies feared at the time that they would be at a serious competitive disadvantage if equipment for making computer chips was no longer produced here. Research was aimed at such tasks as developing equipment capable of making extremely minute semiconductor circuits.

Members of the consortium, which is based in Austin, include such companies as Intel Corp., Motorola Inc. and International Business Machines Corp.

Some industry officials credit Sematech with helping to close the competitive gap with the Japanese in sales of chips and the equipment for making them. The research firm Da-taquest Inc. of San Jose says U.S. suppliers increased their share of the world semiconductor market by several percentage points from 1989 to 1991, reaching 38.4 percent of the \$60 billion market. Japanese companies still hold the lead at 46.4 percent.

VLSI Research Inc., another San Jose research firm, estimates that U.S. companies that make sophisticated chip-making equipment moved ahead of the Japanese in sales in

1990, and will have 48.8 percent of the \$10 billion-per-year market in equipment by the end of this year.

The GAO report said eight out of 12 companies in the consortium reported that overall, they were either breaking even or receiving greater returns than their contributions to Sematech at this stage. NCR Corp. said new technology was introduced into its manufacturing process nine to 12 months sooner as a result of Sematech's programs.

The report noted that some Sematech initiatives emulate Japanese practices by working with key suppliers to develop the next generation of equipment. It added that the consortium also is developing better equipment and more efficient manufacturing techniques.

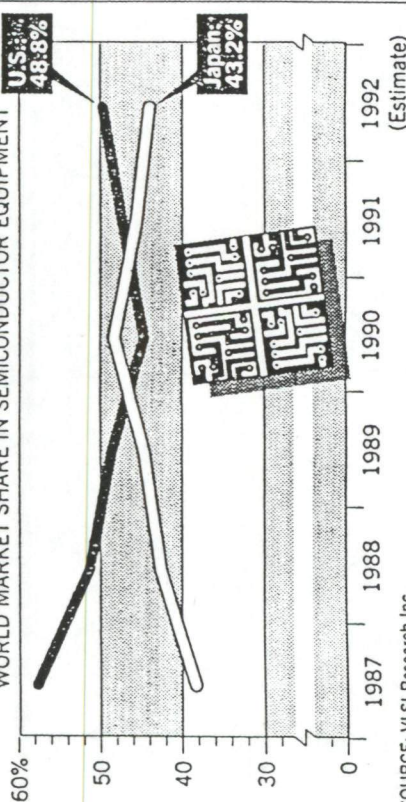
Robert W. Galvin, chairman of Sematech and former chairman of Motorola, said he believed that if Sematech had not been created five years ago, some American semiconductor producers that are now thriving would be out of business today.

"I believe that over the next five years, the payoff from Sematech is going to be even greater," said Ben Anixter, vice president for external affairs with Advanced Micro Devices Inc., in Sunnyvale, Calif., which was one of Sematech's original member companies. "Sematech went through fits and starts early on, but they've made tremendous progress in shoring up infrastructure companies that were weak five years ago."

"I suspect the people in Washington are surprised to see something like this work this well," said Craig Barrett, an Intel executive vice president who is a member of the Sematech board and whose company contributes about \$17 million a year and about 35 employees to the consortium.

A CHANGE IN DIRECTION

WORLD MARKET SHARE IN SEMICONDUCTOR EQUIPMENT



SOURCE: VLSI Research Inc.

THE WASHINGTON POST

But the report said that 10 of the 12 companies were not willing to increase their spending on Sematech if the government reduced its funding. Two companies out of the original 14 members dropped out of the consortium earlier.

Industry executives and a congressional specialist predicted that Congress would appropriate the full \$100 million in funding for Sematech in the fiscal 1993 budget before it adjourns this fall.

"We think we've got strong support in Washington from the Defense Department, Commerce Department and the Office of Science and Technology Policy," said William J. Spencer, chief executive of Sematech.

A Defense Department official said Sematech had been "an excellent model of what a consortium should do," but the Defense Advanced Research Projects Agency (DARPA), which gives the organization its federal money, has other innovative projects that it must consider funding as well. The government's original five-year funding commitment ends this year.

The Defense Department official declined to comment on DARPA's budget plans beyond fiscal 1993 but said that "\$80 million still represents a substantial commitment" for 1993, as well as an attempt to balance that

commitment against other "key technology opportunities."

The official said DARPA needs to fund research into other projects, such as advanced radar technology, infrared focal point arrays used to seek targets for advanced "fire-and-forget" weapons, and other technologies that meet national defense needs.

The Defense Department supports Sematech partly because semiconductor companies are critical components of modern weapons.

During the Persian Gulf War last year, some defense experts voiced concern about the U.S. military's possible dependence, in future conflicts, on Japanese-supplied semiconductors used in the advanced electronics systems of fighter planes and armored vehicles.

SCIENCE

Gene-Fragment Patent Request Is Turned Down

By HILARY STOUT

Staff Reporter of THE WALL STREET JOURNAL

WASHINGTON — The U.S. Patent and Trademark Office rejected an application by the National Institutes of Health for patents on thousands of human gene fragments.

The rebuff, the office's first ruling on the government's controversial attempt to patent human genes, isn't likely to put the issue to rest. NIH Director Bernadine Healy told a Senate committee that the NIH thinks it can address the patent office's reservations. "Our outside attorney says this is common and is confident that most concerns raised in the preliminary finding could be met," she told the Senate Judiciary Committee.

The NIH roiled the scientific world by seeking patent protection for some 2,700 segments of DNA, the substance of which genes are made. While patenting genes and other biological material isn't a new idea, the NIH effort has been enormously contentious because the agency's scientists have identified only the gene fragments' existence, not their function. Generally, something can be patented only if it is found to be unique and to have a specific application.

Human genes are enormously valuable because they hold the key to understanding many diseases. Many people believe that without patent protection on the discovery of genes, companies wouldn't have an incentive to invest the resources needed to develop medicines and treatments for such diseases. The NIH says it would license patented genes to private companies, effectively giving the companies exclusive right to market medicines based on the genes.

The patent office was concerned that the NIH was seeking patent protections for gene sequences whose uses it doesn't know. Dr. Healy, who disclosed the ruling at yesterday's hearing, said the patent office questioned whether the fragments were "novel, useful and nonobvious."

The patent office said the gene fragments weren't novel because they were derived from publicly available libraries of gene sequences, according to Dr. Healy. It also said the fragments didn't have a practical use, or patentable utility. And it said the discoveries failed to meet the criteria of "nonobviousness" because some of the gene sequences contained smaller sequences that were already published.

The last concern, Dr. Healy said, is
Please Turn to Page B7, Column 3

U.S. Rejects Request By NIH for Patents On Gene Fragments

Continued From Page B1

precisely why the NIH decided to file the patent applications even though it didn't know the gene fragments' functions. The NIH, which routinely publishes information on the sequence in which genes occur in DNA, was worried that doing so might jeopardize the possibility of obtaining patents later, when the function of the genes is known.

Dr. Healy said the patent office's position "suggests the need to at least consider a legislative remedy and international agreement that the prior publication of partial gene sequences not preclude a subsequent patent on the full genes and/or partial genes with known function."

The NIH has three months to amend its application to address the office's questions, but that period might be extended. A spokesman for the patent office declined to comment on the ruling, saying the agency is forbidden by statute to discuss pending applications.

NIH officials have said they filed the patent applications as a preventive measure, while the government discusses whether the patenting of genes is appropriate. The NIH isn't seeking patents to make money, Dr. Healy told the Senate panel. "It is doing this as a socially responsible way to ensure that products that are life-saving remedies that can be derived from these [gene sequences] will be developed."

ENVIRONMENTAL POLICY

War Over the Wetlands: Ecologists v. the White House

How wet must a wetland be? That may sound like a riddle, or a scholastic question of interest only to conservation biologists, but in fact it has political implications. At this moment, Vice President Dan Quayle's Council on Competitiveness, using what scientific critics call outdated ecological concepts, is developing regulations for wetlands that would protect only areas that are wet continuously. And that's a mistake, say ecologists, who are alarmed by a 1990 government inventory that found that the nation's total of 104 million acres of wetlands is declining—despite President Bush's promise that it would be protected.

Near the heart of the set-to between the White House and its ecologist-critics is a profound paradigm shift that has taken place in ecology in the past decade. Beginning in the late 1970s and 1980s ecology shifted away from the view that most ecosystems, when they mature, tend toward a steady state. In place of this "balance of nature" view, ecologists adopted a "flux of nature" view, in which an ecosystem is seen as a mosaic of variegated pieces that change character and function over time.

This "patch dynamics" paradigm has critical consequences for understanding wetlands, which are among the most changeable of ecosystems. "A functional wetland—and I emphasize functional—is one in which some patches are indeed wet all year long, but in which other connected patches are wet only part of the year and some patches aren't wet at all in some years," says Leigh W. Fredrickson, director of the School of Forestry, Fisheries, and Wildlife at the University of Missouri, Columbia. In other words, a wetland isn't always wet—and ecologists think the Administration is making a mistake in seeking to protect only the wettest areas. They argue that protecting the nation's wetland's requires setting aside a much larger area—including the sometimes dry patches needed for these ecosystems to function.

Perhaps it isn't surprising that the Administration is relying on the static view. After all, even though patch dynamics was formulated in the late 70s, it was applied initially to problems in forest ecology that traditional methods couldn't solve. And though the concept was rapidly embraced by the ecological community, it takes time for a conceptual shift to have consequences for policy. Not until 1989 did Michael Soulé of the University of California, Santa Cruz, and David Western of the New York Zoological Society call on conservation biologists to

make the new paradigm central to species and ecosystem preservation.

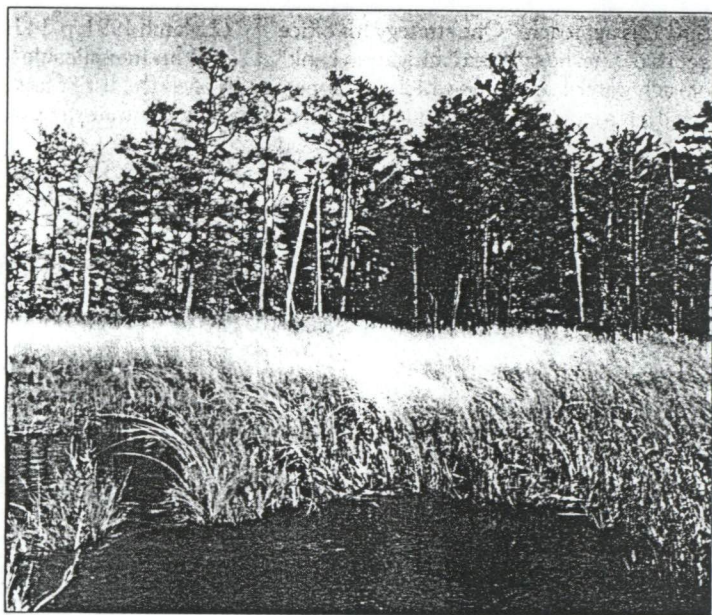
Once patch dynamics began spreading through the ecology community, wetlands ecologists found it of great help in understanding their subjects of study, which are unstable because rain and snowfall are among the most variable of all climatic phenomena. That variability translates into large shifts in the degree of soil saturation in wetland patches. Thus, while a 1- or 2-year inventory might identify certain patches as wet, seasonally wet, or dry, an inventory several years later might find that the patches have changed categories entirely. And with those shifts, the type of species changes. In the wetlands south of San Diego, for example, several endangered plant species show up only in certain years, when the arrangement of patches is suitable—otherwise they remain dormant in the soil.

Critics of the Bush Administration's efforts to rewrite wetlands regulations argue that this ecological dynamism is being ignored. In response to White House criticisms of the 1977 Clean Water Act, the Environmental Protection Agency, the Fish and Wildlife Service, the Army Corps of Engineers, and the Agriculture Department Soil Conservation Service drafted regulations limiting federal protection to wetlands that are permanently saturated. "Under the new regulations, a wetland would have to pass the so-called duck test: If a duck splashes when it lands, it must be a wetland," scoffs Peggy L. Fiedler, wetlands specialist and director of the conservation biology program at San Francisco State University. In some parts of the country, this could declassify as much as 75% of wetlands currently protected by the Clean Water Act.

The draft regulations also contain a mitigation provision: Developers can fill in low-priority wetlands for construction as long as they create an equal amount of similar wetland else-

where. But creating new wetlands has yet to succeed on a large scale—indeed, a report issued by the National Research Council last November stated that, in fact, it may be impossible to recreate a functional wetland. Part of the problem in recreating the system is its dynamic, patchy nature. Says Joy B. Zedler, director of the Pacific Estuarine Research Laboratory at San Diego State University, "you may create something that looks like a natural wetland in one year, but it may not be functional in other years because it is not connected to the other patches that together make up a functional wetland."

The bottom line of patch dynamics for policy, says Zedler, is that preserving the nation's wetlands will require setting aside far more land than most policy makers want to acknowledge. Estimates of how much range from 10% to more than double the acreage of wetlands now protected. Worse, patch dynamics suggests that in states such as California, which has lost more than 90% of its



Is wetter better? An eagle nesting area on Taylor's Island, Maryland, on the Chesapeake Bay. How to protect wetlands is at the center of a dispute between policy makers in the Bush Administration and ecologists.

wetlands, the few wetlands remaining may be in serious danger. "There's not much area surrounding these wetlands to allow the patches to be dynamic. As a result, we're left with trying to force these patches to be static, and that's just not going to work in the long run," Zedler says.

The 1991 regulations were denounced by a broad range of environmental groups, including the Sierra Club, the National Audubon Society, and the National Wildlife Federation. But Zedler and others worry that things could get even worse after the Council on Competitiveness gets through modifying the regulations. Jonathan B. Tolman, the MBA who heads the wetlands office at the Council on Competitiveness, says the coun-

THE WHITE HOUSE
WASHINGTON

August 21, 1992

MEMORANDUM FOR WALTER E. MASSEY

FROM:

D. ALLAN BROMLEY *Duan*

SUBJECT:

PCAST REPORT ON HIGH PERFORMANCE COMPUTING
AND COMMUNICATIONS

I am pleased to present a PCAST report on the High Performance Computing and Communications Program. The report was prepared by a PCAST panel chaired by Dr. Solomon Buchsbaum. The panel consulted with industrial and academic professionals, and has the concurrence of all PCAST members.

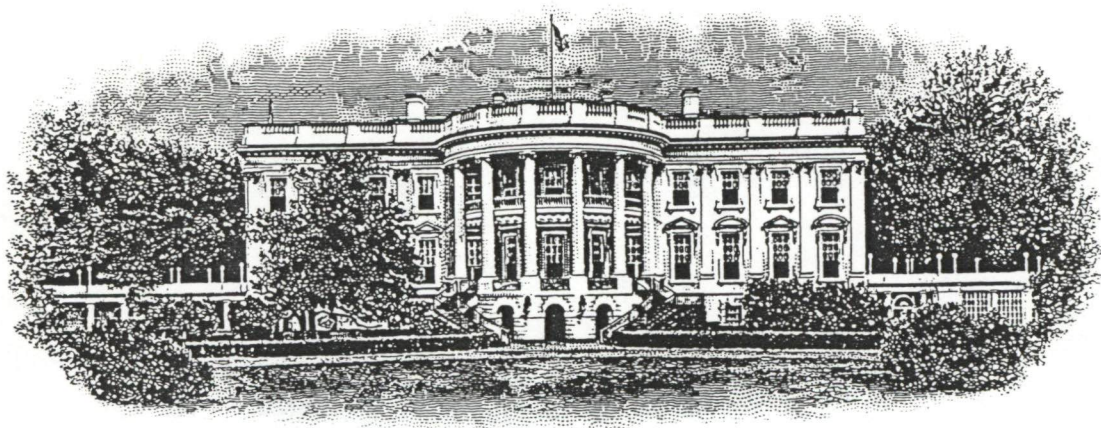
In my opinion, it is an excellent assessment of the state of the program. The report presents a program analysis based on strategy, balance, management and vision. It provides constructive recommendations for program improvement and positive reinforcement of successful program elements. It is my hope that the PCAST recommendations will be given serious consideration by the HPCC participants, and that the recommendations will lead to improvements in the HPCC program.

To further this end, may I suggest that this report be distributed at the next meeting of both the FCCSET Chairmen and Vice Chairmen on Tuesday, September 1, as well as the full FCCSET meeting on Thursday, September 3, 1992.

Thank you for your assistance, and I look forward to seeing you in September.

Attachment

**PRESIDENT'S COUNCIL OF ADVISORS
ON
SCIENCE AND TECHNOLOGY**



**HIGH PERFORMANCE COMPUTING AND
COMMUNICATIONS PANEL REPORT**

**President's Council of Advisors on Science and Technology
High Performance Computing and Communications Panel Report**

Introduction

In FY92, a Presidential initiative was launched, aimed at securing U.S. preeminence in high performance computing and related communication technologies. The initiative, entitled High Performance Computing and Communications (HPCC), is one of five initiatives coordinated by the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) process. Nine federal agencies are currently involved, with the Defense Advanced Research Project Agency (DARPA), the Department of Energy (DOE), the National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF) providing the principal program funding and direction. Lesser but important roles are being played by the National Oceanic and Atmospheric Administration, the National Institute of Standards and Technology, the Environmental Protection Agency, the Department of Education, and the National Institutes of Health.

The stated goal of the initiative is threefold: extend U.S. technological leadership in high performance computing and computer communications; provide wide dissemination and application of the technologies; and spur gains in U.S. productivity and industrial competitiveness, all within the context of the mission needs of federal agencies. The strategy for accomplishing the goals and the program components are highlighted in the report "Grand Challenges: High Performance Computing and Communications," published as a supplement to the fiscal year 1992 and 1993 budgets.

Because of the importance of the HPCC program to the national well-being, especially its potential implication for industrial competitiveness, the Assistant to the President for Science and Technology has asked that the President's Council of Advisors in Science and Technology (PCAST) establish a panel to advise PCAST on the strengths and weaknesses of the HPCC program. The Panel, which includes two PCAST members and experts drawn from industry and academia, has conducted several fact finding meetings, interviewed HPCC program managers from the key participating agencies, and was briefed by the Computer Systems Policy Project, a private sector organization representing all the major American computer and information systems corporations. On this basis, the Panel offers the following observations and recommendations.

Panel Observations and Recommendations

The Panel believes that, in general, the program has important objectives and is structured to achieve the objectives. The Panel also finds that the HPCC program is making excellent progress towards achieving the program objectives.

The Panel's observations and recommendations relate to the following issues: the program **strategy**; the program **balance** among technology, applications, and infrastructure; the program **management**; and the program **vision**.

Strategy

The HPCC program has certain explicit technology goals. The two best known goals are to implement by 1995 a tera-ops (10^{12} operations per second) computer and a skeletal gigabit (10^9 bits per second) National Research and Education Network.

The Panel finds the strategy of using scalable, massively parallel architectures to achieve the tera-ops goal convincing. Evidence to-date lends credence to the viability of the approach. The potential of the scalable, massively parallel computer architectures exceeds that of any competing choice.

The National Research and Education Network (NREN) approach of coupling diverse existing networks, for example, the DARPA, NSF, and DOE networks, is also proving to be effective. The Panel supports the strategy of making NREN both an infrastructure goal and a testbed for technology development.

The integration of computing and communication as manifested in the program is viewed by the Panel as a critical part of its strategy. It will do much to accelerate the Nation to a "digital society." However, the integration of computing and communication also creates enormous challenges for data handling and analysis. Therefore, the Panel recommends that special attention be given to database standardization for ease of utilization.

An effort should be made to encourage additional federal agency participation in the program. The participation of the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), the National Institute for Standards and Technology (NIST), the National Institutes of Health (NIH), and the Department of Education (DoEd) is important, and their role should be continually expanded.

The purpose of NREN is threefold: to satisfy the Government's critical needs for networked computing, to provide a high speed data communication service for the research and education community, and in doing so, serve as a testbed for the development of network technologies and services. The NREN is not intended to "grow" into a commercial network, nor is NREN designed to serve as an all-inclusive educational network. Here, the meaning of "network" is functional, not physical. The optical-fiber physical medium and broadband switches will be owned by common carriers, and the "network" will be implemented by purchasing services from common carriers and other commercial vendors of communications services.

Because of this close relationship with the private sector, there is a special opportunity to stimulate commercial exploitation of products and services developed in conjunction with the NREN program. The panel recommends that a comprehensive study be made on the technical, financial, legal and regulatory problems associated with the commercialization of a nationwide high-speed network to maximize the catalytic effect of NREN. Furthermore, it is critically important to be paying attention to ways in which the common carrier industry can be involved now, along with the other players, in planning how to help a nationwide high performance information infrastructure become effective and commercially viable as soon as possible.

In order to position the United States to take advantage of the evolving computing and communications infrastructure, we must develop a broad approach to the use of and familiarity with high performance computing and communications. In addition to the program of increased support for research and graduate education contained in the original HPCC program plan, the panel recommends increased emphasis on programs to foster the growth of computational science research and education. These programs will need not only to foster capability in traditional computer science, but also to stimulate the use of HPCC in the computational solutions to problems in science, engineering, and other fields.

A dialogue between the HPCC program and industry is essential to the success of the initiative. Without program acceptance by the various industrial constituencies, the results of the program will have little impact. Acceptance by industry depends on strong industrial participation. The HPCC program has successfully included input from industry to date, and the panel recommends that the dialogue between the HPCC program and industry be continued and strengthened as the program evolves.

Balance

Comments on the distribution of funds among the four program components are limited by the Panel's inability to discriminate between hardware purchases and other program tasks. Furthermore, since the program is in the early stages of implementation, it is expected that significant funds earmarked for Advanced Software Technology and Algorithms (ASTA) and Basic Research and Human Resources (BRHR) are being used for one time purchase of hardware. Therefore, the Panel's comments do not address the balance of spending between the various program components.

The panel believes that the High Performance Computing Systems (HPCS) component overemphasizes processing speed relative to other computing needs, for example, memory storage, visualization, and user interface. These technologies enable the user to manipulate the vast amount of information generated by the enhanced computational capabilities of scalable, massively parallel computers. Steps should be taken to ensure that all computing components receive adequate emphasis to allow for the full exploitation of the tera-ops processing capability.

Some agencies may be overemphasizing support for existing constituencies over program objectives. Optimal achievement of program objectives should be the primary determinant of implementation tactics.

In particular, the Grand Challenges should drive the technologies. Agencies should be encouraged to choose Grand Challenges and support them to ensure success. Because the implementation of the Grand Challenges will uncover program deficiencies, these data should be used to assist in the redirection of the program objectives, in particular, with the HPCS and NREN components. Indeed, several of the panelists believe that the successful realization of the Grand Challenges constitutes a more important goal than the development of the supporting technologies.

NOAA, EPA, NIST, NIH, and DoEd engage in research and development which would be substantially advanced by the application of HPCC technology. These agencies should continue to identify and undertake Grand Challenges appropriate to their missions.

Management

The Panel believes that the level of coordination during the planning phase of the initiative was commendable. For example, the HPCS technology development effort, jointly implemented by DARPA, DOE, NASA, and NSF has very little overlap and is effectively addressing the major problems in a coherent manner.

It is the Panel's view that there are no formal structures to expedite program review and to discuss program changes during the implementation phase. Program execution is not reviewed collectively to permit timely program modifications. An effort should be made to implement the level of program coordination during implementation that was achieved during program planning.

The Panel suggests, as a test case to foster more tightly coordinated execution, that each agency could contribute a small portion of their budget, perhaps five percent, toward the funding of a single, coherently-managed project. The project should be well-defined, and in support of a highly visible Presidential initiative, e.g., a model of ozone degradation for the Global Change initiative.

Vision

The panel believes that, successfully implemented, the HPCC initiative will significantly accelerate the advance toward a "digital information society" in which computing and communications are combined in a seamless manner to change our lives in profound ways. The panel believes that this vision has a good chance of being realized. This vision is widely shared even among those who do not understand the technical details, and accounts for the strong interest and support that HPCC enjoys.

A unification of computing with communications is inherent in the HPCC strategy. In NREN, networking makes the power of a single computing resource available to many users. In massively parallel computing systems, speed is achieved by making it possible for many processors to work on a single problem in an efficient way through sophisticated inter-processor communication. Thus, computing is made available in both "one for many" and "many for one" modes of operation, thanks to effective communication technology.

The long awaited synthesis between communications and computing technologies will have an impact that transcends the development of the technologies themselves. It will be another significant step in the transformation of our society through information technologies.

THE WHITE HOUSE

WASHINGTON

May 28, 1992

MEMORANDUM FOR THE PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE
AND TECHNOLOGY

FROM: D. ALLAN BROMLEY

SUBJECT: Briefing Materials for June PCAST Meeting

In preparation for the June 4-5 PCAST meeting, here are copies of several documents for your review.

1. Revised June meeting agenda.
2. First draft of the report from the Panel on Bioscience and Biotechnology.
3. Draft Executive Summary and Outline of the revised report from the Panel on Megaprojects in the Sciences.

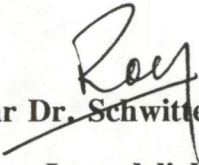
If you have any questions regarding the draft reports or the agenda, please contact Dr. Alicia Dustira. I look forward to seeing you at the June meeting.

Attachments

THE WHITE HOUSE

WASHINGTON

May 21, 1992


Dear Dr. Schwitters:

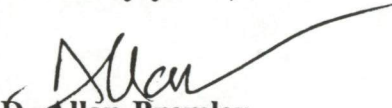
I am delighted to hear that you have agreed to join us for the meeting of the President's Council of Advisors on Science and Technology (PCAST) on Thursday, June 4, 1992. As you are aware, the PCAST was established by the President to provide him with private sector advice on science and technology issues of national importance. For your convenience, I have enclosed a list of the PCAST members along with the Agenda for the June 4 meeting.

If you can provide us with handout materials by Friday, May 29, we will include them in our briefing books. Finally, please note that the meeting will be open to the public and we expect that 10 to 15 members of the press will attend.

My office will be in contact with you shortly regarding your travel arrangements. If you should have further questions regarding the meeting, please feel free to contact Dr. Alicia Dustira, Executive Secretary for PCAST, at (202) 395-4692.

The PCAST and I look forward to seeing you on June 4.

Sincerely yours,


Dr. Allan Bromley
Assistant to the President
for
Science and Technology

Enclosures

Dr. Roy Schwitters
SSC Laboratory
2550 Beckley Meade Avenue
Dallas, TX 75237

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

March 16, 1992

DETERMINATION TO CLOSE
PORTIONS OF THE APRIL 2-3, 1992 MEETING OF THE
PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY (PCAST)

The President's Council of Advisors on Science and Technology (PCAST) will meet on April 2-3, 1992. This meeting will be held at the Conference Room, Council on Environmental Quality, 722 Jackson Place. The Council will start its deliberations at 9:00 AM on Thursday, April 2, and conclude at approximately 12:00 Noon on Friday, April 3.

The proposed agenda for the meeting of the President's Council of Advisors on Science and Technology is as follows:

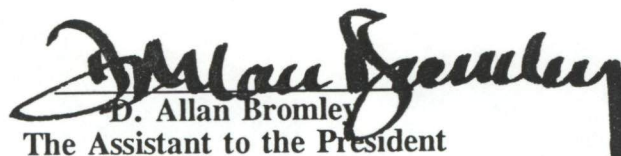
1. Briefing of the Council on the current activities of the Office of Science and Technology Policy.
2. Briefing of the Council on current federal plans, programs, activities and policies in science and technology.
3. Discussion of progress on working group panels.

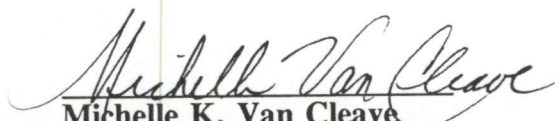
Some of the priority business of the PCAST should be open to the public, and the background non-sensitive material should be fully available. Therefore, I have determined that the agenda should be ordered to group material together and to permit public access to that part of the meeting.

Certain activities of the PCAST and certain of the panel studies concern matters which are entirely or inseparably classified under formal national security classification procedures. Other portions of the PCAST activities relate solely to internal personnel procedures of the Executive Office of the President.

A portion of the discussion on federal plans and programs will necessarily involve discussion of agency budget preparation plans which, if prematurely disclosed, would frustrate the purpose for which the PCAST was established and would significantly complicate and frustrate the implementation by Federal agencies of recommendations arising from the PCAST. The important purposes, distinguished membership, and unique context of the PCAST amplify greatly the effects which public disclosure of these presentations and deliberations would have.

Therefore, I have concluded that in this instance many matters to be presented to the PCAST and discussed by it permit the meeting to be closed under Section 10(d) of the Federal Advisory Committee Act, Public Law 92-463, as amended, principally, 5 U.S.C. 552b.(c)(1), (2), (6), and (9)(B).


D. Allan Bromley
The Assistant to the President
for
Science and Technology

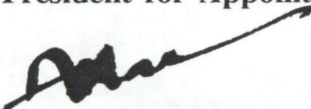

Michelle K. Van Cleave
OSTP General Counsel

THE WHITE HOUSE
WASHINGTON

April 16, 1992

SCHEDULE PROPOSAL

TO: KATHERINE L. SUPER
Deputy Assistant to the President for Appointments and Scheduling

FROM: D. ALLAN BROMLEY 
Assistant to the President for Science and Technology

REQUEST: To meet with the President's Council of Advisors on Science and Technology (PCAST).

PURPOSE: The PCAST will brief the President on several pending Science and Technology issues that will be especially relevant in the upcoming months. In particular, the council would like to advise the President on recent Panel findings regarding Technology and the American Standard of Living as well as Science, Technology, and National Security. PCAST will also present to the President plans for the Council's upcoming study of the Health of U.S. Colleges and Universities, chaired by David Packard.

BACKGROUND: The PCAST was established by President George Bush, in Executive Order 12700 on January 19, 1990, and meets with the President. The PCAST consists of twelve eminent American scientists, industry leaders, and distinguished members of the academic and research communities appointed by the President to advise him directly on issues involving science and technology. PCAST panels are subgroups of the full PCAST, created to focus on single areas of interest in science and technology.

PREVIOUS PARTICIPATION: In 1991: February 8, May 2, and July 12.
In 1992: none

DATE AND TIME: Friday, May 8, 1992 between 9:00 AM and 12:00 NOON is optimum. Also, between 1:00 PM and 5:00 PM May 7, 1992 is a good opportunity.

LOCATION: The Roosevelt Room

PARTICIPANTS: list attached

OUTLINE OF EVENT: The President joins the meeting in progress. He then asks the Chairman to proceed with the discussion.

REMARKS REQUIRED: None

MEDIA COVERAGE: White House Photographer only

RECOMMENDED BY: D. Allan Bromley

OPPOSED BY: No one

PARTICIPANTS

The President

D. Allan Bromley, Chairman, PCAST

PCAST Members

**Norman Borlaug
Solomon Buchsbaum
Charles Drake
Ralph Gomory
Mary Good
Peter Likins
Thomas Lovejoy
John McTague
Thomas Murrin
Daniel Nathans
David Packard
Harold Shapiro**

White House Senior Staff (Invited)

**Richard Darman
Samuel Skinner
Brent Scowcroft
Michael Boskin
Michael Deland**

OSTP Staff Members

**Karl Erb
D. A. Henderson
J. Thomas Ratchford
Eugene Wong
Vickie Sutton
Charles A. Dickens
Alicia Dustira
Ralph Brescia
William Snyder**

THE WHITE HOUSE
WASHINGTON

April 22, 1992

MEMORANDUM FOR

DR. BROMLEY

FROM:

KATHERINE L. SUPER *K. Super*
DEPUTY ASSISTANT TO THE PRESIDENT
FOR APPOINTMENTS AND SCHEDULING

SUBJECT

ATTACHED SCHEDULE PROPOSAL

The attached request was declined due to time constraints on the President's schedule on the requested date.

I am forwarding a copy to you for your information and any further follow-up you deem appropriate.

NOTE: THE PRESIDENT WILL BE OUT OF TOWN ON THE REQUESTED DATES.

Damn!

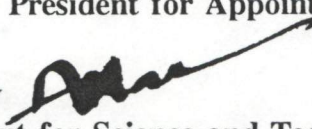
THE WHITE HOUSE

WASHINGTON

April 16, 1992

SCHEDULE PROPOSAL

TO: KATHERINE L. SUPER
Deputy Assistant to the President for Appointments and Scheduling

FROM: D. ALLAN BROMLEY 
Assistant to the President for Science and Technology

REQUEST: To meet with the President's Council of Advisors on Science and Technology (PCAST).

PURPOSE: The PCAST will brief the President on several pending Science and Technology issues that will be especially relevant in the upcoming months. In particular, the council would like to advise the President on recent Panel findings regarding Technology and the American Standard of Living as well as Science, Technology, and National Security. PCAST will also present to the President plans for the Council's upcoming study of the Health of U.S. Colleges and Universities, chaired by David Packard.

BACKGROUND: The PCAST was established by President George Bush, in Executive Order 12700 on January 19, 1990, and meets with the President. The PCAST consists of twelve eminent American scientists, industry leaders, and distinguished members of the academic and research communities appointed by the President to advise him directly on issues involving science and technology. PCAST panels are subgroups of the full PCAST, created to focus on single areas of interest in science and technology.

PREVIOUS PARTICIPATION: In 1991: February 8, May 2, and July 12.
In 1992: none

DATE AND TIME: Friday, May 8, 1992 between 9:00 AM and 12:00 NOON is optimum. Also, between 1:00 PM and 5:00 PM May 7, 1992 is a good opportunity.

LOCATION: The Roosevelt Room

PARTICIPANTS: list attached

OUTLINE OF EVENT: The President joins the meeting in progress. He then asks the Chairman to proceed with the discussion.

REMARKS REQUIRED: None

MEDIA COVERAGE: White House Photographer only

RECOMMENDED BY: D. Allan Bromley

OPPOSED BY: No one

PARTICIPANTS

The President

D. Allan Bromley, Chairman, PCAST

PCAST Members

**Norman Borlaug
Solomon Buchsbaum
Charles Drake
Ralph Gomory
Mary Good
Peter Likins
Thomas Lovejoy
John McTague
Thomas Murrin
Daniel Nathans
David Packard
Harold Shapiro**

White House Senior Staff (Invited)

**Richard Darman
Samuel Skinner
Brent Scowcroft
Michael Boskin
Michael Deland**

OSTP Staff Members

**Karl Erb
D. A. Henderson
J. Thomas Ratchford
Eugene Wong
Vickie Sutton
Charles A. Dickens
Alicia Dustira
Ralph Brescia
William Snyder**

THE WHITE HOUSE

WASHINGTON

February 18, 1992

MEMORANDUM FOR THE PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE
AND TECHNOLOGY

FROM: D. ALLAN BROMLEY 
SUBJECT: Revised 1992 PCAST Meeting Calendar

As promised during the February PCAST meeting, I have asked my staff to revise our 1992 PCAST meeting schedule (attached). This revision of the calendar has led to the reinstatement of meeting dates in May, August, and November. These additions are in response to the Council's general consensus that more meetings will be necessary in order to accomplish the robust agenda we are setting for ourselves.

In addition to these changes, I have also asked my staff to schedule six additional sets of tentative meeting dates between now and November. These six additional dates will allow for any additional Council meeting time necessary to complete work on the Health of U.S. Universities project. Thus, these dates will only be used as necessary.

I would ask that you please have someone contact Dr. Alicia Dustira, the PCAST Executive Secretary, at (202) 395-4692 to let us know your availability for each of these 1992 dates.

Finally, please note that we have attached a bound copy of the President's FY 1993 R&D Budget for your future reference. This is identical to the photocopied version that was included in your February briefing book.

I am looking forward to a most productive year for PCAST.

Attachments:

Revised 1992 PCAST Meeting Schedule
Bound Copy of the President's FY 1993 R&D Budget

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

January 24, 1992

DETERMINATION TO CLOSE
THE FEBRUARY 7, 1992 MEETING OF THE PCAST PANEL ON
HIGH PERFORMANCE COMPUTING AND COMMUNICATIONS

The Panel on High Performance Computing and Communications of the President's Council of Advisors on Science and Technology (PCAST) will meet on February 7, 1992. The meeting will begin at 9:00 a.m. in the Room 180 of the Old Executive Office Building, Washington, DC. The meeting will conclude at about 5:00 PM.

The purpose of the Panel is to advise the PCAST on issues related to high performance computing and communications that have a bearing on long-range national goals, government regulation, the transition of Federal programs to industry, and on foreign access.

Proposed Agenda

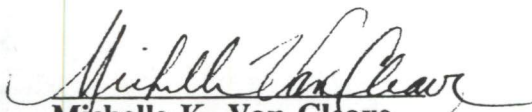
1. Briefing of the Panel by expert witnesses from industry on high performance computing and communication issues.
2. Briefing of the Panel by agency personnel on ongoing Federal activities in high performance computing and communications.

The briefing of the Panel by expert witnesses will necessarily involve exchanges of potentially sensitive proprietary commercial information. Also, the briefings of the Panel by agency personnel will necessarily involve presentation and discussion of detailed Federal agency budget information which, if prematurely disclosed, would significantly frustrate the implementation of agency budget decisions.

Therefore, I have concluded that in this instance the matters being presented and discussed by the Panel permit the meeting to be closed to the public under Section 10(d) of the Federal Advisory Committee Act, Public Law 92-463, as amended, principally, 5 U.S.C. 552b.(c)(1), (2), (6), and (9)(b).



D. Allan Bromley
The Assistant to the President
for
Science and Technology



Michelle K. Van Cleave
OSTP General Counsel

THE PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY

The President's Council of Advisors on Science and Technology (PCAST) reports directly to the President and is the Nation's highest level, independent advisory body in science and technology.

Established by the President in 1990, PCAST is designed to provide the President and senior members of his Administration with direct input from 12 distinguished members of the private sector spanning a very wide range of expertise, background and experience. The members are listed in Attachment A.

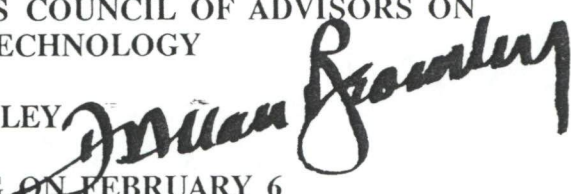
Beginning with its first meeting with the President at Camp David in February 1990, the Council with Presidential participation has held monthly one and one half day meetings. Additionally it has established a number of panels, each chaired by a Council member, but drawing widely on the private sector for membership, to address both questions raised by the President as well as issues that, in the opinion of the Council members, merit Presidential attention.

In addition to this input to the President, PCAST serves to provide vitally important validation and calibration from the private sector for a wide range of issues and decisions that are under consideration at Presidential level.

THE WHITE HOUSE
WASHINGTON

January 15, 1992

MEMORANDUM FOR THE PRESIDENT'S COUNCIL OF ADVISORS ON
SCIENCE AND TECHNOLOGY

FROM: D. ALLAN BROMLEY 
SUBJECT: PCAST MEETING ON FEBRUARY 6

A copy of the agenda is attached for the next meeting of the Council on February 6, 1992. As was indicated to you earlier, this will be a one day plenary meeting followed by Panel meetings on Friday, and will include a cocktail reception and dinner in the evening on Thursday.

Most of this meeting will focus on the President's FY1993 Budget. This year the Budget includes five crosscuts prepared by the Federal Coordinating Council for Science, Engineering and Technology (FCCSET). Copies of the crosscut booklets will be sent to you when they are first released immediately following the Budget. Although there will be an extremely short time between receiving the crosscut reports and the PCAST meeting, your evaluation and critique of the reports will be exceptionally valuable to us, particularly in preparing our presentations for Congressional hearings in February.

Therefore, I am asking each of the PCAST members to read one crosscut document carefully before this meeting, and to bring 1 - 2 pages of comments on the assigned crosscut to the meeting. I will be asking for your thoughts concerning the content as well as the process outlined in the proposals. The assignment for each PCAST member is indicated on the attached page.

At the meeting, you will hear very brief presentations on each of the five crosscuts and then we will be discussing your evaluations of each one. After our discussions, I will ask the Council to prepare a short (2-3 page) critique of each crosscut for several possible uses within the Executive Office of the President.

I look forward to seeing you on the sixth.

Attachments



July 8, 1991

To : Dr. Bromley

Re: Your report to me of July 2nd

1. Read it with interest.

2. I think it is important that Dept. Of Education stay informed on any deliberations having to do with Education. Maybe Lamar Alexander could send over a representative when education is on your agenda. This is good stuff and I want to be sure that everyone knows what you are doing on, for example, math and Science. Just a thought !!

cc: John Sununu

CB /

FROM THE PRESIDENT

THE WHITE HOUSE
WASHINGTON

July 2, 1991

91 JUL -5 PM 1:35

07
7-8

MEMORANDUM FOR THE PRESIDENT

FROM: D. ALLAN BROMLEY *Adm*

SUBJECT: Your Council of Advisors on Science and Technology

Mr. President, I would like to summarize the current activities of your Council of Advisors on Science and Technology.

Since February 1990, the President's Council of Advisors on Science and Technology (PCAST) has met 12 times and held 5 discussions with you. During our meetings, you indicated a number of topics you would like PCAST to consider. Also, the Council has had extensive discussions with various senior officials within the Executive Office of the President, including the Vice President, Michael Boskin, Robert Gates, Michael Deland, and Roger Porter, to help better understand the Administration's goals and how the PCAST could be most helpful. Further, the Council talked in detail with many agency and department heads including James Watkins, Richard Truly, Donald Atwood and others to get their views on how the PCAST could be responsive to you and the Administration.

Mr. President, as Chairman I can report that the PCAST has been listening and is working intently on addressing many issues raised during these discussions. Seven of the most important are briefly described below. Each has been given to separate, ad hoc, discussion groups within PCAST for further discussion and at an appropriate time we would look forward to reporting to you on these deliberations.

The first issue is mathematics and science education. The importance of this issue was touched upon in nearly every PCAST discussion. Council member Peter Likins, President of Lehigh University, has taken the lead in this area with the goal of (1) providing an extragovernmental perspective on the work of governmental groups, including the Committee on Education and Human Resources of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET); and (2) undertaking specific studies to address such relevant questions such as: how best to approach the very serious problems in US precollege education, are undergraduate and graduate enrollments in engineering and the sciences appropriate society's needs and the talents of our population? Are Ph.D. recipients likely to be available to meet demands for faculty in engineering and the sciences in the coming decade? How can enrollments in these areas best be altered?

A second issue involves the global environment and natural resources. Council members Thomas Lovejoy of the Smithsonian, David Packard, and Nobel laureate Norman Borlaug, are taking the initiative to: identify areas of potential interaction and collaboration with the private sector in global change research; provide private sector input on societal needs that can be served by further scientific research in the areas of natural resources, and earth and environmental sciences; and identify areas in need of further study in order to protect biological diversity and minimize the impact of human populations upon it.

International economic competitiveness is a third issue for PCAST focus. As with mathematics and science education, maintaining our science and technology base was pointed to by Administration officials as crucial to increased U.S. economic competitiveness. Council member Ralph Gomory, President of the Sloan Foundation, was asked to lead a group considering the areas of new technology, product improvement, and the technical workforce. Ralph will then work to identify ways to enhance the partnership between the government and the private sector with the goal of improving our competitive position internationally.

The war in the Gulf, among other things, demonstrated and confirmed the vital link between technology and national security. In your statement, **National Security Strategy of the United States**, you acknowledge that the economic and military strength of the United States rests on technological superiority. I have asked Council member Sol Buchsbaum, Senior Vice President for Technology System at AT&T Bell Laboratories, and Johnny Foster, Chairman of the Defense Science Board, together with David Packard and others to define and discuss the role science and technology are expected to play vis-a-vis national security during the decade of the 1990's and beyond in a vastly changed world environment. They will examine how effectively science and technology frontiers are being integrated into our national security activities; identify gaps or deficiencies, and where appropriate, propose alternative mechanisms and approaches.

Because of its promise for improved health care and American quality of life, and because the global market holds many promises for American industry, the area of bioscience and corresponding biotechnology is a fifth PCAST topic. Council member and Nobel laureate Daniel Nathans, Professor of Molecular Biology and Genetics at Johns Hopkins University School of Medicine will chair this effort. Daniel and his group will provide information to PCAST on: ways to enhance the transfer of biotechnology from Federally supported laboratories and University groups to American industry and how to encourage private sector leadership; ways to provide private sector input on current and possible future governmental policies that will enhance basic research in the life sciences and long term research and development by the biotechnology industries.

A sixth area of PCAST focus is on research megaprojects in the sciences. Council member John McTague, Vice President for Technical Affairs at Ford Motor Company, is taking the lead with Harold Shapiro, President of Princeton University. They are examining the relative roles of megaprojects, both of the large-scale, single facility type such as the Superconducting Super Collider and the multi-investigator, multi-facility type such as the Human Genome Project, with the smaller individual

investigator-initiated science projects. They will examine the potential for greater international cooperation in the megaprojects, and suggest the most appropriate fora - governmental and scientific, national and international - in which such cooperation could be further discussed and coordinated.

A seventh topic being addressed by the PCAST is high performance computing and communications. Your Presidential Initiative in the 1992 budget in this very important area laid the groundwork for maintaining and extending U.S. leadership in both the research and education communities. Here, Sol Buchsbaum is taking the lead to build upon current Federal activities and to explore ways to encourage the private sector participation and leadership that will maintain and ensure future U.S. competitiveness in this field.

The Council is pleased to respond to the challenge you have given it in examining these issues, and values the opportunities it has had thus far to provide advice. We look forward to providing you with additional private input on each of these seven areas and on others of importance to you and your Administration.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

July 3, 1991

THE PRESIDENT HAS SEEN

91 JUL -5 PM 1:35

*Allan
read
Tues
7-8-91*

MEMORANDUM FOR THE PRESIDENT

FROM: D. ALLAN BROMLEY *Allan*
SUBJECT: FEDERAL COORDINATING COUNCIL FOR SCIENCE,
ENGINEERING AND TECHNOLOGY

I would like to update you on recent progress of the Federal Coordinating Council for Science Engineering and Technology (FCCSET). As you may recall, in February of this year, I provided you with reports (Global Climate Change, Math and Science Education, High Performance Computing and Communication) that were prepared by FCCSET. These reports described three integrated, coherent, national programs which you recognized as priority areas for research and development in the FY 1992 Budget to the Congress.

✓ Your FY 1992 Budget initiative in High Performance Computing and Communications (HPCC) has drawn much attention in the Congress. Though the HPCC program requires no further legislation, authorization committees in both Chambers are proceeding in this direction. The Office of Science and Technology Policy continues to work closely with the Economic Policy Council, White House Legislative Affairs, Counsel and FCCSET member agencies to negotiate acceptable Congressional language which endorses your Administration's proposal. The House of Representatives is due to take the measure to the Floor on July 11; Senate Energy and Senate Commerce Committees are nearing a compromise measure, with Floor action likely to occur shortly thereafter. We anticipate an enrolled bill in the early fall.

|| I am pleased to be able to report to you that there is an excellent fit between America 2000 and the specific priorities identified by FCCSET for mathematics and science education strategies within the Federal agencies. Lamar Alexander, David Kearns, Jim Watkins, and I have met personally to discuss these issues and I am pleased that the Secretary of Education will be joining the FCCSET as a member of the Council. Deputy Secretary of Education Kearns has accepted an invitation to serve as Co-vice Chairman of the FCCSET Committee on Education and Human Resources (CEHR), thereby helping provide leadership to interagency efforts to develop the FY 1993 Budget options.

Progress continues on your initiative to create regional environmental research institutes to advance global change research, a result of your leadership during the White House Conference on Science and Economics Research Related to Global Change. Through the work of member agencies of the FCCSET Committee on Earth and Environmental Sciences, the United States will convene a workshop from July 15

to July 19, 1991 in San Juan, Puerto Rico to discuss a draft agenda for the Western Hemisphere Institute's scientific and economic research program. The National Science Foundation has played a key role in organizing the workshop and working with the international scientific community. I shall be giving the keynote address and we expect the workshop to result in a report containing a series of options and recommendations on the overall functions of such an institute, identification of the capabilities and facilities required, options for organization, structure, management, funding and criteria for site selection. A second meeting will occur later this year, at which time we anticipate formal agreement on Institute plans and commitment of resources to establish and operate the Institute. This initiative for global change research, which you began, will assist the countries of the Western Hemisphere by promoting development of a global network of regional institutes thereby aiding in our understanding of the very important processes which underlie global change.

As you will recall, Mr. President, on July 17, 1990 you issued the Decade of the Brain Proclamation calling upon all public officials and the people of this country to observe the decade with appropriate programs and activities. Subsequent legislation, sponsored by the late Congressman Silvio Conte, directed OSTP to lead Federal activity in coordinating the scientific effort for the Decade. As Chairman of FCCSET, I asked the FCCSET Committee on Life Sciences and Health to undertake the role of identifying and coordinating Federal research efforts and resource needs of stimulating international cooperation, and assessing national and international policy issues concerning the brain and behavioral sciences. The attached report produced by the FCCSET, Maximizing Human Potential: Decade of the Brain, 1990-2000 recognizes the work of 22 separate Federal agencies and institutes involved in the Decade of the Brain initiative. This report was released on April 24, 1991, when I had the opportunity to pay tribute to the Honorable Silvio Conte for his interest in this field of science as well as to the many Federal agencies that are leading the way in basic research, technology, and international activities.

On April 15, 1990, FCCSET met to discuss opportunities for R&D crosscut analysis as a part of the planning process for the FY 1993 Budget. FCCSET agreed to continue interagency R&D planning in the three fields identified by your FY 1992 budget (global change research, mathematics and science education, and HPCC), and to initiate strategic planning in two other areas: biotechnology research, and advanced materials and processing. As you look to each Cabinet officer to help identify priorities for FY 1993, it is my intent that the FCCSET forum complement this process, recognizing that there are R&D issues that transcend individual agencies. The 5-year budget agreement requires both the Administration and Congress to make difficult choices on spending priorities. I am committed to working with other senior Administration officials to utilize the FCCSET forum as one vehicle to help bring a government-wide planning framework to areas of R&D involving several Federal agencies.

As there have been changes in the leadership of your Federal R&D departments and agencies, membership of FCCSET has been adjusted. Thus, I am attaching an updated list of your appointees currently serving on the FCCSET together with a listing of the FCCSET standing committees.

I look forward to providing you a subsequent update in September on FCCSET activities as we complete preparation of options for your FY 1993 Budget consideration.

Attachments