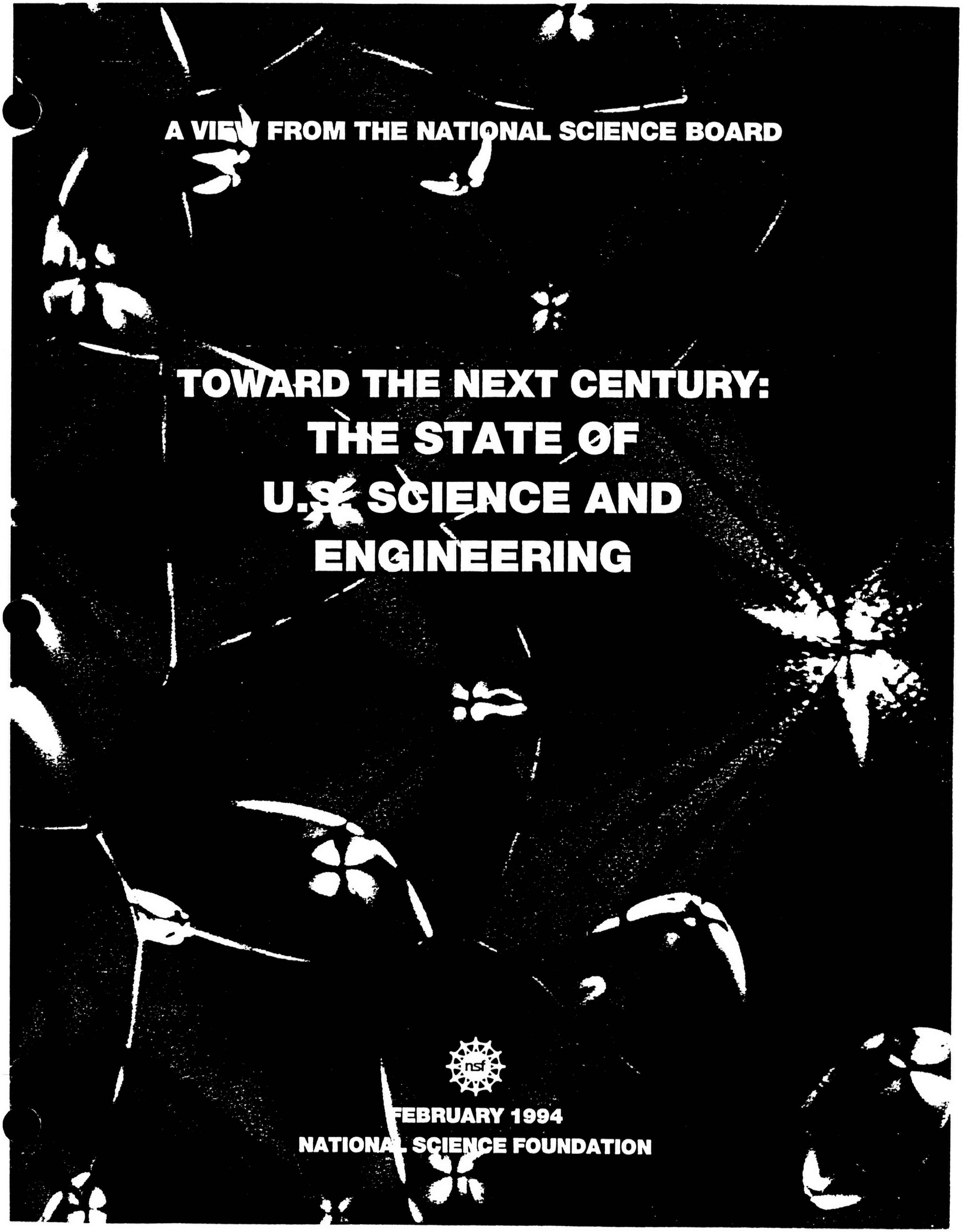

A VIEW FROM THE NATIONAL SCIENCE BOARD

TOWARD THE NEXT CENTURY: THE STATE OF U.S. SCIENCE AND ENGINEERING

FEBRUARY 1994
NATIONAL SCIENCE FOUNDATION

I. Introduction

The National Science Board (NSB) is charged with focusing national attention on major issues of science and engineering research and education. An important aspect of this responsibility is the publication of *Science & Engineering Indicators*, a biennial report of data and trends on American research and education in the sciences, mathematics, and engineering. This report, submitted to Congress through the President, provides a quantitative overview of the health and achievements of the science and technology enterprise. To accompany *Science & Engineering Indicators - 1993*, the Board presents this statement highlighting issues that must be addressed by the Nation to maintain continued U.S. leadership in science and technology and to assure the productivity of our research and education systems.

II. The Changing Context for American Science and Engineering

> *"Investing in science and technology is investing in America's future."* [1]
>
> William J. Clinton
> November 23, 1993

The 11th issue of *Science & Engineering Indicators* appears at a crucial time. As the 20th century draws to a close, the world is reaping the benefits of a half-century of broad-based Federal investment in science and technology. The knowledge produced by scientists, mathematicians, and engineers has dramatically increased agricultural production; it has created new industries such as semiconductor manufacturing and biotechnology; it has connected the world with information networks; and it has created the means for a dramatically healthier and longer lifespan.

Science and technology will be even more important in the next century. With the end of the Cold War and the rise of a global economy, national and international goals for science and technology are being shaped by new forces of economic interdependence and competition. The knowledge produced by scientists, mathematicians, and engineers must be utilized to foster sustainable development in all nations and to contribute to the solution of global problems.

Within the new international context, the health of the U. S. economy and the competitiveness of our industries rely increasingly on the exploitation of scientific and technological advances and on the availability of an adaptable, educated, and technically prepared workforce. The growing internationalization of science and significant improvements in human resources and research capabilities of other nations require that the United States maintain and enhance its own capabilities to take advantage of discoveries around the globe.

The next few years will be critical for establishing the policy directions that will guide us in the new era. In the transition to a new political and economic framework, it is vital that the United States maintain the momentum generated by decades of sustained growth and commitment to excellence in science and engineering. The ability to do good science, and to do good with it, are not guaranteed. Both will require investment in all components of the system—industrial research and development (R&D), national laboratories, and academic institutions—as well as in areas of strategic importance requiring special attention.

III. Trends

Investment in Science and Engineering

The United States still leads the world in total national and industrial R&D investment[2] and continues to set the standard for excellence in research and higher education. At the same time, there are concerns about U.S. performance in the global context.[3]

Other countries are closing the gap with—or are even leading—the United States by some measures.[4] Newly industrialized countries have sharply increased their investment in science and engineering. As one result, in 1991 the combined natural science and engineering baccalaureates of six Asian nations exceeded those of North America and Europe taken together.[5]

Total national R&D expenditures, adjusted for inflation, rose rapidly from the mid-seventies through the first half of the eighties. However, since 1985 they have been virtually flat.[6] Furthermore, as noted by the recent NSB report, *The Competitive Strength of U.S. Industrial Science and Technology*, "... the real rate of growth in U.S. industrial R&D spending has declined since the late 1970s and early 1980s."[7]

The photomicrograph on the cover depicts crystallites of the common vitamin ***Biotin (Vitamin H).***

The current Federal R&D budget reflects continuing adjustment to post-Cold War priorities and renewed focus on civilian needs. In particular, over the last decade defense spending has declined from 69 to 59 percent of the Federal R&D budget.[8] Nevertheless, despite the increasing importance of civilian research to innovation and economic growth, we continue to lag behind some other industrialized nations in the percentage of the gross domestic product devoted to nondefense R&D.[9]

Colleges and universities continue to increase their share of national R&D.[10] But Federal funding as a proportion of the total support for university research has declined since 1980, while the contributions from industry, state and local government, and universities have increased. Also, in spite of greatly increased university investment in research facilities and instrumentation, a substantial proportion of academic research space is in critical need of renovation and repair, and research instrumentation needs have grown.[11]

Human Resources and the Workforce

The public attitude regarding both the value of continued investment in science and technology and the importance of education to achieving personal and national goals remains strongly positive.[12] At the same time, the American public's level of scientific literacy and general technical preparedness are not adequate to meet the needs of the changing economy.[13] A productive, adaptable, and skilled technical workforce for all sectors of the economy depends on the quality of the Nation's education system at all levels. Consequently, the state of education in science and mathematics at the precollege level remains a major national concern. In international comparisons, the United States continues to lag behind the highest achieving nations, even when comparing our best school districts with their national performance.[14]

The U.S. system of higher education is facing new pressures and financial constraints. Enrollments in institutions of higher education continue to rise, and the student body has become increasingly diverse with respect to age, ethnicity, and walk of life. At the same time, the absolute number of undergraduate degrees awarded in engineering, mathematics, and computer sciences continued to decline in 1991. However, the increase in full-time undergraduate engineering enrollments from 1990 through 1992, after a 9-year decline, portends a rise in degrees in the coming years. While women and African American, Hispanic American, and Native American minorities have increased their representation in science and engineering disciplines, their participation rates remain unacceptably low.[15]

Two-year institutions have absorbed most of the increase in college enrollments in recent years. But associate degrees in engineering technology, mathematics, computer sciences, and engineering have fallen since the mid-1980s.[16] Declining interest in these degrees in 2-year colleges has special significance for efforts to increase participation by groups traditionally underrepresented in technical disciplines—groups that form a disproportionate share of the enrollment of 2-year institutions.

Job opportunities and salaries for recipients of science, mathematics, and engineering degrees remain better than for other disciplines.[17] But there has been a decline in overall science and engineering employment rates. In some fields, high proportions of new Ph.D. recipients are taking post-doctoral positions, and part-time employment is becoming more common at universities and colleges. Some professional associations also report extended time for job searching for Ph.D. graduates.[18] A much more pessimistic outlook pervades defense-related industries. In engineering occupations, downsizing among some industries and reduction in defense spending have contributed to a doubling of the unemployment rate from 1987 to 1992.[19]

Partnerships and Institutional Concerns

Partnerships and cooperative arrangements in science, mathematics, and engineering research and education are becoming more important and prevalent both domestically and internationally. The excitement and importance of multidisciplinary research, the cost savings achieved through shared facilities and resources, the more rapid diffusion of knowledge, and the explosion of information networks—all these factors have provided powerful incentives for the increase in collaborative approaches.

In the United States, cooperation in R&D activities within and among sectors increased rapidly over the last two decades. Activities such as university-industry research centers, multi-firm R&D alliances, and coauthorship of scientific articles have increased.[20] States have become important players in promoting cooperation at the local level.[21]

For the Federal Government, the continuing need to encourage innovation and to ensure the most effective use of scarce financial resources has resulted in a stronger focus on cooperative activities. The reorganization and downsizing of defense-related activities underscore the urgency for national laboratories to cooperate with the private sector in defining new missions with benefits to civilian needs.[22]

IV. Issues and Actions

> *"Science, by itself, provides no panacea for individual social, and economic ills; it is effective in assuring the national welfare . . . as a member of a team . . . [But] without scientific progress, no amount of achievement in other directions can insure our health, prosperity, and security as a nation in the modern world."*[23]
>
> Vannevar Bush, 1945

Investment in Science and Technology

A robust knowledge base appropriate for economic growth, long-term job creation, protection of the environment, and social well-being requires a conscious commitment to strong and consistent long-term support for research and education as a part of a balanced portfolio of activities and investments. A coherent national science and technology policy, a stronger industrial research effort, and a refocused mission for Federal laboratories are essential components of this commitment. Equally critical, as stated in the May 13, 1993, NSB white paper, ***In Support of Basic Research***,[24] is a strong foundation of basic research.

The process of research in fundamental sciences and engineering expands the knowledge base and directly contributes to strategic national goals through pioneering discoveries and the continued development of a cadre of educated people who are the source of new solutions and new opportunities. Apart from its contributions to specific areas of national importance, the overriding strategic value of basic research resides in going beyond research areas and questions whose utility is understood to those whose applications have yet to be discovered. As noted by industry leaders in a recent report, the primary value of the university is in basic research and education. These activities require and deserve stable Federal support.[25]

Recommendations:

- *An increased fraction of savings resulting from cuts in defense R&D spending should be redirected to dual-use technologies and support of civilian research priorities in strategically important areas.*
- *A national initiative should be established for the renovation and modernization of university research facilities and major capital equipment.*

A Technically Prepared Workforce, A Scientifically Literate Public

A technically competent and scientifically literate workforce drawing on a diverse and talented population is essential to this Nation's future. Changing labor market conditions for scientists and engineers—and the broad-based requirement for a more technically trained, qualified, adaptable workforce and citizenry—require continued national leadership to ensure quality education at all levels. Increasingly important in this context is the coordination of the educational process with the present and future needs of the marketplace.

Recommendations:

- *Mathematics, science, and engineering curricula at all levels of education should be evaluated to ensure that all students obtain the background needed for the workforce of the future. Appropriate education should be responsive to workforce needs and opportunities in industry and government as well as universities.*
- *Federal agencies must increase their cooperation with state governments, educational institutions, and other groups in systemic educational reforms, such as those promoted by the National Science Foundation, to improve the quality of precollege education in the sciences, mathematics, and engineering.*
- *Building on successful models, Federal and state governments must redouble their efforts to increase the participation of women and underrepresented minorities. At the post-secondary level, special attention should be given to 2-year institutions, which have absorbed the great bulk of growth in enrollments and serve a highly diverse population.*

New Partnerships and Institutional Issues

The coming century will impose greater demands and responsibilities on all who have a stake in the discovery and use of knowledge. A more rapid pace of discovery, the increasing importance of multidisciplinary research, and the confluence of research interests and opportunities across institutional lines call for industry, academia, and government to supplement traditional modes of research support with creative approaches and relationships, both domestically and internationally.

Innovative institutional arrangements appropriate to the needs of complex multidisciplinary research teams have been the focus of many new government programs. These new approaches, complementing the work of individual investigators, must continue to be tested and successful models expanded. New university partnerships with industry respond to pressures for greater relevance to societal needs in research and education, and for more effective diffusion of knowledge and ideas from academic research to industrial applications. They also offer special opportunities to explore new research directions.

At the same time, the growing number of collaborative arrangements often results in more complex issues concerning conflicts of interests and individual property rights. Regional economic development initiatives, incorporating collaborative research arrangements between industry and academia, will call on states to assume a stronger, catalytic role.

Recommendations:

- *Federal agencies that provide substantial support for science and technology must pursue international cooperation more systematically in science, mathematics, and engineering research to expand the global knowledge base, increase diffusion of knowledge generated abroad to U.S. scientists and engineers, and share the opportunities of global research initiatives and expenses of operating costly research facilities and capital equipment.*
- *Clear guidelines are needed with respect to conflicts of interests and intellectual property issues as they apply to academic research.*
- *Federal and state governments must develop more coherent and supportive relationships with academic institutions to encourage a greater use of knowledge generated by academic research.*

A New Context for Science and Technology Policy

The new global environment and constraints on the Federal budget demand a fresh and vigorous national vision for public support of science and technology and better organizational and policy coordination within both the Executive Branch and Congress. Examples of important new approaches to rationalize Federal missions and processes in science and technology include the new National Science and Technology Council, chaired by the President, and its Fundamental Science Research Committee.

There is also a universally recognized need for greater accountability in the planning and implementation of all government missions, including support for research and education. Important Administration efforts to increase the efficient use of resources call on agencies to emphasize: self-assessment; improved performance of their missions; close attention to priority setting and planning; and support for flexible, cooperative arrangements that take advantage of good ideas wherever they are found. New cross-agency initiatives, such as the Technology Reinvestment Project, that focus on the development of technologies serving both civilian and defense-related needs suggest productive models for leveraging limited research dollars.[26]

Recommendations:

- *All agencies should systematically assess their contributions to the Nation's R&D capacity, both by evaluating their own programs and increasing coordination with other agencies in areas of mutual interest.*
- *The science and engineering communities need to communicate to Federal sponsors and the public the linkage of their activities with national goals.*
- *Federal advisory and deliberative structures for science and technology should more systematically seek the input of private industry and other stakeholders.*

V. Conclusion

American science and technology are challenged by extraordinary opportunities to expand the knowledge-based horizons of humankind. Shaping a new national strategy for science and technology and the means to implement it and evaluate its success is the major task confronting Federal science and technology policy today.

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1. William Jefferson Clinton, "Statement of the President" (Washington, D.C.: White House Office of Media Affairs, November 23, 1993).
2. National Science Board, *Science & Engineering Indicators - 1993*, NSB 93-1 (Washington, D.C.: Government Printing Office, 1993) p. xvii.
3. Ibid., pp. xvi, xviii.
4. Ibid., p. xvi.
5. Ibid., p. xvii.
6. Ibid., p. 91.
7. National Science Board, *The Competitive Strength of U.S. Industrial Science and Technology: Strategic Issues*, NSB-92-138 (Washington, D.C., National Science Foundation, 1992), pp. ii.
8. *Science & Engineering Indicators - 1993*, p. xxi.

9. *The Competitive Strength of U.S. Industrial Science and Technology*, pp. i-ii.
10. *Science & Engineering Indicators - 1993*, pp. xix, xxi.
11. Ibid., pp. 141-43.
12. Ibid., p. xxx.
13. Ibid., p. 3.
14. Ibid., pp. 16-17.
15. Ibid., pp. 34, 42-43.
16. Ibid., p. 46.
17. Ibid., p. 60.
18. For data on part-time positions, see Science Resources Studies Division, National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States: 1991* (Washington, DC: NSF, forthcoming.) For other Ph.D. employment data, see *Science & Engineering Indicators - 1993*, pp. 76-78.
19. *Science & Engineering Indicators - 1993*, p. 60.
20. Ibid., p. xxii.
21. Ibid., p. 96.
22. Ibid., pp. 119-20.
23. Vannevar Bush, *Science —The Endless Frontier* (Washington, D.C.: National Science Foundation, reprinted May 1980) p. 11.
24. National Science Board, *In Support of Basic Research*, NSB-93-127 (Washington, D.C.: National Science Board, May 1993).
25. The Government-University-Industry Research Roundtable and Industrial Research Institute, *Industrial Perspectives on Innovation and Interactions with Universities: Summary of Interviews with Senior Industrial Officials* (Washington, D.C.: National Academy Press, February 1991), p. 20.
26. *Science and Engineering Indicators - 1993*, pp. 108-16.

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