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ABSTRACT

This pamphlet presents conclusions related to the compendium of factual data called "Science and Engineering Indicators" (published every 2 years) about the strengths and weaknesses of American science and technology and offers recommendations for action. American science and engineering are vibrant and productive, although the United States no longer dominates science and technology as it once did and although American education in science, engineering, and mathematics is a national problem that has not yet been effectively addressed. There is a need for new commitment to provide human, financial, and physical resources commensurate with the importance of science and technology to America's future. The solution will require cooperative action and increased investment by industry and universities, by state and local governments, and by the federal government. (YP)

A View from the National Science Board

THE STATE OF US SCIENCE AND ENGINEERING

February 1990

I. Introduction

Every two years the National Science Board publishes factual data on the condition of American science and engineering in **Science and Engineering Indicators** — a widely-used resource in government, industry, and academia.

Accompanying **Science and Engineering Indicators**, the Board in this statement presents its conclusions about the strengths and weaknesses of American science and technology and its recommendations for action.

In sum, American science and engineering are vibrant and productive, although the United States no longer dominates science and technology as it once did. And American education in science, engineering, and mathematics is a national problem that has not yet been effectively addressed.

We need a new national commitment to provide human, financial, and physical resources commensurate with the importance of science and technology to America's future. The solutions will require cooperative action and increased investment by industry and universities, by state and local governments, and by the federal government.

II. The Competitive Context for American Science and Engineering

a. *The Shift to a World Economy*

Until recent decades the U.S. economy was largely isolated from the rest of the world. Our market was the largest in the world. Our companies could prosper without exporting, and technological leadership protected them from imports.

None of this is true any longer. Europe and Japan recovered from World War II. Industrialization has spread rapidly in the third world. Better transport and communications have made world-wide industrial and commercial organizations possible, and competition has made them necessary. World trade has increased seven-fold since 1970; today over two-thirds of the goods we produce must compete against merchandise from abroad.

In this situation an effective science and technology policy must recognize that we are now one competitor among many, no longer uniquely advanced over other countries. Policy must emphasize cooperation among all sectors and ask how best to meet international competition.

b. *The Shift to a Knowledge Economy*

Knowledge has become a critical commodity in the global economy, diminishing the importance of natural resources and low-cost labor. Industries based primarily on knowledge and fast-moving technology, such as computers, semiconductors, synthesized materials and biotechnology, are becoming new basic industries, reducing the relative importance of those based on natural resources.

In the knowledge economy, progress is astonishingly fast. Electronics, semiconductors, and computers have been developing rapidly for thirty years, and show no signs of stopping. Biotechnology is beginning an evolution that may be just as important and just as fast. So is manufacturing technology — a field we have neglected, but our competitors have not.

To compete, new knowledge must be both created and then applied quickly and economically to create new products and processes. Failing this, the economic benefits will be largely lost to others. Innovating faster and more effectively than one's competitor is the key to prosperity.

III. The Status of American Science and Technology

The National Science Board finds many signs of strength in American science and engineering in 1989:

- Our R and D effort remains the largest and strongest in the world.[1]
- Since 1980, the number of Americans employed in science and engineering has risen twice as fast as employment in general.[2]
- We have recognized that women and minorities must be brought into science and engineering in much larger numbers, and begun programs to increase their participation.
- The American public believes in the benefits of science and technology.[3]
- More students are taking high school courses in mathematics and science.[4]
- American graduate education remains the best in the world, with large numbers of foreign students coming here to study.[5]
- At least thirty-eight state governments have set up special agencies to encourage science and technology as a key element of economic development.[6]

Yet the Board also finds many trends that suggest weakness in our national effort in science and technology:

- In international competitions in mathematics and science, American students at the 5th, 9th, and 12th grade levels perform poorly in comparison with industrialized nations and even some third world countries.[7]
- Fewer college freshmen expect to major in technical subjects.[8]
- Too few of our citizens pursue graduate degrees in mathematics, science or engineering.[9]
- Despite much effort and some improvement, the number of minorities and women in science and engineering remains disproportionately small.[10]
- Although twenty years ago the United States had a far larger fraction of its labor force employed in science and engineering than any other country, today a number of our competitors have employment fractions comparable to ours, and are increasing their numbers of scientists and engineers more rapidly than we are.[11]
- Similarly, twenty years ago our rate of investment in R and D, as a fraction of GNP, was far higher than that of any other country. Today Japan and West Germany exceed our rate, and other countries equal it.[12]

- Comparing only civilian-oriented R and D, our rate of investment, as a fraction of GNP, is only about two-thirds that of Japan and West Germany. And civilian-oriented R&D is by far the most important in economic terms.[13]

IV. Necessary actions

We should take action to correct the weaknesses in this mixed picture of the state of American science and technology. What should we do?

First, although the individual investigator remains the mainstay of scientific inquiry, modern science and engineering research is more organized, capital intensive, multidisciplinary and cooperative than in the past. Our universities must adapt to meet this need.

Second, we must dramatically improve precollege and undergraduate education. Only a well educated work force can exploit new knowledge effectively, and only a technically competent population can deal with the political issues that modern technology raises.

- Our schools must put first priority on basic education. Students should be required to take science and mathematics throughout high school.
- We need better science and mathematics teachers, and we need more of them. To get them we must be willing to pay what they are worth.
- Undergraduate science and engineering needs major improvement, especially in areas such as research opportunities and instrumentation.

Third, we must persuade more of our best students to study science and engineering, at both undergraduate and graduate levels. Scientists and engineers are our researchers and teachers. They generate the knowledge that makes technological innovation possible. And in a modern technological society, more people with technical training should be leaders in business, government, and the professions.

Persuading enough qualified people to undertake the rigorous training this requires will be a continuing problem. The number of students of college age will continue to decline until almost the end of the century. A larger proportion of the labor force will be women and minorities, who have historically not been attracted to science and engineering. Only a concerted effort with special programs can meet this challenge.

Part of the answer also must be an expanded program of graduate fellowships and traineeships — sufficient to provide incentives to the best science or engineering students to undertake graduate study. We will face serious shortages of research scientists and engineers if we cannot deal effectively with this problem.

Fourth, we must greatly strengthen university basic research. Universities are the source of most of the fundamental new ideas that drive innovation, and of all new research scientists and engineers.

But the nation has paid insufficient attention to university basic research in the last twenty years. To keep us competitive with other countries, investment in it should keep pace with growth in the high-technology sector of the economy. This will take a cooperative effort involving both the public and private sectors.

- Federal support for academic research and development, as a fraction of GNP, is no higher than it was in 1968.[14] Relative to the size of the high-technology sector of the economy – which depends on it uniquely – university basic research has declined in the last decade. Furthermore, the growth that has occurred has been mainly in the life sciences – important for health and biotechnology but less important for international competitiveness than the physical sciences and engineering.

Fifth, we must develop better cooperation among industry, universities, and governments. Although universities create the new ideas and educate the people, industry turns ideas into products and thus drives economic growth. Research that is not rapidly incorporated into new products and processes fails to achieve its economic potential.

- Bridging the gap between industry and universities is an area in which government can lead. One good idea was the development over the last five years of multi-disciplinary science and engineering centers on university campuses. These centers do basic research in economically important areas, and help educate students in practical industrial problems.

Sixth, we must encourage greater international cooperation and sharing in basic research. This is fundamentally a function of the spread of science and engineering capabilities around the world. We can no longer depend entirely on our own resources to stay ahead.

- Young scientists and engineers must prepare themselves to work in a global environment through study of foreign languages and cultures and experience in foreign research sites.
- In basic research, open communications among researchers in all nations must remain the rule. More active exchange programs can help develop the personal contacts on which such communications depend.
- More international sharing of the costs of expensive research facilities like telescopes is desirable.
- Coordinated use of national facilities such as satellites, ships, and aircraft can increase the effectiveness of large observational programs, especially in the geosciences.
- Increasing economic integration in Europe raises the possibility that cooperative research activities there will become less accessible to American scientists and engineers. Fair reciprocal arrangements for participation in such programs are important. A special effort to strengthen cooperation with Western Europe is thus desirable.
- Adequate protection of intellectual property rights in all countries is a critical need.

V. A Cooperative Effort

The remedies suggested can only be accomplished by a cooperative effort among all concerned sectors.

Although the National Science Foundation is the only agency whose sole responsibility is the health of American science and engineering, many other agencies play important roles in this area. The Board strongly urges all Federal agencies with a mission in this area to address the remedies suggested in a cooperative manner.

Beyond the Federal government, however, industry, the universities, and state governments also have major responsibilities. State governments have been much more active in supporting research in recent years, and have been major forces in bringing industries and universities together in joint projects. And the responsibility of state and local governments for most precollege and undergraduate education means that they must take the lead in addressing those problems.

Industry's interest in having available a well educated workforce, able to deal effectively with modern technology, has led it already to spend substantial sums in support of local education, and its interest in the latest technology has led it into cooperative relations with universities. These trends should be encouraged and expanded wherever possible.

Finally, universities must reach out to industry and to state and local governments in order to develop cooperative programs that address the real needs of these sectors. Through activities of this sort universities can demonstrate anew their importance to our national economic well-being, and ensure that they have the resources necessary to fulfill their historic missions.

1. *Science and Engineering Indicators - 1989*, pp. 3, 96.
2. *Id.* pp. 6, 63-65.
3. *Id.* pp. 170-72.
4. *Id.* pp. 32-33.
5. *Id.* p. 53.
6. *Id.* p. 100.
7. *Id.* pp. 8, 27-31.
8. *Id.* pp. 9, 50-52.
9. *Id.* pp. 10, 53-55.
10. *Id.* pp. 7, 67-69.
11. *Id.* pp. 80-81.
12. *Id.* pp. 3, 96.
13. *Id.* pp. 4, 96.
14. *Science and Engineering Indicators - 1987*, p. 78.

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