[COMMITTEE PRINT]

REPORT OF THE TASK FORCE ON THE HEALTH OF RESEARCH

CHAIRMAN'S REPORT

TO THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED SECOND CONGRESS

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GEORGE E. BROWN, Jr., *Chairman*

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LETTER OF TRANSMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, DC, June 26, 1992.

Members of the Committee on Science, Space, and Technology

I am pleased to transmit the report of the Task Force on the Health of Research. The Task Force was convened at my request in May 1991, in order to investigate widespread reports of "stress" in the federal research system, and to define a more active role for the Committee in the forging of science policy for the national good. The Task Force was composed of staff representatives of full Committee and all subcommittees. This report summarizes their deliberations and conclusions. It does not represent either findings or recommendations adopted by this Committee.

For the last fifty years, the United States has supported the world's most innovative and productive scientific research system, a system designed to create new knowledge and technology that can help, in the words of Vannevar Bush, to "insure our health, prosperity, and security as a nation in the modern world." Today, however, the United States faces wide-ranging societal crises and challenges, in our educational system, our environment, our manufacturing sector, our health care system, our inner cities, our financial institutions, even our system of government.

This paradox—growing knowledge, accompanied by growing societal crisis—implies a complex, nonlinear relationship between advances in knowledge and advances in society. More specifically, it suggests either that we are not adequately using the knowledge that we already have, or that we are not sufficiently producing the knowledge that we actually need. Of course, both of these conditions may be partly true.

This report offers some strategies and insights that may help us begin to solve the knowledge paradox. It challenges us to create better linkages between the research that we authorize, and the national goals that we seek. The report is intended to be a beginning, a tentative agenda for Committee action and future debate. I commend it to your attention.

Sincerely,

GEORGE E. BROWN, Jr.,
Chairman.

REPORT OF THE TASK FORCE ON THE HEALTH OF RESEARCH

SUMMARY

This report outlines broad strategies by which the Committee on Science, Space, and Technology (SST) can strengthen its oversight of the federally funded research portfolio, while crafting policy to improve the linkages between federally funded research programs and national goals such as energy security, environmental protection, innovation in high technology manufacturing, expanding the knowledge base, and educating future scientists and engineers. The report is not intended to be comprehensive; rather, it seeks to expand the current science policy dialogue, which has been too narrowly focused on funding levels, and not sufficiently concerned with the structure of the research system.

The Task Force on the Health of Research views national goals as the motivating force behind federal support for research. This perspective suggests two lines of analysis that must underlie federal research policy:

(1) For a given national goal, what research is most necessary?

(2) How can we best conduct such research? That is, what mechanisms for administering, performing, and evaluating research create the optimal pathways from research to goal attainment?

To answer these questions, the Committee will need to examine and evaluate traditional science policy assumptions and recommend new approaches; expand the range of experts upon whom it calls for advice to include the users of research, rather than just the performers; and establish programs that compare and assess alternative methods of research administration and performance. In this context, the Task Force recommends two nested lines of action aimed at creating more explicit linkages between national goals and federally supported research programs:

(1) Strengthen mechanisms for setting government-wide research-policy goals, and for oversight of the federal research portfolio, by exploiting Committee jurisdiction over the Office of Science and Technology Policy;

(2) Integrate performance assessment mechanisms into the research process using legislative mandates and other measures, to help measure the effectiveness of federally funded research programs.

Implementing the recommendations of this report will require a long term, strategic approach by the Committee that will probably include hearings, pilot projects, and legislative initiatives embracing the jurisdictions of most or all of the SST subcommittees. The report itself is not a detailed recipe; rather, it is designed to serve as the starting point of a constructive dialogue and evolutionary process that can strengthen the Committee's ability to forge science policy for the national good.

Problem Statement

The present system of research in the United States was established in the two decades following World War II. This period was characterized by policy consensus, minimal international competition, and a relatively small and homogeneous research community.

Today, there is a widespread perception that the federally funded research system is under stress. From the perspective of researchers dependent on federal support, this may simply mean that there is more competition for available funding, or that mission-oriented research budgets are insufficient to fulfill agency mandates. From the perspective of policy makers, stress may be manifested by discord between the promised benefits of research and a society beset by a range of seemingly intractable economic, environmental, and social problems.

Research policy designed forty years ago may no longer be suitable for addressing the problems of today's world. Traditional disciplinary and agency boundaries, unsophisticated models of innovation and economic benefit, and ideological approaches to federal involvement in the research process must be reconsidered.

The Administration's budget request establishes an implicit research agenda, and Congress responds. The Committee on Science, Space, and Technology has reinforced the status quo by addressing policy issues and reauthorization on an agency-by-agency and year-by-year basis, and by providing what often amounts to a rubber stamp for agency budgets, agendas, and policies.

The Committee must consider new strategies for addressing increasingly urgent policy dilemmas and societal challenges. Such strategies should be rooted in the development of explicit linkages between the conduct of federally funded research and the achievement of national goals. The need for change is clear.

Introduction

The U.S. system of scientific, engineering, and mathematical research is widely perceived to be under stress. The scientific community, science-policy makers, and the press have each sought to explain the sources and potential impacts of this stress, often arriving at highly divergent interpretations. From a Congressional perspective, concern over the health of the federally funded research system demands a reconsideration of the proper role of the federal government in supporting research.[1]

Alleged causes of this stress include: [2]

(1) Inadequate federal resources to support a growing academic research community at levels which the community believes are necessary (for research and training);

(2) Inadequate federal resources to support mission-oriented research (i.e., research designed to achieve established policy objectives) at federal agencies;

(3) Increased demand for new interdisciplinary research programs to investigate complex and/or high profile research problems (e.g. global climate change, AIDS);

(4) Lack of mechanisms and criteria for setting priorities in federally funded research both within and between disciplines, fields, or programs;

(5) Increasing proportion of federal research funds spent on "big science" projects; and

(6) Declining private-sector investment in research, resulting in fewer research jobs and increased demand for federal support of research that had formerly been carried out by private industry.

Perceived symptoms of stress in the research system include: [3]

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[1] The Task Force defines the federally funded research system to include all nondefense research supported by federal funds, regardless of performer. The system encompasses all basic and applied scientific and engineering research, as well as development of facilities and equipment for research, but does not include development of products and processes when they become directly linked to commercial applications. A comprehensive reconsideration of the federal role in this system is contained in U.S. Congress, Office of Technology Assessment, *Federally Funded Research: Decisions for a Decade*, OTA-SET-490 (Washington, DC: U.S. Government Printing Office, May 1991).

[2] For university research, see, for example: *Science: The End of the Frontier?* a report by Leon M. Lederman, President-Elect, to the Board of Directors of the American Association for the Advancement of Science, January 1991; Robert M. White, "Too Many Researchers, Too Few Dollars," *Issues in Science & Technology*, vol. 7, Spring 1991, pp. 35–37; Erich Bloch, "Optimists, Skeptics, and Realists: Other Views of the Research 'Crisis'," in *Science and Technology Policy Yearbook 1991*, M.O. Meredith et al., eds. (Washington, DC: AAAS, 1991); and Roland W. Schmitt, "The Sources of Discontent in Academic Research," presented at the annual meeting, American Association for the Advancement of Science, Feb. 9, 1992, Chicago, IL. For mission-oriented research, see, for example: W.D. Kay, "The Politics of Fusion Research," *Issues in Science and Technology*, vol. 8, Winter 1991/92, pp. 40–46; E.S. Rubin, L.B. Lave, and M.G. Morgan, "Keeping Climate Research Relevant," *Issues in Science and Technology*, vol. 8, Winter 1991/92, pp. 47–55; Expert panel on the role of Science at EPA, *Safeguarding the Future: Credible Science, Credible Decisions*, U.S. Environmental Protection Agency EPA/600/9-91/050, March 1992.

[3] In addition to references in footnote 2, see, for example, U.S. Congress, Office of Technology Assessment, *Competing Economies: America, Europe and the Pacific Rim*, OTA-ITE-498 (Washington, DC: U.S. Government Printing Office, October, 1991); National Academy of Sciences, *The Government Role in Civilian Technology* (Washington, DC: National Academy Press, 1992); Glenn McLaughlin and Richard E. Rowberg, "Linkages Between Federal Research and Development Funding and Economic Growth," *CRS Report for Congress* 92-211 SPR, February 21, 1992; John F. Ahearne, "Why Federal Research and Development Fails," Resources for the Future Discussion Paper EM88-02, July, 1988; Bruce Stokes, "High Tech Tussle," *National Journal*, June 2, 1990, pp. 1338–1342; and Leon Jaroff, "Crisis in the Labs," *Time*, August 26, 1991, pp. 44–51.

(1) Declining competitiveness of U.S. high-technology products in international markets;

(2) Inability of mission-oriented research programs at many federal agencies to achieve policy-relevant results or statutory goals;

(3) Increased competition for funding among researchers, and increased time spent on administrative, versus research, activities;

(4) Neglect of undergraduate-level science education at many universities because of an excessive emphasis on pursuit of research funding and performance of research;

(5) Increasingly vocal debates over the appropriate role of federal funding in applied civilian research;

(6) Publicity about issues such as misconduct in research, academic earmarking, misuse of indirect cost reimbursements, conflicts of interest, and animal testing.

This report accepts the premise that these and related concerns are indicative of "stress" within the research system. Regardless of the merit of these and other commonly cited problems, it is clear that neither policy makers nor scientists are satisfied with the implementation of science policy today. **In this context, this report seeks to outline broad strategies by which the Committee on Science, Space, and Technology can strengthen its oversight of the federally funded research portfolio, while crafting policy directed at improving the linkages between federally funded research programs and national goals.**

To broaden and deepen the science policy dialogue, this report questions basic assumptions about the operation and goals of the federal research system. This dialogue, on the whole, has been too narrowly focused on funding levels, and not sufficiently concerned with how to increase the ability of federally supported research to contribute to the welfare of the nation. The emphasis on funding levels indicates a complacency with institutional structure and performance that is unwarranted and perhaps dysfunctional for the times. The ongoing federal budget crisis should be viewed as a motivation for the Committee to examine fundamental science policy assumptions—still rooted in a cold war mentality—and consider new approaches to implementing a science policy for the 1990s.

A principal objective of this report, then, is to propose specific strategies that the Committee may wish to pursue to enhance the contribution of federally funded research to national goals such as increased economic competitiveness, enhanced human health, energy security, environmental protection, and expansion of the knowledge base. Two principal strategies are identified:

(1) Strengthen mechanisms for setting government-wide research-policy goals, and for oversight of the federal research portfolio, by exploiting Committee jurisdiction over the Office of Science and Technology Policy (OSTP);

(2) Integrate various performance assessment mechanisms into the research process using legislative mandates, in order to help measure the effectiveness of federally funded research programs.

Background

Current federal science policy was articulated during and shortly after World War II.[4] Federal funding for civilian research was seen as a means of supporting research that the private sector could not, or would not, support. Universities became the principal basic research performers, Federal labs carried out mission-oriented tasks, and the private sector pursued most of the non-defense applied Research and Development (R&D). Disciplines and sectors tended to operate in isolation from one another. Cooperation and collaboration in most civilian research was left to informal agreements, not to formal joint ventures strategically planned to achieve targeted goals. A fundamental assumption of this system was that it should operate in a more-or-less *laissez-faire* manner, with minimal governmental interference. A principal tenet of U.S. science policy has been that researchers are most qualified to judge and administer the work of the research community, and, in the case of basic research, that attempts to control direction or outputs of research would stifle creativity, innovation, and, ultimately, technological development.

The role of scientific research during World War II, as exemplified by the Manhattan project, created a new national legitimacy for scientists (especially physicists) as contributors to national well-being. With the exception of national-prestige "research" projects such as Apollo and the War on Cancer, the U.S. civilian research agenda, both basic and applied, has been driven as much by the imagination and expertise of scientists as by any particular set of policy goals. Culture and policy have bestowed highest status to basic research and its performers, located mainly at universities. Thus, scientific leaders and research models are largely defined at our research universities, and are strongly influenced by disciplinary and departmental structure. This is *de facto* science policy today, and may grow stronger as industry reduces its basic research capability.[5]

Federal mechanisms for funding and administering research have remained relatively unchanged for 45 years.[6] However, there appears to be a growing mismatch between the demands and expectations of the research community (forged during the 1950's and 1960's) and the goals of policy makers (which reflect current political, economic, and societal pressures). Fundamental problems facing our society require interdisciplinary research approaches rather than reliance solely on traditional disciplinary paradigms.

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[4] Everybody's benchmark is Vannevar Bush, *Science: The Endless Frontier*, (Washington, DC: U.S. Office of Scientific Research and Development, July 1945, and reissued as a National Science Foundation report, 1960). Also see reports associated with this Committee: National Academy of Sciences, Committee on Science and Public Policy, *Basic Research and National Goals*, a report to the Committee on Science and Astronautics, U.S. House of Representatives (Washington DC: March 1965); and U.S. Congress, House Committee on Science and Technology, Task Force on Science Policy, *A History of Science Policy in the United States, 1940–1985* (Washington, DC: U.S. Government Printing Office, September 1986).

[5] Private industry is increasingly unwilling to invest in research that offers no promise of short-term payback; see: John M. Rowell, "Condensed Matter Physics in a Market Economy," *Physics Today*, May, 1992, pp. 40–47; "Wasted dollars," *The Economist*, September 3, 1988; pp. 64–66; John Markoff, "A Corporate Lag in Research Funds is Causing Worry," New York *Times*, January 22, 1990, p. 1.

[6] For description and analysis of the "Federal research system"—agency sponsors, research performers, the budget process, and the participation of various constituencies—see OTA, *Federally Funded Research*, chapter 3–5, op. cit., footnote 1.

There is a recognized need for closer cooperation between private and public sector scientists, as well as between U.S. and foreign scientists, and natural and social scientists. In attacking such fundamental problems, boundaries between basic and applied research will be ever more difficult to demarcate. Social science research, once a marginal part of the federal research agenda, is now thought by some to be a necessary component of a balanced research portfolio (as well as a prerequisite for understanding how that portfolio can be constructed and modified to achieve societal goals).[7] Finally, and perhaps most conspicuously, it is becoming increasingly clear that maintaining the world's preeminent (and most expensive) federal research system is not, in and of itself, adequate to insure economic vitality.[8] Overall, there is a growing recognition that the organization and conduct of research may not be appropriately designed to address the explicit goals of society (as articulated by policy makers), or to supply policy makers with the information they require to make informed science- or technology-based decisions.[9]

RETHINKING SCIENCE POLICY

Perhaps we must reconsider the ways in which Federal agencies define their roles in the research system. It is unlikely that stress in the research system can be relieved simply by increasing research funds.[10] For example, major increases in federal biomedical research support in the 1980s seem to have had, if anything, the opposite effect.[11] This is probably because a substantial fraction of any new funding goes to universities, which stimulates graduate enrollments, and leads to growth in the number of researchers that inevitably outstrips the ability of the federal government to provide adequate support. However, the debate over funding level ig-

[7] For example, see John Ziman, "A Neural Net Model of Innovation," *Science and Public Policy*, Vol. 18, February 1991, pp. 65–75; and Howard Newby, "One Society, One Wissenschaft: A 21st Century Vision," *Science and Public Policy*, Vol. 19, February 1992, pp. 7–14. Both papers challenge the "linear model" of science translating into technology, which provides the impetus for social and economic progress. The latter in addition sees social science as central for understanding the interactive process linking scientific excellence and technological innovation to economic and social well-being.

[8] The correlation between research and economic vitality is a cornerstone of post-War federal science policy. According to one influential report: "If we are to remain a bulwark of democracy in the world, we must continually strengthen and expand our domestic economy and foreign trade. A principal means to this end is through the constant advancement of scientific knowledge and the consequent steady improvement of our technology" [(John R. Steelman, *Science and Public Policy, A Report to the President* (Washington, D.C.: U.S. Government Printing Office, 1947) v. 1, pp. 3–4]. A more recent observer suggests that there is no evidence of a positive correlation between the strength of our academic basic research capability, and our economic vitality; see Derek Bok, "Reconciling Conflicts—The Challenge for the University," in D.S. Zinberg (ed.), *The Changing University*, (Dordrecht: Kluwer Academic Publishers, 1991), pp. 15–16.

[9] This recognition is reflected in the recent activities of mainstream science-policy and science-advocacy organizations. For example, the Carnegie Commission on Science, Technology and Government will soon issue a report on "Linking Science and Technology to Societal Goals." The Council of Scientific Society Presidents has also proposed a study on "Establishing Priorities for Scientific Research" which would address the issue of priority-setting in the context of societal goals.

[10] One of the few representatives of the academic research community to acknowledge this point is the President of Rensselaer Polytechnic Institute, Roland Schmitt. For example, see his talk "Science—The Frontier of Challenge: Adjusting to Finite Resources," NAS/NAE/NSB Symposium, February 15, 1991, Irvine, CA.

[11] OTA, *Federally Funded Research*, chap. 2 and p. 223 (box 7–D) op. cit., footnote 1. Barbara J. Culliton, "Biomedical Funding: The Eternal 'Crisis' ", *Science*, vol. 250, December 21, 1990, pp. 1652–1653.

nores the broader context. The real question is whether available resources are being allocated in a manner that can best achieve national goals. Yet this question has never been addressed in a comprehensive manner.

Traditionally, the federal research mandate has called for the support of research that is neglected by the private sector. For 1991, this included federal funding for about 50 percent of all basic research performed in the U.S., and about 30 percent of the applied research.[12] This has translated into a leading role for U.S. universities as performers of research. In 1991, 38 percent of all federal, non-defense research funds went to universities. Intramural federal laboratories were the second largest research performer, receiving 28 percent of all non-defense funds. Industrial performers received 11 percent, and university-administered National Laboratories received 10 percent. How do we know that this is an optimal distribution? We don't.

In attempting to rethink the fundamental nature of federal science policy, it must be recognized that the community of federally funded researchers shares many attributes with other interest groups that receive federal support: it resists change; it seeks additional resources as a cure for internal stress; it develops political (i.e., subjective and partisan) strategies to promote its agenda and demonstrate the need for special treatment; it unselfconsciously gives its own values primacy; and, in particular, it strives to show that it is an essential contributor to the national interest. Furthermore, the research community has certain political advantages over other interest groups. One is a product that is reputedly unique—objective data upon which the nation can make policy decisions and build economic growth. This creates an apparent moral superiority over other interest groups that are shackled to more obviously partisan or pecuniary agendas.

Another political advantage enjoyed by the scientific community is the privilege of being trusted to judge and police itself. This privilege applies not merely to expert peer reviewers, but to witnesses at Congressional hearings, administrators in federal agencies, and members of agency advisory committees. Thus, in the postwar science policy paradigm, advice is sought from the producers of knowledge. The users of science are rarely canvassed for their views on research policy (and when they are, they appear to be less disturbed by "stress" within the research system than by a lack of connectedness between research and practical application).[13]

It is clear that scientists are especially qualified to judge the scientific merit of research. Although many research programs offer

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[12] National Science Board, *Science and Engineering Indicators—1991*, Tenth Edition, (Washington, D.C., U.S. Government Printing Office, 1991).

[13] Indeed, many economists and representatives of industry suggest that our research system is just about the only sector of our economy that is in reasonably good health. For example, see recent testimony by Robert M. Solow at hearing on "Policy Options for Promoting Economic Growth," Committee on Science, Space, and Technology, May 5, 1992; Keith Pavitt, "What Makes Basic Research Economically Useful?" *Research Policy*, Vol. 20, 1991, pp. 109–119; National Research Council, *Research on the Management of Technology: Unleashing the Hidden Competitive Advantage* (Washington, DC: National Academy Press, 1992); Lewis M. Branscomb, "Does America Need a Technology Policy?" *Harvard Business Review*, March–April 1992, pp. 24–31.

the explicit promise of achieving certain nonscientific payoffs, the research programs which Congress authorizes and funds rarely include mechanisms to judge progress toward such goals. Thus, the success or failure of a research program is typically judged in terms of "scientific excellence." Few programs are modified or terminated for failing to achieve promised policy goals.

Despite the acknowledged stresses within the research system, there has been little or no change in the fundamental assumptions and principles that have been guiding federal science policy.[14] This policy is captive to its own history, which asserts:

(1) Basic research is the source of fundamental knowledge that eventually leads to innovation, technology development, and economic growth.

(2) Basic research should be carried out primarily at universities, in isolation from political constraints or applications-oriented management.

(3) Individual-investigator research is the most productive of new ideas.

(4) "Scientific excellence," as judged by peer review, is the best criterion for determining which projects should receive funding.

(5) Federally funded applications-oriented research should be managed by individuals with technical expertise, i.e. scientists and engineers.

(6) Applied research restricts creativity and serendipitous discovery.

(7) Academicians must perform cutting-edge research in order to be effective educators.

(8) The connection between research results and societal benefits is indirect, but we accept as an article of faith that more high-quality research will necessarily translate into more benefits for society at large.

(9) Mission-oriented research can provide objective data to guide public policy decision-making in a wide range of areas, including the general economy, energy, and environment.

(10) Traditional scientific disciplines form the most natural and appropriate framework for funding, administering, performing, and evaluating research.

A major failing of U.S. science policy has been the absence of institutional mechanisms designed to test the validity of these and related assertions. There are three fundamental reasons for this failure. First, the U.S. research system was designed primarily by and for scientists, and these assertions serve to preserve the autonomy and legitimacy of the research community. Second, it is the researchers themselves who are called upon to evaluate a system which they have little incentive to alter. Third, the economic per-

[14] The Lederman report, cited in footnote 2, is the most prominent recent iteration; another is a speech by Frank Press, "Science and Technology Policy for a New Era," presented at the National Academy of Science's 129th annual meeting, Washington, DC, April 27, 1992. Conversely, it is worth noting that there have been isolated calls for change and predictions of coming stress for at least the past 25 years [e.g. Alvin Weinberg, *Reflections on Big Science* (Worcester, MA, The Heffernan Press, 1967); and Ralph Sanders and Fred R. Brown, Eds., *Science and Technology: Vital National Assets* (Washington, DC: Industrial College of the Armed Forces, 1966), especially pp. 93–94]. However, this message has only recently begun to find an audience, as stress has grown within the research system, the federal budget, and society as a whole.

formance of the United States in the 1950's, 60's and 70's has been construed as a vindication of these science policy principles. (It must be emphasized, however, that the economic preeminence of the U.S. after World War II was virtually a foregone conclusion because the production capacity of most of our economic competitors had been destroyed.)

Since we have lived with only one post-war science policy paradigm, we cannot know whether a different one might have been more or less effective. What we do know is that a paradigm predicated on a distinctive blend of rugged individualism and unfettered competition led the United States to world leadership in Nobel prizes, numbers of publications, and numbers of patents. We also know, however, that several of our economic competitors have adopted radically different science policy principles (Japan being the shining example), and have had great success in linking research with national goals, especially in the area of sustained economic growth.[15] There are lessons to be learned as well as imparted. Perhaps, too, it is time to experiment with our own approach. Such experiments should be carefully defined and modular, to avoid throwing out the good with the bad, but they should test a wide range of policy alternatives.

Setting Priorities

Priority setting has become a catchphrase in science policy discussions. The debate over priority setting tacitly reinforces the sentiment that the major science policy problem of the day is inadequate funding. The lack of adequate resources to support all worthy research projects and programs demands that priorities be set and choices be made—this is now accepted by much of the research community. Within specific disciplines it is generally acknowledged that the researchers themselves are best suited to set priorities.[16]

Choices between disciplines, however, often cannot be made on the basis of scientific merit, because there is no clear framework for comparison.[17] Thus, it is commonly accepted that nontechnical criteria, and political considerations, will play a role in determining priorities between disciplines. All the same, the research community has made some attempts to set priorities across disciplines,

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[15] Perhaps the most obvious indicator of differing national science policies is the variation in distribution of research funds by socioeconomic objective. For example, the U.S. devotes a much greater proportion of its R&D budget to health, and a much smaller proportion to energy and industrial development, than do most other industrialized nations. See *International Science and Technology Data Update: 1991* Special Report NSF 91-309 (Washington, D.C., National Science Foundation, 1991). For brief descriptions of science and technology policies of several other nations, see previously cited Office of Technology Assessment reports *Federally Funded Research* and *Competing Economies*, footnotes 1 and 3.

[16] The most recent example comes from the National Academy of Sciences, Space Studies Board, *Setting Priorities for Space Research: Opportunities and Imperatives* (Washington, DC: National Academy Press, 1992).

[17] This was clearly revealed in hearings held three years ago by this Committee. See U.S. Congress, House Committee on Science, Space, and Technology, Subcommittee on Science, Research, and Technology, *The Hearings on Adequacy, Direction and Priorities for the American Science and Technology Effort*, 101st Cong., Feb. 28–Mar. 1, 1989, (Washington, DC: U.S. Government Printing Office, 1989). These hearings highlighted Members' frustrations with evaluating witnesses' arguments for increased resources. Sustaining disciplines and research programs was the chief reason given, with only vague reference to "enhancing economic competitiveness." The question of national goals was not prominent in the discussion, but became a prime motivation for the aforementioned OTA study on *Federally Funded Research*.

especially in the case of "big science" projects, which are seen as potentially threatening to funding for individual-investigator research.[18]

If priority setting is undertaken predominantly as a response to tight funding, then it threatens to entrench further the existing science policy model by reinforcing disciplinary boundaries and focusing on funding as the single most important determinant of a successful national research effort.[19] Thus, the much-lauded efforts of various disciplinary communities to set priorities may be seen as an indication of fiscal responsibility, while having the effect of circumventing a more fundamental reconsideration of the tenets of science policy.

As an alternative to priority-setting exercises driven by fiscal concerns, and circumscribed by disciplinary boundaries, science-policy makers could view priorities as derivatives of societal or policy goals. This approach suggests two lines of analysis and action in setting priorities:

(1) For a given national goal (e.g., energy independence; expansion of the knowledge base), what research is most necessary?[20]

(2) What mechanisms for administering, performing, and evaluating research create the optimal pathways from research to goal attainment?

These two areas of concern occupy the core of the recommendations for policy action made in this report. These recommendations can be viewed as priority setting from a science-policy perspective, rather than from the more common resource-allocation perspective.

Policy Recommendations: Linking Research To National Goals[21]

U.S. science policy has traditionally focused on facilitating the performance of research, while neglecting to evaluate the overall organization of the research system, and the ways that research results are integrated into society and translated into societal benefit.[22] In this context, the Committee may wish to consider a fundamental reformulation of science policy principles, with the view toward exploiting research as a tool designed to achieve national

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[18] For example, during the 1991 debate over appropriations for NASA's Space Station Freedom, 12 scientific societies cosigned a letter to members of the Senate Appropriations Committee stating opposition to continued funding for the station. In 1989, the Industrial Research Institute conducted a survey of member corporations in which the corporations ranked five major federally funded "big science" projects in order of potential benefit to the U.S. industrial base.

[19] The latest example is Albert H. Teich, "Discussions of Setting Science Priorities Are Filled With Misunderstandings," *The Chronicle of Higher Education*, Jan. 22, 1992, p. A52.

[20] See testimony from a hearing on "Setting Priorities in Science," held by the Subcommittee on Science, Committee on Science Space and Technology, on April 28, 1992. Witnesses unanimously endorsed the concept that priority-setting could only be carried out in the context of clearly stated goals.

[21] There will be considerable debate over whether such a linkage should be attempted. The arguments against it are various, familiar, and murky, ranging from the difficulty of agreeing on goals, to the fear that explicit linkages will stifle creativity. The arguments for such a linkage are clearer, but may conflict with conventional science policy tenets: we should try to ensure value returned for federal tax dollars expended, by striving to maximize the capability of federally funded research programs to meet the expectations and needs of policy makers and society.

[22] Perhaps the most comprehensive (and controversial) revisionist view of science policy presented to date is Deborah Shapley and Rustum Roy, *Lost at the Frontier: U.S. Science and Technology Policy Adrift*, (Philadelphia, PA, ISI Press, 1985).

goals, rather than as a black box into which federal funds are deposited, and from which social benefit is somehow derived.

The flip side of stress within the research system is a growing perception that federally funded research is not sufficiently contributing to long-term national goals such as economic competitiveness, human health and environmental protection.[23] In spite of the promised contribution of research, both basic and applied, to high technology innovation, long-term economic vitality, and standard of living, the U.S. seems less able to translate scientific and technological advance into societal gain than several of our international competitors. Similarly, the promise of mission-oriented research to address a wide range of policy issues in areas such as energy, environment, and public health, has frequently not been realized.[24] Although the failure to achieve such long-term national goals is not necessarily the fault of the research system per se, neither has there been a successful attempt to link research programs explicitly to goals in a manner that would optimize the policy-relevance of the research while maintaining the highest possible degree of scientific excellence.

There are many reasons why such linkages do not now exist. In part, the complex organization of the Executive Branch makes it difficult to view the federal research system as a whole, and the many Congressional committees with jurisdiction over some portion of the research portfolio make it difficult to impose any sort of uniform policy standards.[25] Furthermore, the historical dominance of science policy by researchers themselves has often precluded any requirement to explain and justify the research system to Congress and other users of research. Indeed, the Committee has traditionally been engaged in creating policy for science and scientists, which may not be the same as creating mechanisms to improve the application of research to societal problems.

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[23] These goals are explicitly and implicitly set by Congress and by the Executive Branch, and they presumably reflect, to some degree, the desires of the populace, as filtered through elections, the press, etc. However, mechanisms to measure progress toward goals (or to assess the reasonableness of goals) are rarely implemented or even considered. For some specific cases, see *Technology and Economic Performance: Organizing the Executive Branch for a Stronger National Technology Base*, report of the Carnegie Commission on Science, Technology, and Government, September, 1991; Mark Andersen and Kosta Tsipis, "Federal R&D policy and its implications for U.S. economic competitiveness: A compendium of facts," Massachusetts Institute of Technology, Program in Science, Technology and International Security, unpublished ms., November, 1989; Kelly Day and Vernon Ruttan, "The deficit in natural resources research," *BioScience*, vol. 41, January, 1991, pp. 37–40; Leslie Roberts, "Counting on science at EPA," *Science*, vol. 249, August 10, 1990, pp. 616–618; and George E. Brown, Jr. and Radford Byerly, Jr., "Research in EPA: A Congressional point of view," *Science*, vol. 211, March 27, 1981, pp. 1385–1390.

[24] The previously cited OTA report on *Competing Economies* outlines the relationships between U.S. science and technology policy, and twenty years of decreasing competitiveness. Also, see: Erich Bloch, "Basic Research and Economic Health: The Coming Challenge," *Science*, vol. 232, May 2, 1986, p. 595–599; and Susan L. Sauer (ed.), *Science and Technology and the Changing World Order*, (Washington, DC: AAAS, 1990). A conspicuous example of a mission-oriented research program that is failing to achieve desired goals is the high-level nuclear waste disposal program; see: Board on Radioactive Waste Management, *Rethinking High-level Radioactive Waste Disposal*, (Washington, DC. National Academy Press, 1990). For examples of other programs that have failed to achieve anticipated goals, see: Leslie Roberts, "Learning From an Acid Rain Program," *Science*, vol. 251, March 15, 1991, pp. 1302–1305; and Eliot Marshall, "Artificial Heart: The Beat Goes On," *Science*, vol. 253, August 2, 1991, pp. 500–502.

[25] In the Executive branch, 10 departments and independent agencies have civilian research budgets in excess of $100 million, while nine House and six Senate committees have jurisdiction over major portions of the research budget. Also, see National Academy of Public Administration, *Beyond Distrust: Building Bridges Between Congress and the Executive*, (Washington, DC: NAPA Panel on Congress and the Executive, January 1992).

To create a more rigorous and socially-responsive science policy, a necessary first step is to define goals toward which the research should be expected to contribute. Such goals may be general and long-term such as: achieving national energy security, enhancing environmental protection, improving human health, increasing the productivity and profitability of high technology industries, maintaining a healthy research infrastructure, expanding the knowledge base, educating future scientists, and creating a scientifically and technologically literate work force. Goals may also be more focused and/or shorter-term such as determining the impacts of changing climate patterns on regional agriculture or sea level, or recommending a site for nuclear waste disposal.[26]

Such goals may seem obvious (many of them have been generally accepted for years), but in fact they serve more often as rhetorical devices, exploited by policy makers and researchers alike, than as guides to the implementation of research strategies. Furthermore, the goals articulated by Congress may not be shared by the scientists and engineers who conduct the research aimed at achieving these goals.[27] In addition, the criteria by which progress toward goals is measured may differ for policy makers and researchers. Whereas scientific excellence is the foremost criterion by which research is judged within the research community, such excellence does not guarantee policy relevance or potential application to technological innovation. It may be necessary but not sufficient. The creation of new scientific knowledge does not guarantee the utility, diffusion and implementation of that knowledge.[28] In fact, the barriers that separate researchers from policy makers (designed to protect researchers from political interference) may also act to impede diffusion and implementation.

Congress is a part of this problem. The federal research system is organized in such a way that congressional committees and executive agencies are most directly responsive to the voices of the researchers that they support. Committees and agencies become advocates for the programs (and scientists) under their jurisdiction, rather than for the achievement of policy objectives and national goals that do not fall neatly within jurisdictional bounds.

There is a broad range of concrete actions that the Committee could consider to link national goals more closely to research performance. Some of these actions focus on creating and strengthening mechanisms of knowledge diffusion (i.e., the "links" themselves—pathways from research performance to knowledge utilization). This area of activity has been explicitly emphasized in the fiscal 1993 *Views and Estimates of the Committee on Science, Space,*

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[26] In addition to clearly articulating its own goals, the Committee may want to ask the proposers of research programs to state the goals that they are addressing (and to suggest metrics of success), in order to determine if the Committee's aims are consistent with the aims of those who will carry out the research.

[27] For example, a recent analysis of the Global Change Research Program suggests that the questions that policy makers most want to see answered are often very different from those which the researchers are pursuing. See Joint Climate Project to Address Decision Makers' Uncertainties, *Report of Findings* (Washington, D.C., Science and Policy Associates, Inc. 1992). Also, see the statement by Dr. William O. Baker in: Committee on Science and Technology, *Seminar on Research, Productivity and the National Economy,* (Washington, D.C., U.S. Government Printing Office, 1980), pp. 60–72.

[28] E.g., Branscomb, "Does America Need A Technology Policy?" op. cit., footnote 14.

and Technology,[29] a report to the House Budget Committee that recommends increased federal coordination of technology policy; expanded industry-government consortia and other partnerships; and expanded use of manufacturing technology extension centers.

Another way to help define research-policy linkages without interfering excessively in the research process is to identify and exploit new sources of information that can contribute to the science policy process. The Committee could expand the range of witnesses on which it calls for expert advice, to include a greater emphasis on the users, rather than the performers of research.[30] Users of research may include members of the business and legal communities; educators; state and local policy planners; public interest groups; journalists; the military; and other researchers. Congress and the Executive Branch of course are also users of research, and the Committee must be willing to assess the utility of research provided to the federal government for policy-making purposes. Research performers may also be able to identify the potential users of their own work.

In addition to the users of research, there is a growing number of science policy analysts who conduct "research on research," and have much to contribute to the science-policy dialogue. It should be noted that these analysts are often considered to be "outside" the research system, yet it is they who are conducting rigorous ("scientific") study of the practice and use of science in society. As well as seeking a wider range of witnesses, the Committee could encourage greater diversity and independence in the membership of agency advisory committees. The dominant role of scientists and engineers on these committees may represent an inherent conflict of interest, while excluding critics of the status quo.

The Committee could also acquire new information about the process of knowledge diffusion in today's research system. For example, the Committee could ask CRS or OTA to do a long-term study on mechanisms of knowledge transfer in fostering the application and utilization of "breakthrough" technologies. Such a study might focus on current examples, such as Fullerenes, high-temperature superconductors, and global change. What are the feedback paths between basic research, applied research, and knowledge utilization? How can Congress act to facilitate the development and utilization of such paths?

Most importantly, the Committee can act to strengthen its ability to establish government-wide science-policy goals, and to institutionalize mechanisms for measuring progress toward such goals. These two areas of action are discussed in more detail below.

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[29] *Views and Estimates of the Committee on Science, Space, and Technology on the Fiscal Year 1993 Budget for Civilian R&D*, 102nd Cong., Second Session (Washington, DC; U.S. Government Printing Office, 1992).

[30] The ability and/or willingness of Congress to use this advice is a separate problem, and beyond the scope of this report. Certainly the availability of sound advice does not guarantee its wise use; see Lawrence E. Lynn (ed.), *Knowledge and Policy: The Uncertain Connection* (Washington, D.C.: National Academy of Sciences, 1978).

1. Exercising jurisdiction over the Office of Science and Technology Policy [31]

The Office of Science and Technology Policy (OSTP) and the Federal Coordinating Council on Science, Engineering, and Technology (FCCSET) have the combined authority and responsibility to develop and implement coherent, government-wide science policy.[32] The Committee's jurisdiction over OSTP and FCCSET gives it unique leverage over the science-policy-making capability of the Executive Branch. No other House Committee has a mechanism for exercising influence over the entire civilian research portfolio. The Committee should therefore strive to increase its level of oversight and strengthen its guidance of OSTP and FCCSET. In parallel, the Committee should seek to strengthen OSTP's mandate to formulate, coordinate and implement research policy.

In most of the 15 years since its creation, OSTP has not been a strong player in the Executive Branch. The influence of OSTP may be growing, however, because of the increasing demand for a more explicit U.S. technology policy, and a need for a coordinating mechanism for large, interdisciplinary, interagency research programs. The Committee can strengthen OSTP's standing and importance within the Executive Branch by treating it as a command center for implementing and evaluating all major research policy decisions. This may require additional funds, additional statutory authority, and, in particular, additional oversight by the Committee. The goal is to help move science-policy making from the current, ad hoc, agency-by-agency, OMB-dominated process that exists today, to a more strategic process oriented toward the conduct, goals, and users (not just the performers) of research.

The Committee's jurisdiction over FCCSET should be prudently exercised. FCCSET is the mechanism through which the Administration coordinates research programs that are not limited by the boundaries of agencies and disciplines. FCCSET membership includes the heads of all federal research agencies, and as such it has the potential (thus far exercised on a limited basis) to engage in government-wide science-policy planning. The Administration is using the FCCSET process to initiate inter-agency research programs in five areas of particular national interest.[33] In this sense, the Executive Branch is ahead of the Congress, and the Committee, in terms of exploring new ways to implement research policy in the context of evolving national goals.[34] The FCCSET "cross-cuts" may represent a major component of a shifting science-policy paradigm.

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[31] Of course, exercising jurisdiction is a means, not an end. The end is better science policy judged by its contribution to achieving the types of goals discussed in the previous section.

[32] OSTP and FCCSET were established by the Science Policy Act of 1976 (PL 94-282). The act states that, among other responsibilities, OSTP shall "seek to define coherent approaches for applying science and technology to critical and emerging national and international problems and for promoting coordination of the scientific and technological responsibilities and programs of the Federal departments and agencies in the resolution of such problems." FCCSET shall, among other responsibilities, "provide more effective planning and administration of Federal scientific, engineering, and technological programs."

[33] High performance computing; advanced materials and processing; biotechnology; global change; and mathematics and science education. Note that only the High Performance Computing Program (P.L. 102-94) and the Global Change Research Program (P.L. 101-606) are authorized in specific statutes.

[34] However, the National Climate Program Act of 1978 (P.L. 95-367) provided for such a cross-cutting program of climate research, to be coordinated through OMB in a manner analogous to the way that FCCSET coordinates such programs today.

The process by which the FCCSET cross-cuts are selected is still somewhat mysterious. Administration sources emphasize a "bottom-up" process through which cross-cutting initiatives are proposed by researchers and research administrators, and considered and adopted by FCCSET membership. There is no clear set of policy goals toward which the cross-cuts are directed. Criteria for success, and procedures by which FCCSET initiatives may become institutionalized as National Research Programs, have not been fully aired or analyzed. Similarly, criteria for evaluation of National Research Programs have apparently not been established. The Committee must exercise close oversight, implement mechanisms to measure the effectiveness of the cross-cuts, and work to increase Congressional input into the FCCSET process. At the same time, the Committee must be sensitive to the importance of flexibility, creativity, and informality in the FCCSET process. These attributes (as opposed to political inertia and agency "turf" protection) can facilitate the effective linking of research and goals, by permitting an evolutionary approach to research policy planning. The Committee's involvement in this process could begin with oversight of the recently initiated cross-cut in advanced materials and processing.

The objective of strengthening OSTP's science-policy capability is not to consolidate power in one office; rather, it is to create a mechanism for making science policy that responds to the broad needs of the nation, not only to the narrower needs of individual agencies, disciplines, institutions, or scientists. Under OSTP, FCCSET offers a forum for bringing together directors of all research agencies. The Committee could introduce legislation requiring that this group convene on an annual or semi-annual basis in order to develop a coherent science policy rooted in explicit, articulated goals. Alternatively, the Committee could create a new administrative structure (separate from FCCSET) that would require this type of inter-agency planning activity. In either case, the interests of each agency would be represented, but the process of developing national science policy would be coordinated, and potentially strategic. Furthermore, the federal research budget should be developed as an outgrowth of this coordinated approach, rather than emerging piecemeal from the arbitrary bounds of agencies and their research constituencies.[35]

The process for achieving this type of policy making could begin with OSTP drafting a document which sets out explicit, strategic research goals for federally funded research. These goals should be developed independently of consideration of budgetary constraints and agency boundaries. Goals should be reviewed by the Committee, and evaluated by experts within and outside the research community, including the intended users of the research results. Analysis and assessment of goals should be revisited on a periodic (e.g., biennial) basis. Development of a research portfolio designed to meet these goals within existing budgetary limits could then be un-

[35] The need for this type of coordinated Executive-Branch approach to science policy was strongly endorsed by National Institutes of Health Director Bernadine Healy at an April 7, 1992 hearing on "Setting Priorities in Science," held by the Subcommittee on Science, Committee on Science, Space, and Technology. Healy's comments were conspicuous enough to be reported in *Science & Government Report,* vol, 22, May 1, 1992, p. 1.

dertaken through the FCCSET (or alternative) process, and implemented via existing agency procedures.

2. Integrating performance assessment into the research process

Federal policy has effectively created or facilitated the creation of new research opportunities, while providing resources for a growing research community and supporting the education of future generations of scientists. Federal policy has been less effective, however, in monitoring the progress of research programs toward particular goals once the programs are underway. The need for performance assessment mechanisms is suggested by a number of observations: [36]

- Cost overruns and the ongoing political debate over "big science" projects;
- Discord between promised and actual performance of federally funded research programs;
- Difficulty of turning high quality science into policy-relevant and/or economically beneficial science in federally funded research programs;
- Failure to identify, modify, and shut down unsuccessful research programs;
- Lack of criteria for measuring the effectiveness of ongoing research programs;
- Difficulty in meeting mandated goals in federally funded research programs.

Federal research policy decisions must not be based solely on input criteria (i.e., funding based on the promise of research), but on concrete outcomes as well. The Committee could require that the programs it authorizes be subject to performance assessment that is fully integrated into the administration of the research process. For such mechanisms to be effective, the assessments would have to be carried out by persons or organizations independent of the research performers, who are knowledgeable about both the scientific and policy aspects of the research. Performance guidelines could be built into authorizing legislation,[37] or determined through an independent evaluation process. Furthermore, there would have to be a clear statutory mandate to redirect or terminate programs that are not making sufficient progress toward stated goals. Performance assessment could have the following positive effects on research authorized by the Committee:

- Agencies and researchers alike would be more likely to set goals and recommend budgets that are realistic and achievable;

[36] E.g., U.S. Congress, Congressional Budget Office, *Large Non-defense R&D Projects in the Budget: 1980–1996* (Washington, DC: CBO Papers, July 1991); U.S. Congress, Congressional Budget Office, "Federal Investment in Intangible Assets: Research and Development," *How Federal Spending for Infrastructure and Other Public Investments Affects the Economy*, (Washington, DC: CBO study, July, 1991), pp. 73–101; dialogue between Senator Albert Gore and Prof. Lewis Branscomb in: Senate Subcommittee on Science, Technology, and Space, Committee on Commerce, Science, and Transportation, *Hearings on National Science and Technology Policy*, 101st Congress, September 28 and 29, 1989, (Washington, DC: U.S. Government Printing Office, 1989), pp. 86–97; also see footnotes 23, 24 and 27.

[37] For example, the Committee linked the availability of authorized funds for the Superconducting Super Collider (SSC) to the achievement of a series of technical and administrative criteria in the SSC authorization bill passed by the House of Representatives in 1990 (H.R. 4380).

- The Committee would have a source of information to evaluate programs under its jurisdiction that is independent from the actual performers or supporters of the research;
- Weaknesses and strengths of the research portfolio would be more quickly revealed;
- Research performers would have a greater incentive to work toward promised goals of their programs.

The Committee could initiate this effort by authorizing one or two pilot programs, such as those recommended for NASA missions, or for the multi-agency Global Change Research Program.[38] It must be emphasized that there are significant obstacles to integrating performance assessment into the research system. Politically, there will be resistance from the federally funded research community to any suggestions of interference in the current research process. There will also be a justifiable fear of even further increases in paperwork and red tape. Indeed, any assessment process, while serving the Committee's oversight responsibilities, should be designed to lessen the bureaucratic responsibilities of the research community, preferably by replacing other audit activities.

More daunting than political resistance to performance assessment are the technical obstacles. Because policy-oriented assessment has not been a part of the research process in the past, its implementation must be both gradual and flexible.[39] In general, neither researchers nor policy makers have the practical or theoretical expertise to design assessment mechanisms without considerable input from other disciplines and sectors that have more regularly incorporated evaluation procedures into their operation. In particular, the Committee could identify and seek advice from corporations that have included performance assessment as a part of their research programs.[40]

As an ancillary part of the performance assessment process, the Committee could establish programs to test and compare alternative methods of research administration and performance, such as:

- Peer review of grant proposals vs. alternatives such as block grants, grants based on past performance, start-up grants for young researchers, funding decisions by "smart managers," etc.;

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[38] Ronald D. Brunner, "Performance as promised: Restructuring the civil space program," *Space Policy* 8, May, 1992, pp. 116–136; Rubin et al., "Keeping Climate Research Relevant," op. cit., footnote 2.

[39] There are some initial efforts underway; see, for example, Ronald R. Kostoff (Director, Technical Assessment, Office of Naval Research), "Research Impact Assessment," presented at the Third International Conference on Management of Technology, February 17–21, 1992, Miami, FL.

[40] Performance assessment must integrate all criteria which bear on the ability to achieve goals; failure to achieve goals can be the fault of unrealistic goals, unfocused research, and/or failure to adequately link the research process to the implementation process. See Eleanor Chelimsky, "Expanding GAO's Capabilities in Program Evaluation," *The GAO Journal*, Winter/Spring 1990, pp. 43–52; Thomas Cook and William Shadish, Jr., "Program Evaluation; The Worldly Science," *Annual Reviews of Psychology*, vol. 37, 1986, pp. 193–232; and Carol H. Weiss (ed.), *Organizations for Policy Analysis* (Newbury Park, CA; Sage Publications, 1992). For brief discussions of corporate approaches to performance assessment in research, see Michael Schrage, "When Innovation Leads Corporations Away From Their Strategic Interests," *Washington Post*, May 31, 1991; and Testimony by C. Kumar N. Patel before the Subcommittee on Science, Committee on Science, Space, and Technology, Hearing on "Setting Priorities in Science," April 7, 1992.

- Individual-investigator and small-team research vs. research aggregated and administered through centers of excellence or other larger units;
- Disciplinary vs. interdisciplinary approaches to research problems;
- National vs. international research teams;
- Mission-oriented research conducted at intramural, vs. extramural, laboratories;
- Basic research conducted at universities, national laboratories, and corporate laboratories;
- "Scientific excellence" vs. more restrictive funding criteria (i.e., excellence plus additional criteria such as innovativeness, educational potential, policy-relevance);
- Other more creative approaches.

Some of these comparisons could be conducted by analysis of existing data, and performed by organizations such as the Office of Technology Assessment. Others may require that the Committee authorize research agencies to set aside certain portions of their budgets to support alternative research approaches and assess relative effectiveness. Overall, the Committee should begin to test the science policy assumptions that have guided its decision making, and develop new models governing science policy that are responsive to the needs of the nation as we move toward the twenty-first century.

Conclusions and Prospects

This document provides a first rationale for rethinking federal research policy. As part of this process, policy makers must look beyond the traditional categories that dominate research policy dialogue: basic versus applied; research versus development; science versus technology; knowledge creation versus knowledge diffusion; big science versus little science. The Committee should strive to develop a systemic approach to research policy which is not restricted by artificial tradeoffs and vested interests.

Recommended policy action focuses on creating better linkages between research performance and national goals. Federal policy is one (but not the only) avenue for building and strengthening such linkages. Two nested areas of systemic policy action are recommended: developing better mechanisms for government-wide science-policy making; and establishing a system of performance assessment that is integrated within the research system. These recommendations are strategic in nature. They are intended to provide a long-term context for Committee action leading to improved integration of the research and policy processes, and more effective application of research to the problems of society.

Acknowledgements

The Task Force requested informal, off-the-record briefings from active members of the research policy community, in order to broaden its perspective on the research system. Briefings were pre-

sented by: Norman Metzger (National Academy of Sciences); Erich Bloch (Council on Competitiveness); Don Phillips (Government-University-Industry Research Roundtable, National Academy of Sciences); Marta Cehelsky (National Science Foundation); Rustum Roy (Pennsylvania State University); and Dan Greenberg (Editor and Publisher, *Science and Government Report*).

In addition to individual briefings, several outside groups were asked to conduct performance assessments of a number of different research efforts. The objective of these assessments was to better understand how research goals are set, and how progress toward goals is measured, within both the research communities and federal R&D agencies. A uniform series of questions was provided to each group that conducted an assessment, in order to ensure some consistency in approach. Three of the outside assessments were particularly valuable as background for this report, and they are available to interested readers:

1. "Pilot Assessment of the Mathematical Sciences," by the American Mathematical Society; published in *Notices of the American Mathematical Society*, vol 39, No. 2, February 1992, pp. 101–110.

2. "NASA's Office of Space Science and Applications: Process, Priorities, and Goals," An OTA Background Paper, January, 1992; available from Office of Technology Assessment, International Security and Commerce Program, Washington, D.C. 20510–8025 (202–228–6420).

3. "Case studies of agency evaluations of research and development projects," CRS Memorandum, February 3, 1992, by Genevieve Knezo, Congressional Research Service, Science Policy Research Division, Washington, D.C. 20540 (202–227–6610).

Daryl Chubin (Office of Technology Assessment) acted as an informal technical advisor to the Task Force. Drafts of this report were reviewed by John Andelin (Office of Technology Assessment), Reid Edwards (Lawrence Berkeley Laboratory), Irwin Feller (Pennsylvania State University), Barry Gold (Committee on Science, Space, and Technology), David Goldston (Committee on Science, Space, and Technology), Sheryl Handler (Thinking Machines Corporation), S. Allen Heininger (American Chemical Society), Lawrence McCray (National Academy of Sciences), Jonathan Lunine (University of Arizona), Norman Metzger (National Academy of Sciences), Jerold Roschwalb (National Association of State Universities and Land-Grant Colleges), Gene Shultz (Washington University), Thomas Thompson (University of Virginia), and Carl Weinberg (Pacific Gas and Electric Company). We thank the reviewers for their thoughtful comments. Their participation in the review process should not be construed as an endorsement of the content or conclusions of the report.

Committee staff members participating in the Task Force were: Daniel Sarewitz, Radford Byerly (Chair), Shana Dale, Edith Holleman, Frank Murray, Richard Oberman, Grace Ostenso, John Sigmon, Tina Van Sickle, and James Wilson.

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