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National Science Board

Federal Research Resources: A Process for Setting Priorities

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NATIONAL SCIENCE BOARD

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Anita K. Jones

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The National Science Board consists of 24 members plus the Director of the National Science Foundation. Appointed by the President, the Board serves as the governing board of NSF and provides advice to the President and the Congress on matters of national science and engineering policy.

Contents

Preface

Science and technology have served the Nation well in war and in peace. The Federal role in U.S. science and technology is essential and unique, enabling broad and sustained national capabilities to seize new opportunities for science and technology and to respond to current and future national needs. Recent events dramatize the importance of maintaining a future oriented science and technology policy to be prepared to address both the challenges we are able to articulate now and those not yet imagined. The growing reliance on science and technology in government, the economy, national security and the society raises the urgency for adopting a comprehensive Federal process for research budget coordination and priority setting to align Federal support for research with broad national goals.

In March 1999, in response to a request from the House Appropriations Committee and with the encouragement of Office of Management and Budget, the National Science Board reconstituted its Ad Hoc Committee on Strategic Science and Engineering Policy Issues and charged it to undertake a study on budget coordination and priority setting for government-funded research. This report, *Federal Research Resources: A Process for Setting Priorities*, presents the findings and recommendations developed by the committee and approved unanimously by the National Science Board. The study included review of the literature on Federal budget coordination and priority setting for research, and invited presentations from and discussions with representatives of the OMB, the Office of Science and Technology Policy, the Federal R&D agencies, congressional staff, high-level science officials from foreign governments, experts on data and methodologies, and spokespersons from industry, the National Academies, research communities, science policy community, and academe. Discussions focused on research priority setting as it is practiced in government organizations, and possibilities for enhancing coordination and priority setting for the Federal research budget.

On behalf of the National Science Board, I want to commend my colleagues and fellow members of the Ad Hoc Committee on Strategic Science and Engineering Policy Issues—Drs. John Armstrong, MRC Greenwood, Anita Jones, Joseph Miller, Robert Richardson, and Warren Washington—for their tenacity, energy, and wisdom throughout this complex study. Jean Pomeroy, Senior Policy Analyst in the National Science Board Office provided outstanding and tireless support as Executive Secretary to the Committee.

The Board is grateful to National Science Foundation Director, Rita Colwell, and Deputy Director, Joseph Bordogna, for their strong support and for the crucial participation by many members of the science and technology policy communities within and outside of the Federal Government throughout this project.

Eamon M. Kelly
Chairman
National Science Board and
Ad Hoc Committee on Strategic Science
and Engineering Policy Issues

Acknowledgments

A large number of people assisted the National Science Board's study as speakers, panelists, and presenters, whose names and contributions are listed in appendices to this report. Several of our colleagues were critical to initiation of the Board and Committee study. These include former National Science Board Chairman Richard Zare, who oversaw the previous phase of this inquiry and Franklin Raines, former Director of the Office of Management and Budget, who challenged the Board to address this topic.

Extensive contributions have been made over the course of this study by Office of Management and Budget staff, Kathleen Peroff, Steven Isakowitz and David Radzanowski, who encouraged us and helped shape the direction of our inquiry in numerous productive conversations. Neal Lane, former Director of NSF and subsequently of the White House Office of Science and Technology Policy and Adviser to the President for Science and Technology, deserves our special thanks for his encouragement and crucial participation in several important events sponsored by the NSB Committee. Also deserving special mention are James Duderstadt, National Acadamies' Committee on Science, Engineering, and Public Policy and former Chairman, National Science Board, who contributed to several important discussions, and encouraged the Board to pursue its study; and the House Appropriations Committee Chief of Staff, Frank Cushing, who provided important insights on the Congressional perspective.

We are also grateful for the participation of many members of the science policy community who, like us, are wrestling with the issues addressed in this report. They include spokespersons from the National Academies; Federal departments and agencies; academic, industrial and professional organizations; public policy organizations; science officials of foreign governments; and experts on data and methodologies to guide, track and measure the impacts of Federal investments in research.

We appreciate the unstinting support of NSF staff. We would like to acknowledge the critical contributions of Richard Ries, NSF Division of International Programs, who advised on both the content and participants for the Symposium on International Models of S&T Budget Coordination and Priority Setting co-sponsored by the Committee; Steven Payson, Science Resources Studies Division, who provided economic expertise; William Butts, Social, Behavioral and Economic Sciences Directorate, who coordinated SBE staff input on research relevant to priority setting in Federal research; and Robert Webber, Division of Administrative Services, who assisted with several special meetings of the Committee.

The National Science Board Office staff provided essential support to the Committee's activities. Several NSB staff deserve special recognition, including Marta Cehelsky, Executive Officer, National Science Board, who guided and supported to all aspects of the Board's effort; Daryl Chubin, Senior Policy Officer, NSB, who provided helpful feedback and guidance and Gerard Glaser, his successor; and Janice Baker, NSB Writer/Editor.

Executive Summary

Context and Framework for Study

The Federal Government's policy for investment in science and technology over the last 50 years has yielded enormous benefits to the economy, national security, and quality of life in the U.S. The Federal share of total national science and technology investment is critically focused in areas that would be inadequately funded or not supported by the private sector. These include research to support Federal missions; research that is high-risk or requires long-term investment in the expectation of future high payoffs to society; unique, costly, cutting-edge research facilities and instruments; and academic research that, as a primary purpose, supports the education of the future science and engineering workforce.

"Our challenge, now and in the future, will be to maintain a steady flow of understanding-driven scientific and engineering studies even in the face of limited federal resources. Meeting this challenge means that priorities for spending on science and engineering by the federal government will have to be set." — *U. S. House of Representatives, Unlocking Our Future*

Over $90 billion[1] was allocated to Federal R&D in the most recent budget—representing a little more than a quarter of all national R&D. With such a large investment of public funds, policy makers in Congress and the Executive branch are asking for convincing evidence of the effectiveness of Federal investments in the form of hard data on benefits. There is general recognition among policy makers that outstanding opportunities for excellent research far exceed any reasonable level of funding by the Federal government. Choices must be made. Wise, well-informed choices among alternatives will sustain a strong, balanced research infrastructure to enable the discoveries that will be a foundation for future prosperity.

The current system for priority setting in the Federal research budget lacks a coherent, scientifically based process for systematic review and evaluation of the broad Federal investment portfolio for effectiveness in achieving national goals. Moreover available data and analyses are often ill suited for informing

[1] Executive Office of the President, Office of Management and Budget, "Analytical Perspectives," *Fiscal Year 2002 Budget of the United States Government*, Table 7-2, Research and Development Spending.

"Science and technology are critically important to keeping our nation's economy competitive and for addressing challenges we face in health care, defense, energy production and use, and the environment. As a result, every federal research and development (R&D) dollar must be invested as effectively as possible." — *OMB, The President's Management Agenda, Fiscal Year 2002*

budget allocation decisions that affect U.S. research infrastructure.

Decision makers must rely on the scientific community to provide the best advice on the most promising research investment choices for the future. The form and timing of such advice is also important. Appropriate advice must include a reasonable estimate of the level of funding that would be required for adequate support of a new initiative over time, provide tradeoff options to enable funding for priorities, and be available on a schedule compatible with the Federal budget process.

No process now exists for weighing the available evidence on competing research investment opportunities across broad fields of research. It is critical that the choices among such opportunities be based on a process that is transparent and credible with the scientific communities and the general public and its representatives. Such a function requires an organizational home, appropriate expert resources, and adequate financial support.

Since the mid 1990s, the National Science Board has been actively engaged in issues of priority setting for the Federal research portfolio.[2] In 1999, the Board charged its Ad Hoc Committee on Strategic Science and Engineering Policy Issues to undertake a study of research budget coordination and priority setting methodologies across fields of science and engineering in the U.S. and in other countries.

Conduct of Study

The study, *Federal Research Resources: A Process for Setting Priorities* (NSB 01-156), which follows on recommendations of the Board's previous working paper on *Government Funding of Scientific Research* [NSB 97-186), responds to a request by the House Appropriations Committee[3] and the encouragement of the Office of Management and Budget. In its November 1998 *Strategic Plan* (NSB-98-215) the Board identified this effort as a high priority for national science policy.

The Committee on Strategic Science and Engineering Policy Issues commissioned reviews of the literature in two areas.[4] The first focused on Federal research budget coordination, priority setting across fields of science and engineering, and available data and analytical tools to support priority setting. A second study of the same subject reviewed international models of S&T budget coordination and priority setting. It also included a symposium with presentations by S&T officials from eight foreign governments.

[2] The National Science Board issued *In Support of Basic Research*—NSB 93-127; *Federal Investments in Science and Engineering*—NSB 95-254 and *Statement on Federal R&D Budget Realignment*—NSB 95-26, were issued from 1993 to 1995, in addition to more recent papers.

[3] House Appropriations Committee Report 105-610, 105th Congress, 2nd Session, U. S. House of Representatives. To accompany H.R. 4194.

[4] Steven W. Popper, Caroline S. Wagner, Donna L. Fossum, William S. Stiles. *Setting Priorities and Coordinating Federal R&D Across Fields of Science: A Literature Review* (DRU-2286-NSF). Washington DC: RAND Science and Technology Policy Institute, April 2000; and H. Roberts Coward. *Final Report: Symposium on International Models of Budget Coordination and Priority Setting for S&T*. Washington DC: SRI International, August 2000.

In addition to these studies, the Committee heard presentations by invited experts who discussed a wide range of methodologies and data to support budget allocation decisions for research. It also received written comments on its draft recommendations by mail and through the National Science Board website, and heard presentations broadly representative of stakeholders in Federal research. Stakeholder input culminated with a Symposium on May 21-22, 2001 on the Board's preliminary findings and recommendations, with more than 200 participants.

Principal Findings

- Federal priority setting for research occurs at three levels: 1) establishing Federal goals for research, 2) the budget allocation processes for research within the White House and Congress that in the aggregate produce the Federal research portfolio and 3) Federal agencies and departments in achieving their missions in accord with the President's priorities for research. This report focuses on the second level, that is, the White House and Congressional processes that in the aggregate produce the Federal portfolio of investments in research.

- The allocation of funds to national research goals is ultimately a political process that should be informed by the best scientific advice and data available.

- A strengthened process for research allocation decisions is needed. Such allocations are based now primarily on faith in future payoffs justified by past success. They are difficult to defend against alternative claims on the budget that promise concrete, more easily measured results and are supported by large and vocal constituencies.

- The pluralistic framework for Federal research is a positive aspect of the system and increases possibilities for funding high-risk, high-payoff research. An improved process for budget coordination and priority setting should build on strengths of the current system and address weaknesses in data, analyses, and expert advice.

- There is a need for regular evaluation of Federal investments as a portfolio for success in achieving Federal goals for research, to identify areas of weakness in national infrastructure for S&T, and to identify a well-defined set of the top priorities for major new research investments.

- Additional resources are needed to provide both Congress and the Executive branch with data, analyses, and expert advice to inform their decisions on budget allocations for research.

Recommendations

Implementation of a broad-based, continuous capability for expert advice to both OMB and Congress during the budget process would yield immediate benefits to decision makers. There is also a long-term need for a regular, systematic evaluation of the effectiveness of Federal investments in achieving Federal goals for research through the Office of Science and Technology Policy, drawing broad-based input from scientific experts and organizations in all sectors. Complementing both would be improved analyses on research opportunities, needs, and benefits to society; and timely data that trace Federal research investments through the budget process and beyond.

Keystone Recommendation 1

The Federal Government, including the White House, Federal departments and agencies, and the Congress should cooperate in developing and supporting a more productive process for allocating and coordinating Federal research funding. The process must place a priority on investments in areas that advance important national goals, identify areas ready to benefit from greater investment, address long-term needs and opportunities for Federal missions and responsibilities, and ensure world class fundamental science and engineering capabilities across the frontiers of knowledge. It should incorporate input from the Federal departments and agencies, advisory mechanisms of the National Academies, scientific community organizations representing all sectors, and a global perspective on opportunities and needs for U.S. science and technology.

Research Community Input on Needs and Opportunities:

Presently there is no widely accepted and broadly applied way for the Federal Government to obtain systematic input from the science and engineering communities to inform budget choices on support for research and research infrastructure. The current system often fails to produce advice and information on a schedule useful to the budget process and responsive to needs for broad-based, informed assessments of the benefits and costs of alternative proposals for Federal support. A more effective system for managing the Federal research portfolio requires adequate funding, staffing and organizational continuity.

Recommendation 2

A process should be implemented that identifies priority needs and opportunities for research—encompassing all major areas of science and engineering—to inform Federal budget decisions. The process should include an evaluation of the current Federal portfolio for research in light of national goals, and draw on: systematic, independent expert advice from the external scientific communities; studies of the costs and benefits of research investments; and analyses of available data; and should include S&T priorities, advice, and analyses from Federal departments and agencies. The priorities identified would inform OMB in developing its guidance to Federal departments and agencies for the President's budget submission, and the Congress in the budget development and appropriations processes.

Executive Branch Advisory Mechanism:

The Executive Branch should implement a more robust advisory mechanism, expanding on and enhancing current White House mechanisms for S&T budget coordination and priority setting in OSTP and OMB. It is particularly essential that the advisory mechanism include participants who are experienced in making choices among excellent opportunities or needs for research, for example, vice provosts for research in universities, active researchers with breadth of vision, and managers of major industrial research programs.

Recommendation 2a

An Executive Branch process for ongoing evaluation of outcomes of the Federal portfolio for research in light of Federal goals for S&T should be implemented on a five-year cycle.[5] A report to the President and Congress should be prepared including a well-defined set of the highest long-term priorities for Federal research investments. These priorities should include new national initiatives, unique and paradigm shifting instrumentation and facilities, unintended and unanticipated shifts in support among areas of research resulting in gaps in support to important research domains, and emerging fields. The report should also include potential trade-offs to provide greater funding for priority activities. The report should be updated on an annual basis as part of the budget process, and should employ the best available data and analyses as well as expert input. Resources available to OSTP, OMB and PCAST should be bolstered to support this function.

[5] The designation of a five-year cycle for evaluation of the Federal portfolio reflects both the scale of the effort, which would require a longer time than an annual process, and the increasingly rapid changes in science that demand a frequent reevaluation of needs and opportunities for investments.

Congressional Advisory Mechanism:

There is no coherent congressional mechanism for considering allocation decisions for research within the framework of the broad Federal research portfolio. Though improvements in the White House process—particularly expansion of activities and resources available to OSTP—would benefit congressional allocation decisions, one or more congressional mechanisms to provide expert input to research allocation decisions are badly needed.

Recommendation 2b

Congress should develop appropriate mechanisms to provide it with independent expert S&T review, evaluation, and advice. These mechanisms should build on existing resources for budget and scientific analysis, such as the Congressional Budget Office, the Congressional Research Service, the Government Accounting Office, and the National Academies. A framework for considering the full Federal portfolio for science and technology might include hearings by the Budget Committees of both houses of Congress, or other such broadly based congressional forums.

Definitions, Data and Data Systems:

High quality data and data systems to monitor Federal investments in research would enhance the decision process. Such systems must be based on definitions of research activities that are consistently applied across departments and agencies and measured to capture the changing character of research and research needs. Improving data will require long-term commitment with input from potential users and contributors, and appropriate financial support.

Recommendation 3

A strategy for addressing data needs should be developed. Such a strategy supported by OMB and Congress and managed through OSTP and OMB would assure commitment by departments, agencies and programs to timely, accessible data that are reliable across reporting units and relevant to the needs for monitoring and evaluating Federal investments in research. Current data and data systems tracking federally funded research should be evaluated for utility to the research budget allocation process and employed as appropriate.

International Comparisons:

Both relative and absolute international statistical data and assessments should be a major component of the information base to support Executive Branch and Congressional research budget allocation decisions. International benchmarking of U.S. research performance and capabilities on a regular basis responds to the growing globalization of science and technology and the need for the U.S. to maintain a world-class science and engineering infrastructure.

Recommendation 4

Input to Federal allocation decisions should include comparisons of U.S. research resources and performance with those of other countries. National resources and performance should be benchmarked to evaluate the health and vigor of U.S. science and engineering for a range of macroeconomic indicators, using both absolute and relative measures, the latter to control in part for the difference in size and composition of economies. Over the long term, data sources should be expanded and quality improved.

Federal Research Benefits to the Economy and Society:

In addition to monitoring Federal expenditures for research, measuring the benefits to the public of funded research is essential for prudent management. Implementation of this recommendation should be coordinated with Recommendation 3 on definitions and data systems.

Recommendation 5

The Federal Government should invest in the research necessary to build deep understanding and the intellectual infrastructure to analyze substantive effects on the economy and quality of life of Federal support for science and technology. The research should include improvements to methods for measuring returns on public investments in research.

CONCLUSION

The Board's recommendations provide a framework for improving the quality, content, and accessibility of science and engineering expert advice, data, and analyses to inform decisions on priorities in the White House and Congress for Federal investments across fields of research. We are aware that implementing these recommendations will be difficult and require long-term commitment and support. In the interest of science and the Nation, we urge that the Federal Government and its partners in the research community embrace this difficult task.

Chapter One

Introduction

In the fifty years since the end of World War II and the establishment of a national policy for Government support of scientific research in colleges and universities,[6] historical trends and events have changed the public expectations for Federal research investments. The most important historical event affecting the national post-World War II consensus on Federal participation in science and technology is the end of the Cold War. Until that time, the rationale for Federal investments in research relied heavily on the contributions of science and technology (S&T) to a strong national defense.

"Yet, in holding scientific research and discovery in respect, as we should, we must also be alert to the equal and opposite danger that public policy could itself become the captive of a scientific technological elite. It is the task of statemanship to mold, to balance, and to integrate these and other forces, new and old, within the principles of our democratic system—ever aiming toward the supreme goals of our free society."
—President Dwight D. Eisenhower, Farewell Address, 1/17/61

The last few Federal budget years have been favorable to research, but a favorable budget in one or two fiscal years does not obviate the need for a coherent post-Cold War Federal policy and decision process to guide investment in S&T. It is difficult to envision a reversal of the tide of accelerating competition among exploding scientific opportunities and between science and other worthy claimants on the budget. Today's environment demands more effective management of the Federal portfolio for research, including a sustained advisory process that incorporates systematic involvement of participants in the U.S. research enterprise, including the science and engineering communities, Federal agencies that fund research, industry, nonprofit organizations that fund and perform research, and, increasingly, state governments. Expert input is particularly important for decisions on long-term, high-risk investments in research–-sponsored mainly by the Federal Government-–which are steadily losing ground in the national research portfolio to short-term investments.

The Federal commitment to research over the last half-century has contributed to a continuous outpouring of benefits to the public from advances in science and technology. Furthermore, within the last few decades these benefits have become increasingly visible and pervasive, from economic growth driven by high technology industries, to science and technology based transformations in many areas of public and private life—including, among others, the revolution in communications and information technologies, major medical breakthroughs, and superior defense technology demonstrated in the field. These transforma-

[6] Vannevar Bush, *Science—The Endless Frontier* (National Science Foundation 40th Anniversary edition) Washington DC: National Science Foundation, 1990.

Process for Producing the Report

The study responds to the House Committee on Appropriations FY 1999 report urging the Board to undertake the study and the encouragement from Office of Management and Budget (OMB) for this effort. The Board Ad Hoc Committee on Strategic Science and Engineering Policy Issues was charged to examine the state of the art in budget coordination and priority setting for research across fields of science and engineering in the U.S. and internationally, and to convene appropriate stakeholders to consider the findings of these studies and reviews, to develop recommendations for improved methodologies for coordination and priority setting in the Federal research budget and for building the support of the science and engineering communities and the public for these methodologies. The study included two literature reviews:

- Federal research budget coordination and priority setting
- International models of science and technology budget coordination and priority setting.

The Committee heard presentations by invited experts addressing the following methodologies and topics:

- International models for S&T budget coordination and priority setting; a one-and-a-half day Symposium was held in November, 1999, opened by the U.S. President's Science Advisor, with presentations by officials for eight foreign governments: the United Kingdom, Germany, France, Sweden, the Republic of Korea, Japan, Brazil, and the European Union;
- A project to develop a more complete and accessible database for tracking Federal R&D funding, the RaDiUS database, and data issues in tracking S&T activities in the Federal budget;
- Foresight methods, used by many countries as part of the dialogue toward establishing priorities for S&T;
- The Federal Science and Technology (FS&T) budget analysis by the Committee on Science, Engineering and Public Policy (COSEPUP) of the National Academies and the American Association for the Advancement of Science;
- Experiments in international benchmarking of U.S. research fields—undertaken by COSEPUP;
- Approaches to priority setting for research in the academic sector, and the relationship between Federal and academic priority setting;
- Priority setting practices in industry, and the role of industry and the Federal government in national R&D;
- Economic methods to measure the benefits of Federal investments in research and to inform budget allocation decisions, presented by academic experts on economic methods to measure returns on research investments and experts on the Federal budget from the Congressional Budget Office and Council of Economic Advisors.

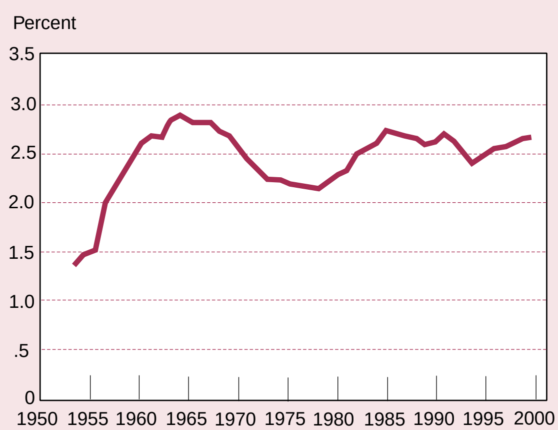
The study included an overview of budget coordination and priority setting in Federal S&T agencies in a August 3-4, 2000 meeting with representatives of the Office of Science and Technology Policy (OSTP), Office of Management and Budget (OMB), Department of Energy (DOE), National Institutes of Health (NIH), National Science Foundation (NSF), National Aeronautics and Space Administration (NASA), U.S. Department of Agriculture (USDA), Environmental Protection Agency (EPA), National Oceanographic and Atmospheric Administration (NOAA), Department of Defense (DOD), Veterans Health Administration (VHA), National Institute of Standards and Technology (NIST), and a discussion with House Appropriations staff.

Finally, the Committee sponsored a stakeholders' symposium on Allocation of Federal Resources for Science and Technology, May 21-22, 2001, focused on the Board-approved discussion document, *The Scientific Allocation of Scientific Resources* (NSB 01-039), containing preliminary recommendations. The report and invitation to the symposium were distributed by webpage, email and mail to members of the stakeholder communities. The symposium included 20 speakers and panelists and encouraged active audience participation. It was attended by more than 200 members of the stakeholder communities including representatives from Congressional staff, science policy organizations, Federal agencies, academic organizations, scientific community organizations, science media, industry representatives and interested individuals.

tions underscore the value of sustained public investments reaching back decades. Moreover, even as the Federal share of funding has declined in national research and development (R&D), non-Federal sectors of the economy—industry, academe, state and non-profit—have come to rely on the Federal Government to play a critical role in funding long-term investments in science and engineering discovery, education and innovation.

The success of the U.S. in encouraging the growth of its high technology industrial sector through public funding for science and engineering research and advanced education led to the U.S. system becoming a widely emulated international model. As Federal Reserve Chairman Alan Greenspan[7] noted: " . . . the research facilities of our universities are envied throughout the world . . . The payoffs in terms of the flow of expertise, new products, and start-up companies, have been impressive." Nonetheless, recognition of the benefits of past public investments does not guarantee public support of the science and technology infrastructure necessary to enable future discoveries that may not yield measurable benefits for decades. Critics and supporters alike note the need for a clearly articulated and compelling rationale for Federal investments in science and technology equivalent in persuasive powers to the rationale of the Cold War.

FIGURE 1:
US R&D/GDP: 1953-2000



Since the 1960s, national expenditures for R&D have been in the range of 2 to 3 percent of GDP

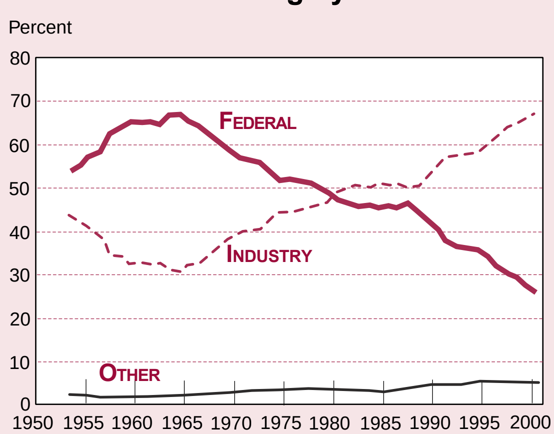
[7] Remarks by Chairman Alan Greenspan, "Structural change in the new economy," before the National Governors' Association, 92nd Annual Meeting, State College, Pennsylvania, July 11, 2000.

CHAPTER TWO

NATIONAL POLICY CONCERNS AND NEEDS

Decision makers in the Executive and Legislative branches of government are concerned about the management of Federal investments in research, which in the most recent budget had reached more than $90 billion for R&D.[8] Articulating this concern, former Office of Management and Budget (OMB) Director Franklin Raines[9] raised the following questions: How large a scientific enterprise does the United States need? How can we set priorities in the Nation's R&D enterprise? How can we measure the success of our Nation's research programs? How can we strengthen the government-university partnership? How do we engage the American people in the excitement and wonder of science?

FIGURE 2:
Shares of National R&D Funding by Source: 1953-2000



Since 1980 Industry has become increasingly dominant in national R&D.

[8] Executive Office of the President, Office of Management and Budget, *Fiscal Year 2002 Budget of the United States Government*, Table 7-2, Special Analyses.
[9] Franklin D. Raines. "Making the Case for Federal Support of R&D," *Science* (12 June 1998):1671.

"I doubt that anyone would sign on to a research project as poorly designed as our current national experiments in science and technology policy . . . our scientific enterprise remains adrift, without a connection to the broader society"
–Representative George E. Brown, Jr., 1998

Likewise, Chairman of the House Science Committee, Sherwood Boehlert,[10] responded to the proposal to double Federal funding for research by questioning: "What are we going to get for that money? How will we know if we are under- or over-spending in any field? . . . We really need to push for more data." He went on to warn: "I want the Committee, early on, to take a serious look at the balance within the federal research portfolio . . . You can . . . count on me to ask tough and uncomfortable questions to ensure that the scientific community is acting in its and the nation's long term interest."

How should the scientific community respond to these questions and expectations? How should it raise public awareness that the quality of life in the future will depend in large measure on the generation of new wealth, on safeguarding human health and the health of our planet, and on opportunities for enlightenment and individual development made possible by science and engineering discoveries? Will the response of the scientific community be effective against competing claims on the Federal budget?

These issues have prompted a vigorous policy debate over the last decade involving the Executive and the Legislature, the National Academies, and professional societies. Nonetheless, the debate to this point has generated no widely accepted process for the Federal Government, with systematic input from the scientific community and its representatives in all sectors of the economy, to make priority decisions about the allocations in and across fields of research in support of Federal goals.

The National Science Board (the Board) has participated in this debate, issuing a series of policy statements, including an NSB working paper on *Government Funding of Scientific Research* in 1997. The Board concluded in that paper that within the Federal budget there should be an overall strategy for research, with areas of increased and decreased emphasis and a level of funding adequate both to serve national priorities and to foster a world-class scientific and technical enterprise. To this end Congress and the Administration need to establish a process that examines the Federal research budget before the total Federal budget is disaggregated for consideration by congressional committees. The Board further concluded in its 1998 *Strategic Plan* that a prerequisite for a coherent and comprehensive Federal allocation process for research is the development of an intellectually well-founded and broadly accepted methodology for setting priorities across fields of science and engineering.

As follow-up to its earlier work, the Board undertook, beginning in March 1999, a focused examination of Federal priority-setting methodologies for research in the United States at three levels: 1) setting Federal goals, 2) allocation decisions by Congress and the Administration that produce the Federal portfolio for research and 3) Federal agencies and departments in achieving their missions in alignment with stated Federal priorities. The Board determined that the appropriate level for its focus is the second level, that is, the White House and congressional processes that in the aggregate produce the Federal portfolio of investments in research.

[10] Congressman Sherwood Boehlert (R-NY), Speech To Universities Research Association, January 31, 2001.

CONTEXT FOR FEDERALLY FUNDED RESEARCH

The Federal role has always encompassed the missions of Federal agencies and departments and, beyond those missions, has helped to sustain a healthy national infrastructure for S&T. The Federal role today is especially critical for research that is high risk, requires long-term investment in the expectation of future high payoffs to society or that is unlikely to be funded by the private sector; for unique, costly, cutting-edge research facilities and instrumentation; and for academic research that, as a primary purpose, supports the education of the future science and engineering workforce. It is this portion of the Federal research portfolio that is especially vulnerable to diversion of funds to areas of research with more clear and immediate payoffs to society or to other important goals of Federal mission departments and agencies. It is also the critical Federal investment in our Nation's future science and technology capabilities.

The national science and technology enterprise has grown and become more pervasive in both the private sector and in government, even as the Federal share of support to the enterprise has declined. Now, more than ever, achieving Federal goals for sustaining U.S. leadership in S&T demands partnerships and cooperation with other sectors. Understanding where Federal funding can be best employed and the level of investment required to assure the health of U.S. science and technology are essential to prudent management of the Federal portfolio. Commitment to an intellectually well-founded, long-term strategy for Federal research must be an integral aspect of a sound fiscal policy, regardless of year-to-year fluctuations in available funds. The Federal budget process for research must assure sustained and sufficient support for a diverse, flexible, opportunistic portfolio of investments, emphasizing the long-term health of the knowledge base and infrastructure for research—including human resources.

NEED FOR A DIFFERENT APPROACH TO BUDGET COORDINATION AND PRIORITY SETTING

The Board's discussions with spokespersons from Executive and Legislative branches and with experts on the budget, data and analytic methods, as well as reviews of the literature on budget coordination and priority setting, identified the following needs.

Methodologies for:

- Determining the appropriate size of the enterprise
- Determining the appropriate level of support to individual fields
- Achieving balance in the portfolio
- Setting priorities for the Nation's research enterprise
- Achieving effective communication on scientific matters with the American people
- Strengthening government partnerships and collaboration in research with other sectors and other international partners

Improved data, expert analyses, and scientific advice include:

- A continuing mechanism for expert advice representing a broad cross-section of the science and engineering research and education community to support difficult decisions on research investments—especially in major infrastructure projects
- Better quantitative data and methods of analysis adequate to measure the benefits of research
- A mechanism to identify and track the relevant Federal funds for S&T through the budget process in the Administration and Congress

The Current Federal System

The current Federal system for allocating funds for research is an incremental process that results in final allocation decisions based on input from a range of stakeholders, including the science and engineering communities. Ultimately, the Federal budget for research rests on aggregated political decisions in thirteen congressional appropriations subcommittees. There has been a host of critiques and suggestions for improving the process, many focused on the goals for research, but some suggesting changes to the process itself. The most frequent critique addresses a perceived lack of a clear methodology for priority setting and coordination. Several possible remedies have been suggested: structural changes to the process, alternative interpretations of the appropriate goals for Federal research, and new mechanisms for funding allocations and better management of the Federal research portfolio.

Since the late 1980s, and under both Republican and Democratic administrations, there has been substantial attention devoted to developing better mechanisms for coordinating the Federal budget for research through OMB and the Office of Science and Technology Policy (OSTP) (Box One).

Box One

WHITE HOUSE S&T POLICY APPARATUS

Office of Science and Technology Policy (OSTP): The legislation that established OSTP "Declares that the United States shall adhere to a national policy for science and technology which includes the following principles: (1) the continuing development and implementation of a national strategy for determining and achieving the appropriate scope, level, direction, and extent of scientific and technological efforts based upon a continuous appraisal of the role of science and technology in achieving goals and formulating policies of the United States; (2) the enlistment of science and technology to foster a healthy economy in which the directions of growth and innovation are compatible with the prudent and frugal use of resources and with the preservation of a benign environment; and (3) the development and maintenance of a solid base for science and technology in the United States."

It "states the declaration of Congress that the Federal Government should maintain central policy-planning elements in the executive branch in mobilizing resources for essential science and technology programs, in securing appropriate funding for those programs, and to review systematically Federal science policy and programs and to recommend legislative amendments when needed". The functions of the Office include: "(1) advise the President of scientific and technological considerations involved in areas of national concern; (2) evaluate the scale, quality, and effectiveness of the Federal effort in science and technology and advise on appropriate actions; (3) advise the President on scientific and technological considerations with regard to Federal budgets; and (4) assist the President in providing general leadership and coordination of the research and development programs of the Federal Government." (Excerpted from Public Law 94-292)

National Science And Technology Council (NSTC): The NSTC functions were to:

1) coordinate the science and technology policy-making process;
2) ensure science and technology policy decisions and programs are consistent with the President's stated goals;
3) help integrate the President's S&T policy agenda across the Federal Government;
4) ensure S&T are considered in development and implementation of Federal policies and programs; and
5) further international cooperation in science and technology (Executive Order 12881, November 23, 1993, Section 4).

Federal Coordinating Council for Science, Engineering and Technology (FCCSET): Established in 1976 under OSTP in the National Science and Technology Policy, Organization, and Priorities Act, FCCSET was "to consider problems and developments in fields of science, engineering, and technology and related activities affecting more than one Federal agency, and to recommend policies designed to provide more effective planning and administration of Federal scientific, engineering, and technological programs." (Title IV, Public Law 94-292).

> "The Federal role today is especially critical for research that is high risk, requires long-term investment in the expectation of future high payoffs to society or that is unlikely to be funded by the private sector; for unique, costly, cutting edge research facilities and instrumentation; and for academic research that, as a primary purpose, supports the education of the future science and engineering workforce."

The cabinet-level National Science and Technology Council (NSTC) (Box One) in the previous Administration and the earlier Federal Coordinating Council for Science, Engineering and Technology (FCCSET) provided mechanisms in OSTP for identifying major national initiatives that cut across agencies in designated priority areas (e.g., nanotechnology, global climate change, and information technology). Under the last Administration, the NSTC was established by Executive order as part of the OSTP science and technology policy apparatus. However, unlike FCCSET, OSTP and the Director of OSTP, which were established through legislation, the NSTC had no permanent status. Likewise, the President's Committee of Advisors on Science and Technology (PCAST), whose purpose was to provide "critical links to industry and academia," was established by Executive order.

Furthermore, in neither the Executive nor the Legislative branches is there a mechanism for evaluation that takes into account the breadth of Federal investments within the context of Federal goals for research. The Executive Branch, through OMB, OSTP and PCAST, made an effort to treat Federal funding of research as a portfolio, recently taking into account the issue of balance among fields of science in Federal support across all agencies and departments.

These steps have been in the right direction but are only a preliminary effort. Congress also has directed attention to what might be done to improve its process but has not yet taken any action to implement formal mechanisms comparable to OSTP to coordinate functions across budget lines, agencies and departments, and committees.

Budget Coordination and Evaluation of the Portfolio

To enhance the effectiveness of Federal investments in achieving long-term goals for research, a regular, credible process that relies in part on expert input from the science and engineering communities is essential for priority setting among competing investment choices. The Federal portfolio for research is an aggregate of the research portfolios of the individual departments and agencies funding S&T. It has not been managed as a portfolio. As a precondition for priority setting across the Federal research budget, coordination must be achieved among its diverse components. While efforts at better coordination through OSTP mechanisms have been useful in managing cross-agency initiatives, coordinating mechanisms are also necessary for evaluating the performance of Federal research investments as a portfolio and for identifying gaps, overlaps, areas for decreased emphasis, and the top priorities for additional investments. Coordination and priority setting therefore must be intertwined in the Federal research budget process.

The Need for More and Credible Data and Analyses

No mechanism exists to provide strong quantitative input to justify a particular level of investment in Federal research based on expected benefits to society, due in part to the lack of data and methods to measure research benefits. Data on Federal research funding, especially at the field level, are often unavailable on a timely basis to inform budget allocation decisions, use outdated research field definitions, fail to capture important characteristics of research activities—particularly growing collaboration across fields, organizations, sectors, and even nations—and suffer from inconsistent applications of definitions across reporting units.

In spite of the need for more and better data on the Federal research enterprise, collecting such data requires consistent cooperation of a large number of Federal agencies and departments. There are few resources available to address the major undertaking that would be required to generate reliable data tailored to the needs of budget decisions and outcomes for research funding allocations.

It would require a concerted effort to define and obtain agreement among the many Federal units that would be involved, and would require support from OMB and Congress to assure collection of high quality, timely data tailored to tracking the Federal funding for science and technology through the budget process and beyond. Nonetheless, National Science Foundation and other major research funding agencies have been open to developing consistent and

Box Two

Coordinating The Budget for S&T in Congress

At no time in the congressional authorization or appropriations process is the research portfolio examined as a whole, across the Federal government. The consideration of segments of the research budget in a large number of committees and subcommittees makes it impossible for Congress to consider the impacts of individual funding decisions on U.S. science and technology capabilities. The House Science Policy Study, *Unlocking Our Future*, argues that:

. . . at a minimum Congress and the Executive Branch should improve their internal coordination processes to more effectively manage, execute, and integrate oversight . . . While the Office of Management and Budget can fill this role in the Executive Branch, no such mechanism exists in the Congress. In those cases where two or more Congressional committees have joint jurisdiction over or significant interest in large, complex technical programs, the affected committees should take steps to better coordinate their efforts. Wherever possible, the affected committees should consider holding joint hearings and perhaps even writing joint authorization bills.

appropriate data tools for managing the Federal research portfolio and for communicating with more credibility to the public concerning their investments in research and education.

IDENTIFYING THE COMPOSITION OF THE FEDERAL RESEARCH PORTFOLIO

OMB requires agencies to report R&D activities that they are funding for the annual budget process. Even if reliably measured across funding units, since "D" (development) at about 55 percent of the total is larger than "R" (research), reporting the sum of the two as the measure of Federal research investment results in an indicator that fails to accurately reflect the Federal funding to discovery and innovation. Also, significant fluctuations in support for "R" tend to be obscured when combined with the larger "D" category funds.

"The nation must reach a common ground and define a more realistic, pragmatic framework for allocating federal R&D resources. Only an inclusive national dialogue that brings together both the executive and legislative branches of government with the private sector and the U.S. university community will produce the needed consensus."
—Council on Competitiveness, Endless Frontier, Limited Resources, 1996

There have been several attempts to provide a better measure for the federally funded activities that contribute to national innovation. The National Academies proposed a coordinated "Federal Science and Technology Budget",[11] a subset of Federal R&D that constitutes "federal support for a national science and technology base." The FS&T budget would provide Congress with a tool for tracking the aggregated pool of Federal departmental and agency funds that support the science and technology base. OMB has employed over the last few budget cycles[12] a similar mechanism for tracking the President's research priorities through the budget process. This mechanism comprised a collection of program budgets that are primarily research programs but also includes non-research elements, such as the education and human resources component of the budget for NSF. OMB found this mechanism useful in highlighting Federal research investments and effective in supporting the President's priorities for research through the budget cycle.

The Board, for the purposes of this study, has focused on S&T. In so doing, the Board follows the approach of organizations such as the National Research Council and OMB, which identify basic and applied research activities for tracking through the budget process. At the same time the Board recognizes that S&T has been defined in a variety of ways in the Federal portfolio, and that as yet there is no consensus on federally funded activities that should constitute Federal S&T. Criteria for inclusion of activities in a Federal budget for research for the purpose of monitoring and evaluating Federal activities as a portfolio will require further discussion and analysis.

The important subset of research funding devoted to the long-term, high-risk basic research is especially vulnerable to becoming invisible in the larger budget for S&T. It is critical that this component receive sustained public support to produce as yet unforeseen major breakthroughs in knowledge and, when performed in academic institutions, to provide opportunities for experience in cutting-edge research for advanced science and engineering students under the guidance of faculty mentors.

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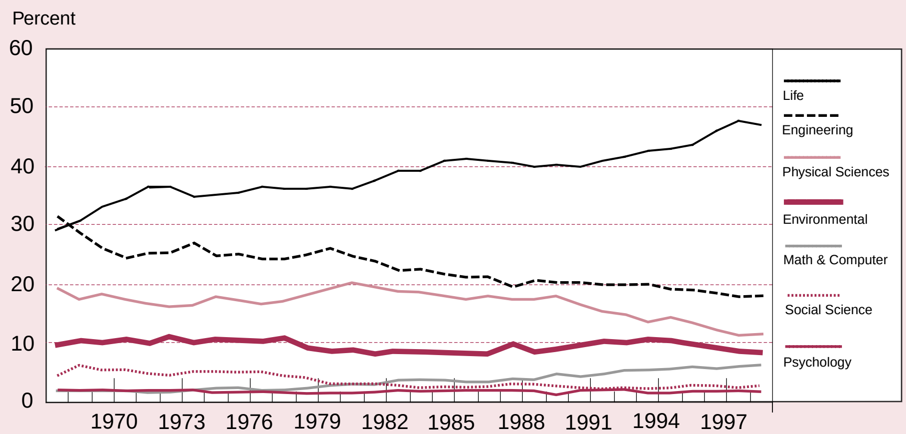
[11] National Research Council, Committee on Criteria for Federal Support of Research and Development, *Allocating Federal Funds for Science and Technology.*
[12] Office of Management and Budget, *Fiscal Year 2002 Budget*, Table 7-3.

CAPTURING THE CHARACTER OF ACTIVITIES SUPPORTED AT THE FIELD LEVEL

Within research, the character of research fields and activities has changed over time, resulting in definitions that no longer capture important distinctions in federally funded research activities. Special areas of weakness include multidisciplinary and cross-disciplinary workgroups and teams, emerging areas, differences in interpretation across agencies' reporting units, and the evolving content of traditional research fields themselves. In addition, educational contributions of research—particularly in academic institutions for graduate education—are not captured in most agencies' databases. Current field-level data have the advantage of providing a time series to reveal trends in support to fields of science and engineering. New information technology is available to support development of richer, more easily accessible and more flexible databases for federally funded research activities.

FIGURE 3:
Shares of Federal Research by Field



Over the last three decades the life sciences have come to dominate the Federal portfolio of research investments.

RELIABILITY AND TIMELINESS

Differences in interpretation have resulted in wide discrepancies in research funding reported by performing and funding units—or even within the Federal Government across agencies and programs—even though they ostensibly describe the same activities. In addition, timeliness, in most cases essential to budget allocation decisions, is not possible with Federal databases based on surveys. Much of the data measuring the Federal research portfolio with respect to programs funded, support for fields of science and engineering, and performing institutions are several years old at best. Timeliness will become increasingly more problematic as rapid changes in science and technology increase the need for current data to monitor Federal investments. Agencies and departments could benefit from coordinated efforts across S&T funding units to develop a more efficient and timely data collection process while assuring the integrity of the data they provide.

ASSESSING WORLD LEADERSHIP OF U.S. SCIENCE AND ENGINEERING

National capabilities in science and technology and the government role in enhancing these assets are growing emphases for governments around the world. As science and technology capabilities have become more broadly distributed, there is a need for the United States to monitor the U.S. enterprise against an international backdrop to detect declines in national capabilities in science and technology relative to other nations or to identify new opportunities for research investment that merit public support. The National Academies have urged regular international benchmarking at the field level to assess the health of individual fields of research in the United States.[13] The use of international comparisons of the productivity of research fields and international expert participation in assessments of research programs are common in other countries. The Board has noted the need for monitoring the relative health of U.S. science and technology as part of a continuing evaluation of the Federal portfolio, drawing on existing data and expert analyses, and continually improving data and methods for international comparisons that inform priority setting.

UNDERSTANDING THE ROLE OF FEDERAL RESEARCH IN PRODUCING ECONOMIC AND OTHER BENEFITS

"In the long run–in good budget years as in bad—it is essential that policymakers... recognize the fragility of (the U.S. S&T) enterprise and the critical Federal role in sustaining it. It is up to the members of the scientific and engineering community to carry this message to them"
–A.H. Teich, AAAS, 1999

A large number of studies have attempted to elucidate, and in many cases measure quantitatively, the relationship between research and innovation and the benefits of research for society. Organizations like the Council on Competitiveness; the Science and Technology Policy Institute, RAND; OSTP; and NSF have explored issues and methods for analyzing the role of a range of factors in innovation—including federally funded research—and resulting economic and social benefits. On the other hand, academic programs are not doing enough to address these questions and are inadequately funded. The development of deeper understanding of the benefits from Federal research is an area where additional investment could improve both qualitative and quantitative data to inform budget allocation decisions, communicate the benefits of research to the public, and contribute to the effectiveness of Federal research investments.

[13] The National Academies, Committee on Science, Engineering and Public Policy. *Science, Technology and the Federal Government: National Goals for a New Era,* 1993 and National Research Council Committee on Criteria for Federal Support of Research and Development, *Allocating Federal Funds for Science and Technology, Appendix B,1995.*

Box Three

Science and Technology Advice to Congress

Congressional mechanisms that could provide review, assessment, and advice on science and technology issues in the past included:

- The Congressional Budget Office (CBO), established under the Congressional Budget Impoundment and Control Act in 1974 (PL 92-599) to provide objective, nonpartisan assistance to legislators, scores the costs of bills and prepares budget and economic forecasts;
- The Congressional Research Service (CRS) provides Congress with quick responses to a large number of requests for reports. CRS recently merged its Science, Technology and Medicine Division into two other divisions: Resources, Science and Industry (RSI) and Domestic Social Policy (DSP);
- The General Accounting Office (GAO) was established as auditor for Congress in 1921, but in the 1970s won broad authority to audit Federal programs; it was subjected to a 25 percent budget reduction in the mid 1990's. The GAO Energy Resources and Sciences Issue Area was reorganized into the Natural Resources and Environment Team in October 2000 as part of a general reorganization;
- The Office of Technology Assessment (OTA) was established by legislation in 1972 (PL 92-484) to provide Congress with "early indications of the probable beneficial and adverse impacts of the applications of technology and to develop other coordinate information which may assist Congress." In total, it prepared about 700 reports over 23 years.

Several of the Congressional support agencies were affected by Congressional budget cuts in the mid 1990s, with all funding eliminated for OTA in 1995.

Other mechanisms legislatively required to provide science and technology support to Federal policymakers, including Congress, are:

- The National Academies, including the Academies of Science and Engineering, the Institute of Medicine, and the National Research Council;
- The National Science Board;
- The Office of Science and Technology Policy.

Congress also employs hearings to obtain expert testimony on science and technology concerns.

Although the need to provide Congress with more systematic S&T review, assessment and advice has been widely supported in concept, opinions vary on appropriate mechanisms to accomplish these ends.

CHAPTER THREE

MAJOR FINDINGS AND ISSUES

The Board's findings are based on an intensive two-year study including review of the literature on Federal budget coordination and priority setting for science and engineering research, and invited presentations from and discussions with representatives of OMB, OSTP, the Federal R&D agencies, congressional staff, high level science officials from eight foreign governments, experts on data and methodologies, and industry, the National Academies, and academic spokespersons. Discussions focused on research priority setting as it is practiced within government organizations and suggestions on how the process might be improved. After considering this information, the Board finds that:

- Federal priority setting for research occurs at three levels:
  1) establishing Federal goals for research,
  2) the budget allocation processes for research within the White House and the Congress that in the aggregate produce the Federal research portfolio and
  3) Federal agencies and departments in achieving their missions and in accord with the President's priorities for research.

- The allocation of funds to national research goals is ultimately a political process that should be informed by the best scientific advice and data available.

- A strengthened process for research allocation decisions is needed. Such allocations are based now primarily on faith in future payoffs justified by past success, but are difficult to defend against alternative claims on the budget that promise concrete, more easily measured results and are supported by large and vocal constituencies.

- The pluralistic framework for Federal research is a positive aspect of the system and increases possibilities for funding high-risk, high-payoff research. An improved process for budget coordination and priority setting should build on strengths of the current system and focus on those weaknesses that can be addressed by improved data and broad-based scientific input representing scientific communities and interests across all sectors.

"A primary resource that would provide immediate benefits to decision makers is a broad-based, continuous capability for expert advice to both OMB and Congress during the budget allocation process."

- There is a need for regular evaluation of Federal investments as a portfolio for success in achieving Federal goals for research, to identify areas of weakness in national infrastructure for S&T, and to identify a well-defined set of the top priorities for major new research investments.

- Additional resources are needed to provide both Congress and the Executive Branch with data, analyses, and expert advice to inform their decisions on budget allocations for research.

APPROPRIATE SCIENTIFIC ADVICE

The scientific community can contribute to the Federal budget process as it now does within departments, agencies and programs, by providing:

- Reliable data and expert opinion on the most compelling major opportunities and needs for science and engineering, in the form of a well-defined set of top research priorities for substantial additional Federal investment;

- Effective processes for priority setting across fields of science and engineering, including multidisciplinary research and emerging areas;

- Estimated costs and benefits of various proposals, as well as overall funding levels, as input to decisions;

- Consensus across broad fields of research on the highest shared priorities for advancing Federal goals for science and technology—through mechanisms of Federal agency advisory bodies, expert scientific staff, the National Academies, and private and non-profit organizations of the research and education communities—to inform Federal allocation decisions.

At the Federal level, advice on priorities for major research facilities is an area for particular attention. Facilities costs must be estimated and include long-term commitments for operation and maintenance. In addition, consideration must be given to tradeoffs to enable funding for priority facilities.

Advice, analyses and data must be coordinated with the Executive Branch and congressional budget processes if they are to be useful for informing research budget allocation decisions.

IMPROVED DATA AND ANALYSIS

Allocation decisions should be informed by available data and should employ a range of methods of analysis and data sources. Over the long term there is a need for improvements in data, methods, and analyses that track Federal funds and measure the costs and benefits of research. Needs include:

- Improved theoretical understanding of the relationship between publicly supported research and innovation;

- Improved measures of economic returns to research investments, as well as non-economic returns in improved quality of life;

- Improved understanding of the relationship between research investments and the S&T workforce;

- Broadly acceptable definitions of “research” especially at the field level—though admittedly difficult to establish—to enable unambiguous, self-consistent tracking of Federal funds and benefits across departments, agencies and sectors;

- Improved data for international comparisons, including both relative and absolute measures; and

- Improved databases and other tools for tracking research funds and measuring outputs.

Toward an Enhanced Process

The analytical and expert support available to inform research budget decisions need to be strengthened in both the Congress and the White House. A primary resource that would provide immediate benefits to decision makers is a broad-based, continuous capability for expert advice to both OMB and Congress during the budget allocation process. A longer-term need is the regular, systematic evaluation of the effectiveness of Federal investments in achieving Federal goals for research through OSTP, drawing broad-based input from scientific experts and organizations in all sectors. Complementing both are improved data and analysis on research opportunities and needs that trace Federal research investments through the budget process and beyond.

Strengthening the Federal mechanisms to inform research budget allocation decisions in the White House would add an important dimension to current mechanisms for scientific advice, which feature agency- and department-based external and internal scientific input as part of their budget deliberations. It would require additional resources in OSTP. Additional resources might also be needed to strengthen Congressional mechanisms to inform research budget decisions. Furthermore, investments in data systems and academic research on the relationship between publicly funded research and economic and social benefits would enable improvements in methods for measuring and estimating returns on public investments. The payoff would be a more effective system for allocating Federal research funds to contribute to national goals, and improved tools for measuring and communicating the benefits of Federal investments to policy makers and the general public.

Chapter Four

Conclusions and Recommendations

Federally funded science and technology support the missions of every Federal department and agency and have enormous long-term impacts on the economy and the quality of life of American citizens. The growth in the national and global science and technology enterprise, the opportunities for discovery and innovation, and the changing Federal role in U.S. science and technology require the Federal Government to direct greater attention to ensuring its investments in research produce the greatest benefits over the long term to the public.

A deliberate, scientifically grounded process is essential for identifying opportunities and needs for Federal research. Needs include human resources, instrumentation and facilities, alignment of the portfolio of Federal investments with national priorities for research, effective distribution of funding among research modes and performing organizations, closure of gaps in research resulting from changes in department and agency programs, and addressing patterns of under-investment in vital areas of fundamental research.

The Board finds that mechanisms that have evolved based on the legislation that established OSTP and on the cooperation between OSTP and OMB represent valuable progress toward a more coherent and sophisticated system to inform major decisions on Federal research investments. The OMB/OSTP/PCAST must be provided with additional resources to expand activities for managing Federal S&T as a portfolio, especially for ongoing evaluation of the effectiveness of Federal investments in achieving Federal goals for research. Additional complementary resources to provide timely expert advice, analyses and data to inform congressional budget allocation decisions are also needed.

Keystone Recommendation 1

The Federal Government, including the White House, Federal departments and agencies, and the Congress should cooperate in developing and supporting a more productive process for allocating and coordinating Federal research funding. The process must place a priority on investments in areas that advance important national goals, identify areas ready to benefit from greater investment, address long-term needs and opportunities for Federal missions and responsibilities, and ensure world class fundamental science and engineering capabilities across the frontiers of knowledge. It should incorporate input from the Federal departments and agencies, advisory mechanisms of the National Academies, scientific community organizations representing all sectors, and a global perspective on opportunities and needs for U.S. science and technology.

Research Community Input on Needs and Opportunities:

Steps can be taken in the short term to improve the information base for Federal research investments. A primary input to any process of priority setting for research is expert scientific advice on current and long-term opportunities and needs for research. Presently there is no widely accepted and broadly applied way for the Federal Government to obtain systematic input from the science and engineering communities for making priority decisions about support for research and research infrastructure.

There is insufficient opportunity and capability within the framework of existing mechanisms for Federal research priority setting to undertake timely and broad-based assessments of the needs for Federal investments. A more effective system for managing the Federal research portfolio requires adequate funding, staffing and organizational continuity.

Recommendation 2

A process should be implemented that identifies priority needs and opportunities for research—encompassing all major areas of science and engineering—to inform Federal budget decisions. The process should include an evaluation of the current Federal portfolio for research in light of national goals, and draw on: systematic, independent expert advice from the external scientific communities; studies of the costs and benefits of research investments; and analyses of available data; and should include S&T priorities, advice, and analyses from Federal departments and

agencies. The priorities identified would inform OMB in developing its guidance to Federal departments and agencies for the President's budget submission, and the Congress in the budget development and appropriations processes.

EXECUTIVE BRANCH ADVISORY MECHANISM:

The Executive Branch should implement a more robust advisory mechanism, expanding on and enhancing current White House mechanisms for S&T budget coordination and priority setting in OSTP and OMB. Enhanced resources should include an adequate professional staff, perhaps on a rotating basis modeled on the Council of Economic Advisors. It is particularly essential that the advisory mechanism include participants who are experienced in making choices among excellent opportunities or needs for research. (For example, vice provosts for research in universities, active researchers with breadth of vision, and managers of major industrial research programs would be appropriate in this role.)

Evaluation criteria should reflect Federal goals for science and technology funding. The evaluation should consider the effectiveness of the broad portfolio of Federal support to science and technology for:

- sustaining and enhancing U.S. world leadership across the frontiers of knowledge;
- assuring the long-term vitality of the U.S. science and technology enterprise by investments in important areas and activities unlikely to be funded by other sectors;
- aligning human resources for science and technology with needs of the S&T workforce in the Federal and other sectors;
- serving Federal departmental and agency missions;

and should identify:

- a well-defined set of top research priorities where enhanced Federal investments could yield high payoffs to society; and
- potential tradeoffs to provide greater funding for priority activities.

Recommendation 2a

An Executive Branch process for ongoing evaluation of outcomes of the Federal portfolio for research in light of Federal goals for S&T should be implemented on a five-year cycle.[14] A report to the President and Congress should be prepared including a well-defined set of the highest long-term priorities for Federal research investments. These priorities should include new national initiatives, unique and paradigm shifting instrumentation and facilities, unintended and unanticipated shifts in support among areas of research resulting in gaps in support to important research domains, and emerging fields. The report should also include potential trade-offs to provide greater funding for priority activities. The report should be updated on an annual basis as part of the budget process, and should employ the best available data and analyses as well as expert input. Resources available to OSTP, OMB and PCAST should be bolstered to support this function.

Congressional Advisory Mechanism:

There is no coherent congressional mechanism for considering allocation decisions for research within the framework of the broad Federal research portfolio. The current system splits areas of research among numerous committees and subcommittees, each considering a limited portion of the portfolio, making impossible consideration of impacts of budget allocation decisions on national science and technology capabilities. While the need for analytical resources for science and technology policy tailored to the congressional process has been growing, available resources have been eliminated or reduced in recent years. And though improvements in the White House process—particularly expansion of activities and resources available to OSTP—would benefit Congressional allocation decisions, one or more Congressional mechanisms to provide expert input to research allocation decisions are badly needed.

Recommendation 2b

Congress should develop appropriate mechanisms to provide it with independent expert S&T review, evaluation, and advice. These mechanisms should build on existing resources for budget and scientific analysis, such as the Congressional Budget Office, the Congressional Research Service, the Government Accounting Office, and the National Academies. A framework for considering the full Federal portfolio for science and technology might include hearings by the Budget Committees of both houses of Congress, or other such broadly based congressional forums.

[14] The designation of a five-year cycle for evaluation of the Federal portfolio reflects both the size of the effort, which would require more than an annual process, and the rapid changes in science, which demand a frequent reevaluation of needs and opportunities for investments.

Advice to Congress in developing its recommendations on Federal priorities and funding levels for research should make use of the best available data and analyses.

Definitions, Data and Data Systems:

In addition to an enhanced process for expert advice and assessment, there is a long-term need to improve tools—databases and analytic methods—for effective management of the Federal research portfolio.

High quality data and data systems to monitor Federal investments in research would enhance the decision process. Such systems must be based on definitions of research activities that are consistently applied across departments and agencies and measured to capture the changing character of research and research needs. Flexibility in defining categories of research for tracking purposes is especially important for monitoring emerging areas and addressing the range of modes for research—from the individual investigator to the major center or facility. Timely collection of data and ease of access are critical to be useful to the allocation decision process.

Improving data and data systems is a long-term objective but one that is necessary and increasingly urgent for managing the large, diverse Federal research portfolio to serve the Nation. It will require long-term commitment to improve data systems, with input from potential users and contributors, and appropriate support.

Recommendation 3

A strategy for addressing data needs should be developed. Such a strategy supported by OMB and Congress and managed through OSTP and OMB would assure commitment by departments, agencies and programs to timely, accessible data that are reliable across reporting units and relevant to the needs for monitoring and evaluating Federal investments in research. Current data and data systems tracking federally funded research should be evaluated for utility to the research budget allocation process and employed as appropriate.

INTERNATIONAL COMPARISONS:

Both relative and absolute international statistical data and assessments should be included as a major component of the information base to support Executive Branch and congressional research budget allocation decisions.[15] International benchmarking of U.S. research performance and capabilities on a regular basis responds to the growing globalization of science and technology and the need for the United States to maintain a world-class science and engineering infrastructure. Maintaining world-class capabilities enables the Nation to take advantage of opportunities for rapid advancements in knowledge in targeted areas of research and to capitalize on breakthroughs wherever they occur worldwide. Although international data and methods of analysis are limited, they should be employed with sensitivity to those limitations and with a long-term commitment to developing better methods and data for monitoring U.S. performance and strength in science and technology.

International comparisons should include a range of measures of national research resources and performance to produce objective assessments of the relative strength of the U.S. in research areas important to national goals. For example, comparisons could include total national S&T investment as a share of Gross Domestic Product (GDP) or as a share of the high technology sector of the economy. Relative performance of individual fields important to national economic or defense priorities can be assessed using bibliometric methods and patent citations. Comparisons should be sensitive to the appropriate basis for comparing different economies, since the composition of the economy may be as important as its size as measured by GDP. For example, it might not be appropriate to compare S&T/GDP ratios for two economies that have very different manufacturing shares of total GDP. Of central importance is the comparison of human resources for research in priority areas in the United States and in other countries, including international migration of science and engineering personnel as well as participation by U.S. students in science and engineering studies in comparison with students in other nations.

Statistical trends are critical for evaluating the adequacy and direction of national research investments. Comparisons might include the following types of relative and absolute statistics:

- Total national S&T; Defense S&T; Civilian S&T; Basic (fundamental) research: National (U.S.) and Federal;

- Civilian S&T by functional categories of: health, energy, environment and natural resources, space research and technology, general science, transportation, agriculture;

[15] National Science Board. Chapter 7, "Industry, Technology, and the Global Marketplace," in *Science and Engineering Indicators—2000* brings together a collection of indicators of national competitiveness.

- Basic science investment categories, such as: engineering, natural sciences, social science, and mathematical sciences; and

- Human resources engaged in or available for research by field, degree attainment, gender and nationality.

Recommendation 4

Input to Federal allocation decisions should include comparisons of U.S. research resources and performance with those of other countries. National resources and performance should be benchmarked to evaluate the health and vigor of U.S. science and engineering for a range of macroeconomic indicators, using both absolute and relative measures, the latter to control in part for the difference in size and composition of economies. Over the long term, data sources should be expanded and quality improved.

Federal Research Benefits to the Economy and Society:

In addition to monitoring Federal expenditures for research, measuring the benefits to the public of funded research is essential for prudent management. Although there is an extensive literature on methods for measuring returns on research investments, usually in the private sector, these methods have not been widely applied in the Federal context for a number of reasons. With regard to economic methods, the difficulties include lack of sufficient data, questions of data quality, selection bias in case studies of specific industries and problems of time lags between research discoveries and their impacts on the economy. In the case of publicly supported research, many benefits cannot be expressed in terms of economic returns. Indicators and methods that have been used for measuring benefits of research include the following:

- *Asset-oriented measures*, which tally such system "assets" as research facilities and human resources for S&T resulting from Federal investments—for example, immigrant and native-born scientists and engineers, and graduate students supported on Federal research grants;

- *Outputs measures,* which track intellectual contributions and often employ bibliometric analysis—such as patent citations, publication counts, article citations, presentations at conferences—or honors received by researchers and research projects, e.g. Nobel prizes;

- *Outcomes or results measures*, including: (1) case studies and retrospective analyses, which are usually qualitative, tracing the inputs and the processes that produced an important innovation and (2) quantitative economic techniques such as production function analyses and surveys estimating economic impacts of public research within specific industries and enabling a better understanding of the channels and mechanisms whereby public research contributes to innovation.

Implementation of this recommendation should be coordinated with Recommendation 3 on definitions and data systems.

RECOMMENDATION 5

The Federal Government should invest in the research necessary to build deep understanding and the intellectual infrastructure to analyze substantive effects on the economy and quality of life of Federal support for science and technology. The research should include improvements to methods for measuring returns on public investments in research.

Federal support for research has been highly successful in contributing to the quality of life that we enjoy in the United States today. Continued national commitment to publicly supported research offers the promise of even greater benefits in the future. The expanding frontiers of knowledge demand careful evaluation to identify the highest priorities for investment of Federal research funds. It is therefore essential that the processes by which allocation decisions are made rest on the best possible information base that high technology and well-prepared minds can produce. The systematic participation of the scientific community in this process along with Federal agencies and departments, bringing its vision and understanding of the needs and opportunities for research, is critical to its success. The Board's recommendations describe a strategy for improving the quality, content, and accessibility of science and engineering input to decisions on the allocation of Federal research funds. We are aware that implementing these recommendations will be difficult and will require long-term commitment. In the interest of science and the Nation, we urge that the Federal Government and its partners in the research community embrace this difficult task.

References

Sidebar quotes:

Executive Summary

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House of Representatives. *Unlocking Our Future: Toward a New National Science Policy* (1998): 16.

Page 2

Executive Office of the President, Office of Management and Budget. *The President's Management Agenda: Fiscal Year 2002*, Chapter 8, "Better R&D Investment Criteria, Department of Energy" (2001): 43.

Chapter I: Introduction

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President Dwight D. Eisenhower, "Farewell Address," January 17, 1961, in John J. Newman and J.M. Schmalbach, *United States History* (1998): 590.

Chapter II: National Policy Concerns And Needs

Page 14

Representative George E. Brown, Jr. "Past and Prologue: Why I am Optimistic About the Future," in *AAAS Science and Technology Policy Yearbook*, Washington DC: American Association for the Advancement of Science (1999): 24.

Page 20

Council on Competitiveness. *Endless Frontier, Limited Resources/U.S. R&D Policy for Competitiveness*, Washington, DC: Council on Competitiveness (1996): 4.

Page 22

Albert H. Teich. "An Introduction to R&D in the Federal Budget," in *Research & Development Report XXIII,* AAAS, Intersociety Working Group (1998): 14.

Boxed Text:

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Box One:

National Science and Technology Policy, Organization, and Priorities Act of 1976 (Public Law 94-292); and Executive Order 12881, November 23, 1993, establishing the National Science and Technology Council.

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Box Two:

Steven W. Popper, C. S. Wagner, D. L. Fossum, and W.S. Stiles. *Setting Priorities and Coordinating Federal R&D Across Fields of Science: A Literature Review* (2000): 12-13; and U.S. House of Representatives. *Unlocking Our Future: Toward a New National Science Policy* (1998): 48.

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Box Three:

On the Congressional Budget Office and General Accounting Office: Congressional Budget Impoundment and Control Act, PL 92-599, 1974; Telephone conversations with staff members from Congressional Research Service and the General Accounting Office, July 2001. On Office of Technology Assessment: PL 92-484, 1972; Daniel S. Greenberg. 1998. "Restore Congress's think tank," in *Journal of Commerce* (November 30, 1998): 4A. On Congressional mechanisms: Discussions with Congressional staff, December, 2000; Symposium discussion, May 21, 2001 and Popper et al., 7-12.

Figures:

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Figure 1: U. S. R&D/GDP: 1953-2000.

Source: National Science Foundation/Division of Science Resources Studies, *National Patterns of R&D Resources* (annual series).

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Figure 2: Shares of National R&D Funding by Source: 1953-2000

Source: National Science Foundation/Division of Science Resources Studies, *National Patterns of R&D Resources* (annual series).

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Figure 3: Shares of Federal Research by Field

Source: National Science Foundation/Division of Science Resources Studies, *Survey of Federal Funds for Research and Development: Fiscal Years 1999, 2000, and 2001.*

Selected Acronyms

AAAS	American Association for the Advancement of Science
AAU	Association of American Universities
AWIS	Association for Women in Science
BMBF	Germany, Federal Ministry of Education and Research
CEA	Council of Economic Advisors
CEO	Chief Executive Officer
CBO	Congressional Budget Office
CNRS	Centre National de la Recherche Scientifique
COSEPUP	Committee of Science, Engineering and Public Policy
CRA	Computing Research Association
CRS	Congressional Research Service
DDR&E	Director of Defense Research and Evaluation
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DTI	Department of Trade and Industry, UK
EC	European Commission
EPA	Environmental Protection Agency
EU	European Union
FCCSET	Federal Coordinating Council on Science and Technology
FY	Fiscal Year
GDP	Gross Domestic Product
GPRA	Government Performance and Results Act
HHS	Health and Human Services (Department of)
HUD	Housing and Urban Development, Department of
IDEA	Indicators and Data for European Analysis
IRI	Industrial Research Institute
NAS	National Academy of Science
NASA	National Aeronautics and Space Administration
NCRR	National Center for Research Resources, NIH
NIH	National Institutes of Health
NIST	National Institute for Standards and Technology
NOAA	National Oceanographic and Atmospheric Administration
NAE	National Academy of Engineering

NRC	National Research Council
NSB	National Science Board
NSF	National Science Foundation
NSTC	National Science and Technology Council(OSTP)
MIT	Massachusetts Institute of Technology
OMB	Office of Management and Budget
OECD	Organization for Economic Cooperation and Development
OST	Office of Science and Technology, UK
OSTP	Office of Science and Technology Policy
PCAST	President's Council (Committee) of Advisors on Science and Technology
PL	Public Law
PSR	public sector research
R&D	research and development
RTD	Research and Technological Development Policy (EU)
RaDiUS	information system on Federal Research and Development
S&T	science and technology
SPI	NSB Ad Hoc Committee on Strategic Science and Engineering Policy Issues
SPRU	Science Policy Research Unit, Sussex
STPI	Science and Technology Policy Institute, RAND
UK	United Kingdom
USDA	U.S. Department of Agriculture
VA	Department of Veterans Affairs

Selected Bibliography

American Association for the Advancement of Science (AAAS). 1999a. "A Preview of AAAS Report XXIV: Research and Development FY 2000." Washington DC.

___. 1999b. "Congressional Budgets Project Cuts to Federal R&D," Washington DC. March.

Boehlert, Sherwood (Congressman (R-NY)). 2001. Speech To Universities Research Association, January 31.

Bush, Vannevar. 1990. *Science—The Endless Frontier* (National Science Foundation 40th Anniversary edition). Washington DC: National Science Foundation.

Clinton, William J. and Albert Gore, Jr. 1993. *Technology for America's Economic Growth, A New Direction to Build Economic Strength.* Washington DC.

Council of Economic Advisers. 1995. "Supporting Research and Development to Promote Economic Growth: The Federal Government's Role." Washington DC.

Council on Competitiveness. 1996. *Endless Frontier, Limited Resources*. Washington DC.

___. 1998. *Going Global: The New Shape of American Innovation.* Washington DC.

___. 1999. *The New Challenge to America's Prosperity: Findings from the Innovation Index*. Washington DC.

Coward, H. Roberts (SRI International). 2000. *Final Report*: *Symposium on International Models of Budget Coordination and Priority Setting for S&T, November 19-20, 1999*. Arlington VA: SRI International.

Eisenhower, Dwight D. 1998. "Farewell Address" in John J. Newman and J.M. Schmalbach, *United States History*, New York: Amsco School Publications: 590.

Executive Office of the President, Office of Management and Budget. 2001a. "Research and Development Funding" in *Fiscal Year 2002 Analytical Perspectives, Budget of the United States Government*. Washington DC.

__. 2001b. "Better R&D Investment Criteria, Department of Energy." *The President's Management Agenda/Fiscal Year 2002*. Washington DC.

Feldstein, Martin. 1992. "The Council of Economic Advisers and Economic Advising in the United States, " *The Economic Journal* (102): September 1992.

Feller, Irwin. 1999. Briefing Outline: "Academic Models of Research Priority Setting." Presentation to the National Science Board Ad Hoc Committee on Strategic Science and Engineering Policy Issues, July 28.

Greenberg, Daniel S. 1998. "Restore Congress's think tank." *Journal of Commerce* (30 November 1998): 4A.

Greenspan, Alan. 2000. "Structural change in the new economy." Remarks before the National Governors' Association, 92nd Annual Meeting, State College, Pennsylvania, July 11.

Kelly, Eamon M. (Chairman, National Science Board). 2000. Statement Before the Committee on Science, U.S. House of Representatives Subcommittee on Basic Research, on international benchmarking of research fields, October 4.

Larson, Charles. F. (President Industrial Research Institute, Inc.). 2000. "Basic Research and Innovation in Industry." Draft paper, presentation to the National Science Board Committee on Strategic Science and Engineering Policy Issues, March 15.

Merrill, Stephen A. and Michael McGeary. 1999. "Who's Balancing the Federal Research Portfolio and How?" *Science* (Vol. 2885 No. 5434): 1679-1680.

Mogee, Mary Ellen. 1999. "National Technology Foresight Methods: Implications for Setting S&T Priorities." Briefing for the National Science Board Ad Hoc Committee on Strategic Science and Engineering Policy Issues, June.

Narin, Francis. 1999. Memorandum on citations to U.S. authored papers over time, June, to the National Science Board Committee on Strategic Science and Engineering Policy Issues.

National Academies, Committee on Science, Engineering, and Public Policy. 1993. *Science, Technology and the Federal Government: National Goals for a New Era*. Washington DC: National Academy Press.

___. 1999. *Observations on the President's Fiscal Year 2000 Federal Science and Technology Budget.* Washington DC: National Academy Press.

___. 2000a. *Experiments in International Benchmarking of US Research Fields*. Washington DC: National Academy Press.

___. 2000b. *Observations on the President's Fiscal Year 2001 Federal Science and Technology Budget*. Washington DC: National Academy Press.

___. 2000c. *Science and Technology in the National Interest/ The Presidential Appointment Process*. Washington DC: National Academy Press.

National Research Council, Board on Science, Technology and Economic Policy. 2000. *Trends in Federal Support of Research and Graduate Education*. Washington DC: National Academy Press.

National Research Council, Committee on Criteria for Federal Support of Research and Development. 1995. *Allocating Federal Funds for Science and Technology*. Washington DC: National Academy Press.

National Research Council, Committee on the Future of Space Science, Space Studies Board. 1995. "Executive Summary" and Chapter 5, "Research Prioritization: Analysis and Findings." *Managing the Space Sciences*. Washington DC: National Academy Press.

National Science Board. 1993. *In Support of Basic Research* (NSB 93-127). Washington DC: National Science Foundation.

___. 1995. *Federal Investments in Science and Engineering* (NSB 95-254) Washington DC: National Science Foundation.

___. 1995b. S*tatement on Federal R&D Budget Realignment* (NSB 95-26). Washington DC: National Science Foundation.

___. 1996a. "Economic and Social Significance of Scientific and Engineering Research." *Science and Engineering Indicators—1996* (NSB-96-21). Washington DC: National Science Foundation.

___. 1996b. *U.S. Science and Engineering in a Changing World*, companion piece to *Science and Engineering Indicators—1996* (NSB-96-21). Washington DC: National Science Foundation.

___. 1997. *Government Funding of Scientific Research* (NSB 97-186). Arlington, VA: National Science Foundation.

___ . 1998a. *Industry Trends in Research Support and Links to Public Research* (NSB-98-99). Arlington, VA: National Science Foundation.

___. 1998b. *National Science Board Strategic Plan* (NSB 98-215). Arlington, VA: National Science Foundation.

___. 2000. "Industry, Technology and the Global Marketplace." *Science and Engineering Indicators—2000*. Arlington, VA: National Science Foundation.

___. 2001. *The Scientific Allocation of Scientific Resources* (NSB 01-139). Arlington, VA: National Science Foundation.

National Science Foundation, Division of Science Resources Studies. 2001a. *National Patterns of R&D Resources* (annual series). Arlington, VA: National Science Foundation.

___. 2001b. *Survey of Federal Funds for Research and Development: Fiscal Years 1999, 2000, and 2001*. Arlington, VA: National Science Foundation.

Payson, Steven. 2000. "Economic Concepts that Underlie the Estimation of the Returns to R&D." National Science Foundation, Staff Technical Memorandum prepared for the Ad Hoc Committee on Strategic Science and Engineering Policy Issues, October 16.

Popper, Steven W., Caroline S. Wagner, Donna L. Fossum, William S. Stiles. 2000. *Setting Priorities and Coordinating Federal R&D Across Fields of Science: A Literature Review* (DRU-2286-NSF). Washington DC: RAND Science and Technology Policy Institute.

"Powerful Visions for Astronomy." 2000. *Nature* (25 May 2000): 379.

Raines, Franklin D. 1998. "Making the Case for Federal Support of R&D." *Science* (12 June 1998): 1671.

RAND. Science and Technology Policy Institute. Undated. "RaDiUS, The Database of Federal R&D Activities and Spending." Washington DC.

Teich, Albert H. 1998. "An Introduction to R&D in the Federal Budget." *Research & Development Report XXIII*, Washington DC: American Association for the Advancement of Science, Intersociety Working Group.

The White House. "About the Council of Economic Advisers." http://www.whitehouse.gov/cea/about.html.

U.S. Commission on National Security/21st Century. 2001. *Road Map for National Security: Imperative for Change* (http://www.nssg.gov).

U.S. Congress. 1972. Technology Assessment Act of 1972, P.L. 92-484; 86 STAT.797 (H.R. 10243).

___.1976. National Science and Technology Policy, Organization, and Priorities Act of 1976 (Public Law 94-282). 1976. Summary—Revised as of 4/26/76. http://thomas.loc.gov/cgi-bin/bdquery/z?d094:HR10230:@@@L#summary.

___. 1998. U.S. House of Representatives, Report 105-610, 105th Congress, 2nd Session, to accompany H.R. 4194.

U.S. Department of Energy. 2000. *DOE R&D Portfolio Overview FY 1999-2001*. Washington DC.

APPENDIX A

CHARGE TO THE COMMITTEE

NSB –99-56
3/23/99

CHARGE
NATIONAL SCIENCE BOARD
AD HOC COMMITTEE ON STRATEGIC SCIENCE AND ENGINEERING POLICY ISSUES

The NSB Ad Hoc Committee on Strategic Science and Engineering Policy Issues is hereby reconstituted to lead a study of methodologies for coordination and priority setting in the development of the Federal budget for science and engineering research.

In its Working Paper on *Government Funding of Scientific Research* (NSB-97-186), the National Science Board identified a national interest in "some form of 'comprehensive' and 'coherent' coordination of Federally-financed research," which would first require the development of "guidelines to provide clear direction on setting priorities within the Federal research budget." The recently adopted Strategic Plan of the National Science Board states that: "...the development of an intellectually well founded and broadly accepted methodology for setting priorities across fields of science and engineering is a prerequisite for a coherent and comprehensive Federal allocation process for research."

Since publication of that paper at the end of 1997, stakeholders in both the Administration and the Congress have urged better coordination for the Federal budget for research, and the development of a methodology for priority setting across fields of science and agencies to further that objective. Specifically, in its report accompanying the NSF Appropriations Act for FY 1999, the House Committee on Appropriations stated its strong agreement with the NSB report and urged the Board to "...develop the guidelines for such a study and provide for the committee at the earliest possible date a proposed plan...to accomplish this task and institute such a study."

The committee will:

- Review, in light of changing circumstances, the goals for Federal investment in scientific research as stated in the Administration report, Science in the National Interest;

- Examine existing structures and processes for coordination and priority setting for Federally-funded research across the Federal government and the role played by individual agencies in this process;
- Conduct a state of the art assessment of methodologies that inform priority setting for research;
- Conduct a study of budget coordination and priority setting for research as it is practiced in other countries to understand their particular advantages or disadvantages; and
- Convene appropriate stakeholders to consider the findings of these studies and reviews, to develop recommendations for improved methodologies for coordination and priority setting in the Federal research budget and for building the support of the science and engineering communities and of the general public in these methodologies.

The committee may employ a variety of mechanisms to accomplish these objectives, including consultants and independent studies, briefings, workshops, conferences, and forums. The committee may consider recommending to the National Science Board the establishment of an NSB Commission for the development of final recommendations on methodologies for coordination and priority setting. An interim report on findings on the current state of the art and next steps to be submitted to the Board in March 2000, and the final report and recommendations no later than December 2000.

Eamon M. Kelly
Chairman
National Science Board

Appendix B

Presentations and Discussions with Committee

The NSB Ad Hoc Committee on Strategic Science and Engineering Policy Issues heard presentations by invited experts, addressing the following methodologies and methodological issues:

- A project to develop a more complete and accessible database for tracking Federal R&D funding, the RaDiUS database, undertaken by the RAND Science and Technology Policy Institute (STPI), and the potential of the database for use as a tool for budget coordination and priority setting across areas of research and government programs, presented by STPI Director Bruce Don and Donna Fossum, May 5, 1999;

- Foresight methods, used by many countries as part of the dialogue toward establishing priorities for S&T, by an expert on Foresight methods in use in Organization for Economic Co-operation and Development (OECD) countries, Mary Ellen Mogee, July 28, 1999;

- The Federal Science and Technology (FS&T) budget analysis by the Committee on Science, Engineering and Public Policy (COSEPUP) of the National Academies and the American Association for the Advancement of Science (AAAS), by James Duderstadt speaking for COSEPUP, March 15, 2000;

- Experiments in international benchmarking of U.S. research fields, sponsored by the National Academies, by Maxine Singer and Marye Anne Fox for COSEPUP, May 3, 2000;

- Approaches to priority setting for research in the academic sector, and the relationship between Federal and academic priority setting, by the Chairman of the NSF Social, Behavioral and Economic Sciences Directorate Advisory Committee, Irwin Feller, July 28, 1999;

- Priority setting practices in industry that might be useful in improving Federal priority setting, and the role of industry and the Federal Government in national R&D, by Charles Larson, President of the Industrial Research Institute, March 15, 2000;

- A meeting with experts on the Federal budget and economic methods to measure the benefits of Federal investments in research, October 20, 2000. (Agenda in Appendix C)

Meetings with participants in the current Federal system include:

- An all-day meeting August 4, 2000, with presentations on priority setting from RAND Science and Technology Policy Institute; 10 Federal S&T agencies; Office of Science and Technology Policy, by Director Neal Lane; Office of Management and Budget by Kathleen Peroff (Agenda in Appendix C);

- OMB staff members, including the Steven Isakowitz, Chief, Energy and Science Division and Program Examiners David Radzanowski, Sarah Horrigan and David Trinkle, who reviewed and discussed the Committee's initial draft recommendations, August 2, 2000;

- House Appropriations Chief of Staff Frank Cushing, December 13, 2000.

- A stakeholders symposium on Allocation of Federal Resources for Science and Technology, May 21-22, 2001, with 20 panelists and speakers, and more than 200 attendees from Federal agencies, Congressional staff, OMB staff, scientific professional organizations, policy organizations, the National Academies, and OSTP staff, as well as interested individuals. (Agenda in Appendix C).

In these meetings the Committee discussed with Federal colleagues the current structure and process for budget coordination and priority setting in the Federal government and thoughts on how the process might be improved.

Finally, a one-and-a-half day symposium on *International Models of S&T Budget Coordination and Priority Setting*, November 19-20, 1999, with presentations by foreign officials intimately involved in S&T budget coordination and priority setting from eight governments was cosponsored by the SPI Committee and Task Force on International Issues in Science and Engineering. Governments represented included: the UK, Germany, France, Sweden, the Republic of Korea, Japan, Brazil, the European Union and the United States.
(Agenda in Appendix C).

Appendix C

Agendas and Guidelines for Selected Stakeholder and Expert Meetings

May 21-22. 2001. Symposium on Allocation of Federal Resources for Science and Technology

October 20, 2000. Meeting with Economists and Federal Budget Experts

August 3-4, 2000. Meeting with Federal Agencies on the Federal R&D Budget Allocation Process

November 18-20, 1999. Symposium on International Models for S&T Budget Coordination and Priority Setting

Agenda

Symposium on Allocation of Federal Resources for Science and Technology

Monday, May 21

2:00-2:20 Introduction and Overview: Eamon Kelly, NSB Chairman

2:20-2:30 Welcome: Rita Colwell, NSF Director

2:30-3:00 Keynote Address: Newt Gingrich, U.S. Commission on National Security/21st Century and Former Speaker of the House: *The Role of Federal Research in the Nation's Prosperity and Security*

Break

3:10-5:30 The Case for a Better Process

Moderator: Joseph Miller, NSB member

- OMB Perspective: Kathleen Peroff, Deputy Associate Director for National Security
- Congressional perspective: Scott Giles, Deputy Chief of Staff, House Committee on Science
- Research funders and performers: Erich Bloch, Washington Advisory Group, Former Director, NSF
- Higher Education: Donald Langenberg, Chancellor, University System of Maryland

5:30-6:15 Discussion

6:15-7:15 *Reception (by invitation): National Science Board Suite, Room 1225*

Tuesday, May 22

8:30-8:45 Welcome and Introduction: Eamon Kelly, NSB Chair

8:45-10:45 Improving the Budget Process for S&T

Moderator: John Armstrong, NSB member

- Lead: Lewis Branscomb, American Association for the Advancement of Science/Kennedy School of Government, Harvard University
- American Enterprise Institute: Claude Barfield
- Budget Support for the White House and Congress:
    - OMB: Steven Isakowitz, Branch Chief
    - Senate: Cheh Kim, Senate staff
- National Academies: James Duderstadt, University of Michigan

Break

11:00-12:00 Discussion

12:00-1:00 *Lunch (by Invitation): Board Suite, Room 1225*

1:00-3:00 Evaluating and Identifying Priorities for Federal Research: The Role of the Science and Engineering Communities

Moderator: Robert Richardson, NSB Member

- Lead: Senior researcher: Paul Romer, Stanford University
- Disciplinary communities
  - Astronomy and Astrophysics: Joseph Taylor, Princeton University
  - Computing Research Association (CRA): Andries van Dam, Brown University
  - Federation of American Societies for Experimental Biology (FASEB): John Suttie, Past President
  - Environmental Research: Kenneth Brink, Woods Hole Oceanographic Institution, Chair, Ocean Studies Board, NAS
- Industry research: Henry Weinberg, Symyx Technologies, Inc., Chief Technology Officer
- Higher education: Nils Hasselmo, President, Association of American Universities

Discussion

Break

4:00-5:45 Better Data and Analyses

Moderator: Eamon M. Kelly, NSB Chairman

- Lead: Albert Teich, AAAS
- Agencies/Departmental Role:
  - NSF: Rita Colwell, Director
  - DOE: James Decker, Acting Director, Office of Science
  - NIH: Yvonne T. Maddox, Acting Deputy Director
  - DoD: Delores Etter, Acting Director, DDR&E

5:45-6:30 Discussion/Concluding remarks

6:30 Adjourn

EXAMPLE LETTER TO SPEAKERS AND PANELISTS

April 25, 2001

I am writing to invite you to participate in the upcoming National Science Board symposium on the Allocation of Federal Resources for Science and Technology, May 21-22. Enclosed is the draft discussion paper, *The Scientific Allocation of Scientific Resources*, that lays out our preliminary recommendations on improving the expert advice and data to inform Federal research budget allocation decisions, which will serve as the focus of the symposium. I hope you will be able to participate in a panel discussion on May 2X, emphasizing on our recommendation(s) on (one or more specific recommendations in the discussion document) representing the perspective of (sector, organization, or community).

By way of background, over the last two years the Board has undertaken a study of methodologies and criteria to set priorities for Federal research funding across scientific fields and, further, to define a process that would be effective in building broad public and scientific community support for, and involvement in, priority setting for federally supported research. Our study has addressed priority setting practices for publicly funded research, both in the U.S. and in other countries.

We have commissioned two literature reviews, one by the RAND Science and Technology Policy Institute on Federal support for research, the existing tools to support research budget allocation decisions, and current mechanisms for input on those decisions. The second study, by SRI International, examined the literature on international models of S&T budget coordination and priority setting, focusing on eight foreign governments, with presentations by top-ranking science officials for each. We also heard presentations from experts on specific methodologies proposed or in use to assist priority setting in research budgets.

The Strategic Science and Engineering Policy Issues committee, which is undertaking this study for the Board, has met with representatives of the Office of Science and Technology Policy (OSTP), Office of Management and Budget (OMB), the National Academies, and Congressional staff who expressed considerable interest in improving the process by which funding decisions are made for federally supported research. The committee has arrived at some preliminary conclusions from these sources and, as part of our study, begun a dialog with policy officials most intimately involved in the budget process in the Federal research funding agencies.

Enclosed is a copy of a preliminary agenda for the event. We would ask that you and other panel members take a few minutes at the beginning of the panel discussion to outline your reactions and thoughts on the report, focusing on recommendation(s)___, followed by a discussion with other members of the panel. A more general discussion including NSB members and others in the audience will follow.

This panel is scheduled to begin at_____ on _____, May 2X. I have asked the National Science Board office to contact you concerning your availability for this event. I hope you will be able to join us and contribute to this important discussion.

Sincerely,

Eamon M. Kelly, Chairman
National Science Board and
Committee on Strategic Science
and Engineering Policy Issues

Enclosures

Agenda

NSB Ad Hoc Committee on Strategic Science and Engineering Policy Issues Meeting with Federal Budget Experts and Economists

October 20, 2000

8:30-8:45	Introductory remarks, Dr. Eamon Kelly, NSB Chairman
8:45-10:45	*Setting Priorities for Federal Research: Economists' Perspectives on the Federal Budget Process* Moderator: Dr. Eamon Kelly, NSB Chairman (1) June O'Neill, Baruch College, Former Director, CBO (2) Kathryn Shaw, Council of Economic Advisors
10:45-11:00	*Break*
11:00-12:30	*Social and Private Returns on Investment in Federally-funded Research* Moderator: Dr. Joseph Miller, NSB (1) Wesley Cohen, Carnegie-Mellon (by video) (2) Paul Romer, Hoover Institution, Stanford (by video)
12:30-1:00	*Lunch*
1:00-2:00	*Committee Discussion*

AGENDA

NSB COMMITTEE ON STRATEGIC SCIENCE AND ENGINEERING POLICY ISSUES MEETING WITH FEDERAL AGENCIES ON THE FEDERAL R&D BUDGET ALLOCATION PROCESS

August 3-4, 2000

August 3	Room 1225, Board Suite
6:00-7:30	Reception, NSB, DPG and Agency guests
August 4	Room 1225, Board Room
8:30-8:45	Introduction by E. Kelly, Chairman, Strategic Policy Issues Committee
8:45-9:15	Remarks by Dr. Neal Lane, Assistant to the President for Science and Technology
9:15-10:00	Dr. Bruce Don, Science & Technology Policy Institute, RAND, "Setting Priorities and Coordinating Federal R&D Across Fields of Science" Comment from OMB, Kathleen Peroff, Deputy Associate Director for Energy & Science
10:00-10:15	*Break*
10:15-12:15	**Major civilian research agencies:** *Anita Jones, NSB* ▪ Dr. Ernest Moniz, Under Secretary, DOE ▪ Dr. Mildred Dresselhaus, Director, Office of Science, DOE ▪ Dr. Ruth Kirschstein, Acting Director, NIH (HHS) ▪ Dr. Rita Colwell, NSF Director ▪ Dr. Kathie L. Olsen, Chief Scientist, NASA
12:15-12:45	Discussion
12:45-1:45	*Lunch*
1:45-2:45	**Major defense research agencies:** *John Armstrong, NSB* ▪ Robert V. Tuohy, Director, S&T Plans and Programs, DOD ▪ Dr. David Crandall, Assistant Deputy Administrator for Research, Development and Simulation, DOE
2:45-3:15	Discussion
3:15-3:30	*Break*
3:30-4:45	**Civilian agencies funding natural resources and environmental R&D:** *Joseph Miller, NSB* ▪ Dr. Floyd P. Horn, Administrator, Agricultural Research Service ▪ Dr. Norine Noonan, Asst. Administrator for R&D, EPA ▪ Dr. Ronald Baird, Director, National Sea Grant College, NOAA (DOC)
4:45-5:15	**Other civilian research programs:** *Robert Richardson, NSB* ▪ Dr. John R. Feussner, Chief R&D Officer, VA ▪ Dr. Michael Casassa, Acting Director of the Program Office, NIST (DOC)
5:15-5:45	Discussion, concluding remarks

Agenda

Symposium On International Models For S&T Budget Coordination And Priority Setting

November 19-20, 1999

Co-sponsored by the National Science Board Committee on Strategic Science and Engineering Policy Issues and Task Force on International Issues in Science and Engineering

Thursday, November 18

6:00 pm *Reception/Dinner* (*by invitation*)*;* Guest Speaker: Neal Lane, Science Adviser to the President, Room 375, National Science Foundation

Friday, November 19

Boardroom, Room 1235

8:30-9:00 Opening remarks: Eamon Kelly, NSB; Chairman, Diana Natalicio, NSB Vice Chair
Welcome: Rita Colwell, NSF Director

9:00-1:00 *Models of Change in Industrialized Countries*

Moderator, Dr. Joseph Miller, NSB

- **Germany**: Bernd Kramer, Science Counselor, German Embassy
- **France:** Jacques Sevin, Director of Strategy and Programs, Centre National de la Recherche Scientifique (CNRS)

Break

- **Japan**: Tsuyoshi Maruyama, Director of Planning and Evaluation Division, Science and Technology Policy Bureau, Science and Technology Agency

Summary and Discussion

1:00-2:00 *Lunch break*

2:00-5:15 *Models with Established Central Mechanisms*

Moderator: Dr. Anita Jones, NSB

- **European Union**: Graham Stroud, assistant to the Deputy Director, Research Directorate General, European Commission

Break

- **United Kingdom**: Jo Durning, Group Head of Transdepartmental Science and Technology, Office of Science and Technology (OST)

Summary and Discussion

Saturday, November 20

8:30-11:00 *Models of Change in Smaller R&D Systems*
Moderator: Dr. Pamela Ferguson

- **Korea**: Heeseung Yang, Managing Director, National Research and Development (R&D) Evaluation, Korea Institute of Science and Technology Evaluation and Planning
- **Sweden**: Kerstin Eliasson, Director, Research Policy Directorate, Ministry of Education and Science
- **Brazil**: Luiz Antonio Barreto de Castro, Head of the Secretariat of Intellectual Property Rights, Empresa Brasileira de Pesquisa Agropecuaria – Embrapa

Break

11:00-12:00 Summary and Discussion

I. Background and Objective of the Symposium

In its Working paper on *Government Funding of Scientific Research* (NSB-97-186), the National Science Board identified a national interest in "some form of 'comprehensive' and 'coherent' coordination of Federally-financed research," which would first require the development of "guidelines to provide clear direction on setting priorities within the Federal research budget." The Strategic Plan of the National Science Board states that: "...the development of an intellectually well founded and broadly accepted methodology for setting priorities across fields of science and engineering is a prerequisite for a coherent and comprehensive Federal allocation process for research." In recent years, stakeholders in both the Administration and the Congress have urged better coordination for the Federal budget for research, and the development of a methodology for priority setting across fields of science and agencies to further that objective.

As a consequence, the *Ad Hoc* Committee on Strategic Science and Engineering Policy Issues, acting in concert with the NSB Task Force on International Issues in Science and Engineering, undertook the arrangement of a "Symposium on International Models for S&T Budget Coordination and Priority Setting. The objective of the Symposium and its background preparations was to provide a review of the relevant literature, as well as hearing the views of a number of active R&D policy makers across a variety of internationally representative countries. The Symposium introduced by remarks from the President's Science Advisor on the evening of November 18, was held on November 19-20, 1999, in the NSF Board Room, where Committee and Task Force members heard presentations and engaged in dialogue with representatives of seven countries and one international entity, the European Union, on the topic. The participating countries were selected on the basis of the following criteria:

- Does the country have sufficient experience to serve as a model?
- Does the methodology or aspects of it have potential for application to the U.S.?
- Is the methodology sufficiently different from others to offer special lessons?
- Does inclusion of the country need to be considered for political or representational reasons?
- Are excellent presenters/spokespersons for the country's system likely to be available?
- Does the system for government support of research appear to contribute positively to the scientific and engineering strength of the country?

The countries selected for participation included three large European nations – France, Germany, and the United Kingdom, as well as the European Union, which is a major sponsor of research. Two other industrialized nations, Japan, a major Asian industrial nation, and Sweden, a smaller but scientifically highly advanced country were included. One "Newly Industrialized Economy," the Republic of Korea, and Brazil, the largest scientific presence in Latin America, filled out the roster of participants.

SRI International, a contractor, was asked to identify as potential speakers individuals with roles like that of the U.S. science advisor: in government; intimately knowledgeable about how the process works; and at a high level. Normally that would not be the minister of science or equivalent, who are often in office very briefly and who cannot speak from extensive experience about their government's funding for R&D. Countries vary, but the individuals invited were all at a high level in government and very knowledgeable about how the research budget is actually developed.

The following framework for presentations was provided to the invited guests of the National Science Board:

Guidelines for Speakers

Your presentation should be limited to approximately 25 minutes, followed by a question and answer period with members of the Committee and the Task Force.

Board members will have received a briefing document on your country's R&D budget process prior to the Symposium, outlining the general structure and procedures for your national system as they are described in the published literature. We will be supplying you with a copy of that background document. We ask, therefore, that you assume that Board members are familiar with the background material and address your presentation to the following questions, as appropriate to your national system.

Questions to Address on R&D Budget Co-Ordination and Priority Setting

Q1: What needs are targeted in your country's R&D budget—government, industry, society as a whole? International cooperative R&D for activities such as megascience projects, major instrumentation, databases, or human resource capacity building?

Q2: In planning for your government's budget for R&D, how are appropriate levels of support determined for the budget as a whole and for programs and activities funded through the R&D budget?

Q3: Are the research activities of other countries a significant factor in developing your R&D budget? How do you evaluate research supported by other countries? Which other countries? How is this information used in your budgeting activities?

Q4: Please describe the priority setting process in detail.

- What are the key organizations or individuals involved in the priority setting process for the R&Dbudget? What measures or indicators, models or methodologies are employed in weighing alternative pros pects for government investments in R&D?
- How is the priority setting process applied to government support for ***fundamental*** research?

Q5: How do you determine that an area is worth pursuing as a national priority, or whether it should be left to other countries? How do you decide which areas should be pursued collaboratively?

- Do multinational themes, e.g. in the environment, enter into the process for determining national priorities for R&D?
- How are international collaborations supported: direct funding, in-kind contributions, other means?
- Does your government make any specific or special provisions for scientific cooperation with developing countries? If so, are these handled out of your science ministry or equivalent or some other part of the government?

Q6: What mechanisms and tools do you use to assess the benefits of scientific research and development and its contributions to your society?

- What units of analysis are used in measuring the return on government investment? e.g., government agencies and their programs; nongovern mental organizations or sectors that receive government support, such as universities or research institutes; scientific fields of study/disci plines; industrial research and technologies; occupational groups;

geographic/political units?

Q7: What data are available for measuring R&D investments and returns on your country's investments? Are these sources available in published or electronic form?

APPENDIX D:

NAMES AND AFFILIATIONS OF THOSE SUBMITTING WRITTEN COMMENTS

ON THE BOARD'S DRAFT DISCUSSION DOCUMENT, *THE SCIENTIFIC ALLOCATION OF SCIENTIFIC RESOURCES* (NSB-01-39)

ORGANIZATIONS:

American Institute of Physics: Mark H. Brodsky, Executive Director and CEO

American Psychological Association Raymond: C. Fowler, Chief Executive Officer and Norine Johnson, President

Association of Women in Science (AWIS): Linda Mantel, President, and Catherine Didion, Executive Director

Council of Scientific Society Presidents: Martin Apple, Ph.D., President

Federal Aviation Administration, Dr. Aston McLaughlin

McGeary and Smith: Michael McGeary and Phil Smith

National Academy of Engineering (NAE): Lance Davis, Executive Officer, reported three responses from individual members

Alfred P. Sloan Foundation: Ralph Gomory, President

U.S. Commission on National Security/21st Century: Adam Garfinkle

University of California: C. Judson King, Provost and Senior Vice President, Academic Affairs

Individuals:

Lewis Branscomb, Harvard University (also symposium panelist)

George Brimhall, Department of Geology and Geophysics, University of California, Berkeley, CA

Harry Cook

George Dacey

Professor Earl H. Dowell, Dept. of Mechanical Engineering and Materials Science, School of Engineering, Duke University, in response to NAE request for comment

Rebecca Dresser, JD, Professor of Law and Ethics in Medicine, Washington University, St. Louis

Thomas W. Eagar, Materials Science and Engineering, MIT

Albert Henderson, Publishing Research Quarterly

John D. Holmfeld

Ruben Samuels, in response to NAE request for comment

Jeff Ullman, Stanford University, in response to NAE request for comment

Professor Richard Zare, Stanford University

Appendix E:

Contractor Reports:
Executive Summaries and Bibliographies

RAND

Setting Priorities and Coordinating Federal R&D Across Fields of Science: A Literature Review

SRI International

Symposium on International Models of Budget Coordination and Priority Setting for S&T

These reports were prepared as background for the study undertaken for the National Science Board by the NSB Ad Hoc Committee on Strategic Science and Engineering Policy Issues. The contents of these reports are the responsibility of the respective contractors and do not necessarily reflect the views of the Committee or the National Science Board.

RAND

SETTING PRIORITIES AND COORDINATING FEDERAL R&D ACROSS FIELDS OF SCIENCE: A LITERATURE REVIEW

Steven W. Popper, Caroline S. Wagner, Donna L. Fossum, William S. Stiles

DRU-2286-NSF

April 2000

Prepared for the
National Science Board

Science and Technology Policy Institute

PREFACE

The National Science Board is presently exploring how the U.S. federal government sets priorities in research and development and whether changes are needed in the decision-making process. Accordingly, the NSB's Committee on Strategic Science and Engineering Policy Issues asked RAND's Science and Technology Policy Institute for a comprehensive review of the relevant literature and experience on R&D priority setting across fields of science. The resulting report surveys the literature to identify descriptions of the budget coordination and priority setting methodologies currently employed by the federal government as well as to examine critiques of currently employed methodologies. The report will be of interest to those with general interest in the realm of science and technology policy and specifically treats issues of priority setting and coordination of the federal R&D portfolio across fields of science.

Originally created by Congress in 1991 as the Critical Technologies Institute and renamed in 1998, the Science and Technology Policy Institute is a federally funded research and development center sponsored by the National Science Foundation and managed by RAND. The Institute's mission is to help improve public policy by conducting objective, independent research and analysis on policy issues that involve science and technology. To this end, the Institute

- Supports the Office of Science and Technology Policy and other Executive Branch agencies, offices, and councils
- Helps science and technology decisionmakers understand the likely consequences of their decisions and choose among alternative policies
- Helps improve understanding in both the public and private sectors of the ways in which science and technology can better serve national objectives.

Science and Technology Policy Institute research focuses on problems of science and technology policy that involve multiple agencies. In carrying out its mission, the Institute consults broadly with representatives from private industry, institutions of higher education, and other nonprofit institutions.

Inquiries regarding the Science and Technology Policy Institute may be directed to the addresses below.

Bruce Don
Director
Science and Technology Policy Institute

Science and Technology Policy Institute,
1200 South Hayes Street, Arlington, Virginia 22202-5050

RAND, Phone: (703) 4113-1100x5351

Web: http://www.rand.org/centers/stpi
Email: stpi@rand.org

Executive Summary

The National Science Board Committee on Strategic Science and Engineering Policy Issues asked RAND to provide a comprehensive review of recent literature and data sources on priority setting and coordination in federal R&D. The full review presents a synthesis of how the literature describes priority setting across fields of science and the issues involved. We have identified gaps in the literature where the process remains unclear and needs explication. We conclude with suggestions for further study. The following summary presents a cursory overview of the main points in the review.

Overview of Findings

General Assessment of the Literature

- The literature is weighted toward the prescriptive rather than the descriptive and tends to take a broad view rather than examine operations at the agency level.
- There is a robust literature offering advice to government on how best to set goals and allocate funds, both as a national endeavor and across governmental agencies, falling into three broad categories:
- a shift to a national-goals approach, tying the priority setting process to national goals;
- a scientific-goals approach advocating cross-cutting assessments of existing spending in areas of science and realignment of budgets, if needed, to further scientific advancement;
- fine-tuning of the existing complex, political process.
- A smaller but growing base of procedural publications describes how the process of R&D allocation should be done within an agency or a discipline.
- Only a few reports describe how the process actually takes place within the government and no publications describe the process across fields of science.
- There is only a sparse literature describing efforts at coordination.
- There is a richer discussion of goals and priority-setting within the Executive branch than within Congress. Qualitative discussions of how, or even whether, Congress decides among funding options for different areas of science, different federal R&D programs, or different research project areas are comparatively rare.
- Agencies differ in setting priorities for science based on whether they have a scientific or mission orientation. Most agencies now gather views from various stakeholders combined with strategic planning and goal-setting.

Key Gaps in the Literature

While high-level goal setting is discussed, and the process of peer review and scientific advice is also detailed, there is very little about the vast middle ground where goals-setting meets actual funding obligations. Although reports cite the primary role of the Executive Office of the President in priority setting and coordination, relatively little exists about actual operations such as the role of the NSTC in coordinating federal R&D. The literature cites NSTC as coordinating larger initiatives and crosscuts, although the importance of it's decisions versus those of OMB staff is not detailed. Likewise, there is little description of the NSTC role, if any, in determining funding in agency core R&D programs not connected to a larger budget priority or "crosscut."

There is even less detail about the process that takes place within the Executive Branch in the 11 months leading up to the release and explanation of the President's budget. The deliberation within agencies for resources in the period prior to the submission of the proposed budget submission to OMB in September is nowhere in the literature. Likewise, the give-and-take between OMB and the agencies prior to the agencies being "locked out" of the budget in December is not described. There is no mention of how the individual divisions of OMB make decisions, set priorities, or allocate funding. The readjustment of the budget that occurs after the agency "lock out" in December, and when final Presidential priorities are set, is not described in the literature.

Furthermore, there is little description of the ways in which Congressional committees influence the direction and conduct of federal R&D though a number of informal means. Rarer still are documents that elaborate on either the details of these procedures in practice or the degree to which the practice corresponds to formal procedures.

Finally, despite the sizable academic literature on methods for assessing research benefits, there is virtually no discussion of whether or how these have been implemented by the research-sponsoring community.

Best Practices in the Literature

The literature itself offers no clear concept of best practice nor attempts formally to make such an assessment. Doing so would require establishing a metric, a task difficult to perform when agency missions vary so greatly. Yet, the literature might be said to imply a definition of best practice by critiquing present practice, as discussed below. As noted, these critiques generally advocate some selective change rather than offer an integrated design and might be said more to offer views of "ideal" practice than identify best practice.

There are some cases where the U.S. government has adopted some of the recommendations made in different reports but the effectiveness of these changes remains unclear. For example, the White House's creation of a "21st Century Research Fund" addresses some of the criticism that too much development has been lumped together with basic research. Responses to the increased demand for accountability of science and technology have also affected priority setting practice in many R&D agencies. The literature has yet to catch up with these developments, but these changes may be worth further examination.

Government-Wide Coordination and Priority Setting

There is no formally defined process within the federal government to set goals and priorities or make allocation decisions for science. The system is a pluralistic one based in principle on promoting excellence and relevance. Many players with different interests interact to influence the outcomes. Recommendations found in the literature on setting broad goals for federally funded research fall into three broad categories:

- Tying science funding more tightly to national goals;
- A science goals approach with realignment of budgets, if needed, to better meet the needs of scientific advancement; and
- Fine tuning the existing complex, political process.

Suggestions for more detailed models of priority setting in turn may be ascribed to three categories:

- Engaging the scientific community in determining priorities based on scientific needs;
- Benchmarking U.S. capabilities and determining where more emphasis might be placed;
- Seeking scientific and stakeholder input in science to meet agency missions;

Critiques of Currently Employed Methodology

The most frequent criticism addresses a perceived lack of clear methodology for performing priority setting and coordination. Enactment of GPRA has led to changes in agencies' practices, yet a further implicit critique may be found in the actions of the House Science Committee which held hearings in 1996 and 1997 on implementation in the civilian science agencies and announced, in 1997, that this would be a major oversight target. A major argument in the 1995 NRC "Press" report is the need for some form of "comprehensive" and "coherent" coordination of federally-financed research. However, even this recommendation is by no means universally accepted.

Advantages and Disadvantages of Different Methodologies

Best practice in the use of different methodologies suggest that a pluralistic approach is actually the more rational way to make determinations among competing priorities. For example, one argument against a more coherent and integrated federal S&T budget suggests that trade-offs should be made at the agency level between S&T investment and other expenditures; the Press report underestimates the value of the mechanisms already in place, especially the NSTC; and warns against the "overly comprehensive process" proposed by the Press panel.

Other voices argue that the budget process will not provide a method or even an analytic framework for setting the major priorities in the budget because of the diversity of agency goals. The current process recognizes R&D's value and the broad acceptance of its major federal role. Yet, it is too difficult to budget by individual projects. The "level of effort" approach is hard to defend, especially in light of the difficulty of making causal arguments by tracking direct benefits. Further, under current practice, the fate of entire disciplines sometimes depends upon the funding decisions of individual agencies.

Suggested Approaches to Improving Process

Alternatives to the present processes fall into one of three areas: alternative weightings or other means for deriving priorities from larger national goals; suggestions for alternative mechanisms within existing institutions; and changes in those institutional structures themselves.

Alternative Weightings. In the first area, there are calls to clarify the *raison d'être* for federal R&D support. There are frequent recommendations, for example, to link allocations more directly to specific societal goals. Whatever criteria are chosen, actual processes of selection and allocation should be more explicit. OTA provided an example of one set of criteria for selecting among competing initiatives summarized in Table S-1.

Table S-1. OTA's Suggested Criteria for Selecting Among Competing R&D Initiatives

Scientific Merit	Scientific objective and significance
	Breadth of interest
	Potential for new discoveries and understanding
	Uniqueness
Social Benefits	Contribution to scientific awareness or improvement
	Of the human condition
	Contribution to international understanding
	Contribution to national pride and prestige
Programmatic Concerns	Feasibility and readiness
	Scientific logistics and infrastructure
	Community commitment and readiness
	Institutional implications
	International involvement
	Cost of proposed initiative

In addition to priorities set by issue area, there are also calls to do so by stage of the research and innovation process or other criteria. Similarly, there are also suggestions to shift the focus of funding in the federal R&D portfolio dramatically toward basic research while others warn that parsing the federal R&D budget by the old definitions of basic and applied research has proved politically ineffective.

Alternative Mechanisms. The second major group of alternatives addresses the mechanisms by which allocations should occur within existing institutions. The concept of best practice might be applied by adapting already-existing models to other federal agencies. Several suggestions have been made for fundamental changes in allocation methods. One would use an options approach where the portfolio is constantly updated, balanced for risk, and takes advantage of increased information availability. Many view the current system as largely successful for the bulk of research needs but suggest that within a pluralistic, multi-agency budgeting approach, some areas require special attention owing to their large potential for spillover effects to other agencies. Several reports point to the paucity of data gathering and the necessity for establishing a database of the federal R&D budget.

Structural Changes. The last category of suggestions addresses the institutions of federal research portfolio management themselves. Several studies advocate a greater role for NSTC, OSTP, and/or OMB in setting portfolio guidelines. This would constitute a fundamental redrafting of the role of these agencies and the nature of their interactions with the rest of the federal research portfolio management structure. Improved coordination could require

- a comprehensive, comparable data base on R&D budgets;
- a detailed "directory" report to provide information on what agencies are engaged in what kinds of R&D; and
- a report on "R&D in the Budget" each year.

Alongside suggestions for different goals stands the suggestion that a new institutional structure be created, such as a non-governmental National Forum on S&T. Such a body might also define what the essential elements in the federal R&D portfolio must be and suggest ways in which the portfolio's composition may be more readily adapted. Some proposals call for creating a Federal S&T Budget in lieu of the existing post hoc accounting concept and also shifting from a bottom-up to a top-down process. This would force trade-offs at the programmatic level. Yet, at the same time there are voices stating that the current process of trade-offs and political decisionmaking, influenced by advocates of science, actually works fairly well and meets the needs of science for adequate funding.

DEFINING AND DETAILING "R&D" AND "S&T"

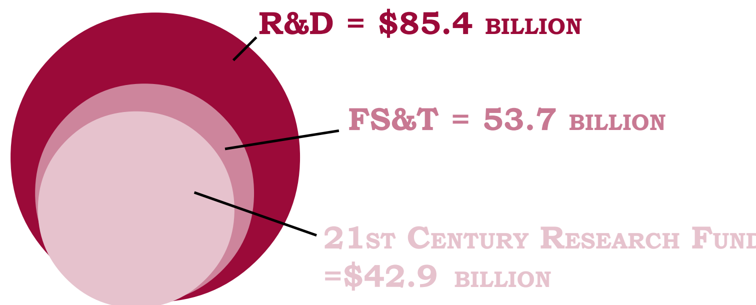
DEFINING R&D

From the outset, a terminology problem confounds attempts to characterize the literature on priority setting and R&D. Although the terms S&T and R&D are often used interchangeably, they have very different meanings in the context of the federal government. Specifically, there is one overarching and official definition of R&D used by all federal agencies[1]. Because R&D activities consti-

[1] R&D is a budget category that is defined by the Office of Management and Budget (OMB) in Section 25 of Circular A-11.

tute the primary long-term investment of the federal government (education and training is number two), R&D is separately tracked in the federal budget.[2] Complicating the discussion is the fact that other terms have been introduced, including the "Federal Science and Technology Budget" and the "21st Century Research Fund." Figure S-1 shows the relationship between these three terms.

Figure S-1: The National Academy of Sciences Comparison of 3 "R&D" Budgets



Source: Research & Development FY2001. Washington, DC: American Association for the Advancement of Science, April 2000.

Defining S&T

Parallel to the designation of specific federal activities as R&D, there is a simultaneous labeling as to general purpose (i.e., mission) or function activities for S&T. R&D activities are found in every functional category in the federal budget. Of particular interest are the R&D activities in Function 250 – General Science, Space and Technology. All such activities, most especially those of NSF and much of DOE, are officially labeled as S&T activities. Only a part of the activities are categorized as R&D. Consequently, for these agencies, R&D is a sub-set of S&T.

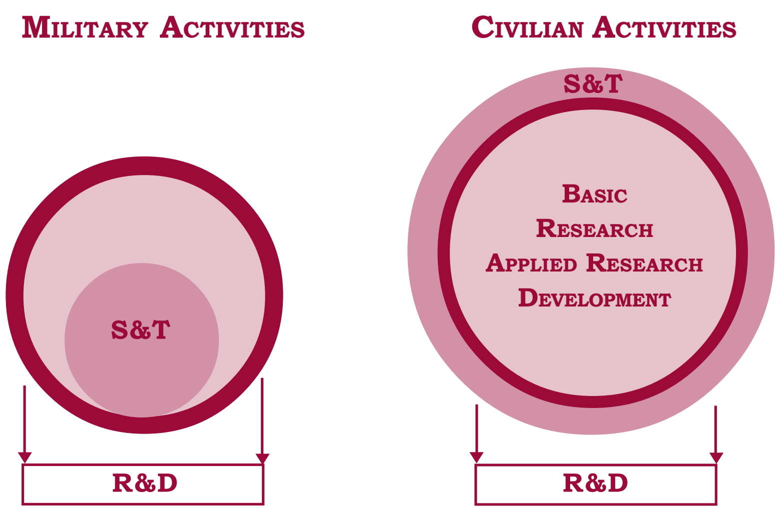
The magnitude of civilian agency S&T activities is hard to determine, because they are not officially labeled S&T. Figure 2 illustrates that specific activities that are widely believed to be R&D are instead S&T activities that fall outside the set of activities officially designated as R&D (e.g., the Manufacturing Extension Program at NIST and the Space Shuttle). Failure to agree on the definition of critical terms and then apply them consistently has defeated and continues to defeat basic communication in the federal R&D community.

[2] The Department of Defense (DOD) alone among the federal agencies has refined the OMB definition by sub-dividing the Development category. DOD then takes one of these sub-categories, groups it with Basic Research and Applied Research, and collectively refers to these three activities as "S&T" thus designating S&T as a sub-set of R&D.

DATA ISSUES

The way R&D is defined affects the collection and sharing of government data. Data on the contents of the federal R&D portfolio contain either highly aggregated budget information or disaggregated project descriptions. There is considerable difficulty finding common bases for combining "crosscutting" data collected by different agencies. Moreover, activities not characterized as R&D but which are scientific in nature (i.e., weather data, space travel, mapping) are not included in descriptions of federal R&D activities, leading to some confusion during priority setting and coordination activities.

FIGURE S-2 CONTRASTING DEFENSE-RELATED AND CIVILIAN DEFINITIONS OF S&T



EXECUTIVE BRANCH ORGANIZATIONS

The actual operation and effectiveness of executive branch organizations and processes for coordinating R&D policy, planning, and funding are poorly described in the literature. Most of the material included here is derived from agency procedural documents.

THE EXECUTIVE OFFICE OF THE PRESIDENT

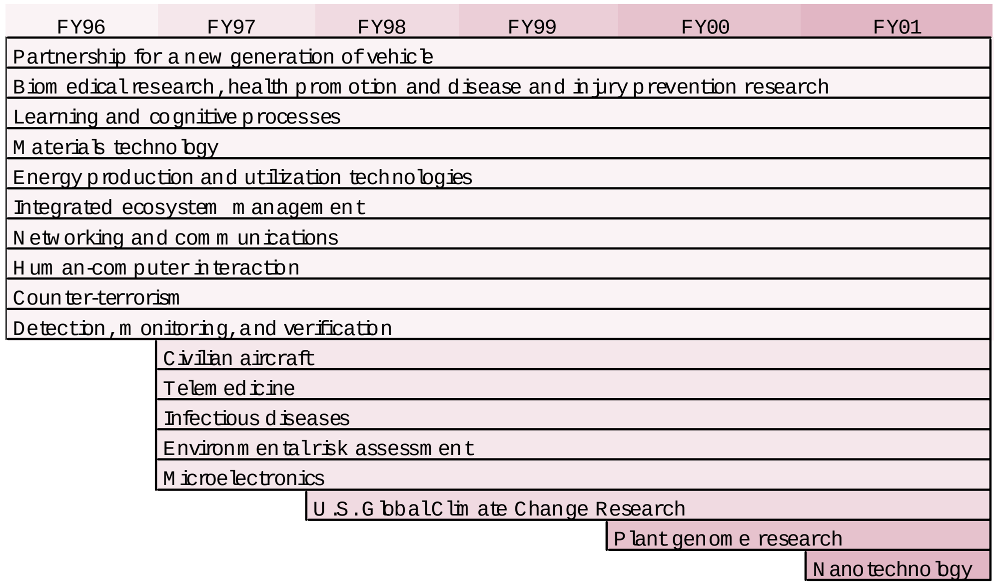
The Executive Office of the President has four offices or councils that advise the President about priority setting in R&D and S&T. These are:

- **The Office of Science and Technology Policy.** OSTP helps coordinate federal science activities to meet the President's goals. This is primarily done, in the Clinton Administration, through the National Science and Technology Council (NSTC) for which OSTP acts as a secretariat. OSTP, together with the Office of Management and Budget, issues a budget memorandum each year on research and development priorities.

- **President's Council of Advisors on Science and Technology (PCAST)**. PCAST's principal task is to assist the NSTC in securing private sector involvement in the latter's activities. Some of its recommendations are general, but PCAST also makes specific recommendations based upon assembled panels as well as its own reviews of reports of the NSTC.
- **National Science and Technology Council (NSTC)** was established to integrate the President's S&T policy agenda across the federal government and ensure that S&T is considered in development and implementation of federal policies and programs. It is a policy and budgetary coordination body through which all executive departments and agencies coordinate S&T activities that require significant levels of interagency coordination. OSTP suggests topics around which the NSTC forms committees to review government spending in specific areas of research and recommend priority or allocation shifts. OSTP then advises agencies and OMB and solicits input from the larger scientific community about where priorities and resource allocation should focus. In preparation for FY2001, NSTC is overseeing the coordination and priority-setting for 11 areas of which the more mature, congressionally-mandated programs are managed as formal interagency crosscuts, while areas being developed for priority attention become the subject of NSTC working groups.
- **The Office of Management and Budget** (OMB) coordinates the President's budget process. This process starts each summer when agencies begin preparing their budgets for the fiscal year that begins in October of the following year. There is no "R&D budget" as such. OMB has the power to shape the budget, but does not set specific priorities for science. It does examine agency proposals for redundancy and looks for opportunities for interagency coordination. It has no means for truly setting priorities between different R&D programs with differing goals. Budget guidelines for R&D are issued jointly by OSTP and OMB. While agency officials report that the budget call does have some effect on R&D allocation, it may actually affect more how existing plans are labeled than on how budget priorities are set.

The priorities for R&D that become guidelines for the agency budgeting process are based on a set of goals named by the Clinton Administration in the first months of its tenure. These goals include: (1) a healthy, educated citizenry, (2) job creation and economic growth, (3) world leadership in science, mathematics, and engineering, (4) improved environmental quality; (5) harnessing information technology; and (6) enhanced national security. The R&D priorities have remained relatively stable over the past six years, with several additions, as illustrated in Figure S-3 on the following page.

Figure S-3. R&D Priorities Set by the OSTP and OMB, FY96-FY01



R&D Agencies Within the Executive Branch

The literature on agency-level R&D priority setting is not a robust collection. The Office of Technology Assessment report "Federally Funded Research: Decisions for a Decade" describes these activities, and this section draws heavily from that report. Beyond this, the agencies themselves have issued GPRA-inspired strategic plans that provide some insights into the priority setting process. Outside of these sources, we found very little concerning what happens in the agencies with regard to priority setting, despite there being over 20 government agencies funding R&D. It makes sense that the largest spenders would be the most well represented in the literature, but smaller agencies most likely make dearer trade-offs in funding. These smaller agencies may be worth further examination. Table S-2 below summarizes what exists in the literature about agency priority setting activities. Not all of these representations may be current. Some of the literature is dated and changes may well have occurred in these agencies since the original report was written.

Table S-2. Agency R&D Priority Setting Activities

AGENCY (IN ORDER OF THE MAGNITUDE OF THEIR R&D BUDGETS)	PRINCIPAL FINDINGS ABOUT PRIORITY SETTING ACTIVITIES REPORTED IN LITERATURE	METHODS USED TO IDENTIFY PRIORITIES
Department of Defense	Planning occurs in the office of the Director of Defense Research and Engineering (DDR&E) which looks to the NSTC and the Joint Chiefs of Staff's Joint Vision 2010 for guidance.	In its Basic Research Plan, DOD uses peer review and competition to achieve its objectives; Technology Area Reviews and Assessments (TARA) provide an oversight function to assess the quality of the research programs.
Department of Energy	A National Energy Strategy (NES) was designed to solicit input from the offices within DOE and from external advisors. Each program has an advisory panel, such as the High Energy Physics Advisory Panel (HEPAP) and the Energy Research Advisory Board (ERAB) which are external boards of scientists. These groups and others like them present to DOE a set of priority research areas that deserve the agency's special attention.	In selecting areas of research, the Office of Science emphasized the use of peer review to evaluate all programs. It also stated that advisory boards play a significant part in its priority setting processes.
NASA	NASA sets priorities in conjunction with the budget process and by selecting specific projects. Influenced more heavily by Congress than other agencies. The process is essentially bottom up with project managers proposing new initiatives. When large missions are proposed, such as Space Station Freedom, top-down direction determines the parameters of the effort. (OTA)	Priority setting results from a combination of input from NASA's own internal managers, staff and directors, and external actors like the National Research Council the Task Group on Space Astronomy and Astrophysics, and the space science community. In its goal to pursue scientific excellence, the Office of Science emphasized the use of peer review to evaluate all programs.
National Institutes of Health (HHS)	The director of each Institute, with the help of NIH's national advisory council, decides funding direction carried out through extramural grants and intramural programs.	Advisory councils are mandated by Congress and composed of people from both the scientific community and the public. The director also consults with intramural investigators, scientists in the extramural program, patients and their families interested in research on particular diseases, professional and scientific groups, representatives of the Administration and members of Congress, and with the public.
National Science Foundation	The NSF process for strategic planning involves calling in advisory committees and committees of visitors, regular reviews of programs and input from the National Science Board, and at the Directorate level reports from external groups on program issues. Goals are set "by scientific opportunity and the proposal process, as well as in special initiatives from advisory panels."	The NSB recommended that the following two criteria be adopted in place of the four criteria that had been used in the past to determine research priorities: 1. What is the intellectual merit of the proposed activity? E.g., does it advance knowledge and understanding in its own field and across fields? Is it creative and original? 2. What are the broader impacts of the proposed activity? E.g., advance discovery and promote teaching? Enhancing partnerships?
Department of Agriculture	USDA derives specific priorities from its 1997 strategic plan. Annual performance plans are modified based on input from the staff and advisory committees. Priority setting is advised by many groups, most important is the Joint Council on Food and Agriculture Sciences created by Congress.	Budgets are developed using a crosswalk that links the strategic goals and objectives of the agency with its overall budget structure and specific performance goals.
Department of Commerce, National Institute for Standards and Technology	NIST sets priorities in specific measurement areas based on the advice of councils created by NIST itself but which are established as independent nonprofit organizations as well as input from customers and NIST scientific and technical staff.	The councils strive to provide a consensus on industrial and academic requirements for standards and programs, including setting priorities. Divisions maintain direct contact with customers and manufacturers and conduct periodic customer surveys in order to set priorities based on customer need.
Environmental Protection Agency	EPA's Office of Research and Development (ORD) has the principal responsibility for research and development. Strategic Plans have relied heavily on EPA's Science Advisory Board (an independent group of engineering and science advisors) and expert panels convened by NAPA and the National Academy of Sciences	The most important of EPA's strategic principles is the explicit use of the risk paradigm to shape and focus EPA's organizational structure and research agenda, including hazard identification, dose response assessment, exposure assessment, and risk characterization.

Congress

Of all the institutions involved in coordination and priority setting across fields of science, the literature as a whole shows its largest gap in its treatment of Congress. Congress has not paralleled the Executive branch in coordinating its own R&D policy, planning, and funding efforts. At least 21 Congressional Committees have direct federal R&D policy or funding responsibility. At no time in the Congressional process is there a comprehensive view taken of the R&D portfolio across the federal government. Further, there are a range of other legislative decisions that can affect planning and priorities of federal agencies and the conduct of federally-funded R&D. Regulatory, tax, or other decisions affecting research institutions are made outside of the Congressional circles in which R&D policy is decided and are frequently not coordinated with the Congressional entities having R&D policy jurisdiction.

Interactions Between the Executive and Legislative Branches on R&D

The need for interaction between branches causes the shortcomings found within each to become compounded by the lack of a formal coordinating mechanism. Since OMB must approve agency testimony, any formal presentation to Congress will serve to ratify the final decisions made during the Budget submission and will not easily provide a vehicle for an R&D agency to comment critically upon decisions made in that process. In addition, agencies are generally nonresponsive to questions of priority put to them by Congress. Yet, oversight hearings play a key role in determining the budgets of specific research programs and encouraging coordination between the research agencies. Absent a formal agreement, the budget, appropriations, and oversight processes constitute the coordination mechanisms and the conduct of this work is subject to individual agency and committee dynamics and is frequently left to the perspectives and proclivities of individual members of Congress and their staffs.

Use of Benefits Measures in Priority Setting and Budget Coordination

With the introduction of new concepts of accountability, the R&D agencies have begun applying benefits measures to R&D and using the results to help set priorities. However, this process has not been studied or systematically documented. It may be too early in the process of adopting these measures to determine if they are effective. Most of the measures identified in the literature were adopted from private sector applications. In many ways, federal research presents greater problems for measurement and benchmarking than does private R&D. A great deal of federally funded research is directed to areas where the market is limited at best. Further, given the types of data available, the returns that result from most calculations must be interpreted as average rather than marginal rates. From a policy perspective, this means we cannot be certain from this aggregate analysis what the effect of an additional dollar of research expenditure might be. The cost/benefit framework itself may be too restrictive, failing to capture the many benefits that may be derived from publicly-funded basic research. The true effect of such outlays may well be indirect, affecting productivity through changing the returns to private research and development rather than directly as a result of the specific research project.

Social rates of return analysis seeks to determine the sum of benefits accrued from changes in the knowledge base and compares these benefits to the cost of investment. This social benefit may be considerably greater than the private benefit taken in the form of profit. As a practical matter, such studies involve selecting a sample of specific innovations upon which to perform these calculations. This is both expensive and subject to unintentional or unavoidable bias in the selection process. Further, the social rate of return calculated by such means is not directly comparable to the internal rates of return calculated for private investment projects. Nevertheless, studies in this area have found a very high return to investment in basic research.

Among potential users of such information is, of course, Congress. Whether it acts as the originator of information requests for the purposes of furthering its own process, or is targeted as the ultimate audience for assessments produced for its benefit by the agencies coming before its committees for funding, Congress would like to have better means for determining the results ensuing from federal funding of R&D. Another body which has considered broad application of performance-based measures throughout the federal government is the NSTC. NSTC has issued a list of performance measures for function 250 (R&D) activities that encourage setting aside 80 percent or more of R&D for peer-reviewed competition as well as call for the majority of assessments to be made by external bodies. These are in reality guidelines for conduct and measures attuned to the first category found in the literature: asset-based measures.

The National Academy of Sciences Committee on Science Engineering and Public Policy (COSEPUP,) suggests general guidelines for measuring U.S. position in a given field of science: 1) What is the U.S. position in a field? 2) What key factors determine relative position? and 3) What is the trend for relative position in the near and long term? These yardsticks do not necessarily track well with the needs of mission agencies. Further, in practice, most measures appear to be of the asset-accounting type.

At the agency level, the DOE Office of Science Strategic Plan lists a series of success indicators for each of its five main goal areas (e.g.: "photochemical systems that hold promise for economical, highly efficient solar cells.") The indicators are outcome-oriented but seem to be of a checklist-type, attuned to achieving particular milestones and not quantitative in nature. They do not seek to track direct benefit back to specific R&D project outcomes

Documents on the performance assessment process in use by NSF point to heavy reliance on external assessment. Attempts are being made to shift from a somewhat ad hoc basis to a more formal procedure that will provide a common format to the review process that extends across NSF. For example, beginning in 1998, annual reports to the Director have been required from NSF units using a variety of indicators and data series to demonstrate effect.

Generally speaking, however, although new advances continue to be suggested in the academic literature and new methodologies for identifying and selecting new research, managing existing research, and evaluating and assessing research retrospectively have been designed, the implementation of these methods by the research sponsoring community remains minimal.

Conclusions

The alternative approaches for managing the federal research enterprise that emerge from the literature fall into three areas:

- alternative readings of what are the appropriate *goals* federal research support should seek to fulfill;
- suggestions for alternative *mechanisms* for allocation of funds within the existing institutions for managing the federal research portfolio; and
- elements for a design leading in whole or in part to changes in those *institutional structures* themselves.

The two consistent themes are a desire to establish priorities and to do so in a coordinated fashion. This assumes that improvements in either the top-down or the bottom-up approach or both would improve the outcome. This assumption has not been questioned in the literature.

This is understandable. A frequent theme of the literature is that the federal R&D portfolio is only a *post facto* accounting concept. It is, by default, the aggregation of individual mission agency portfolios but is in no sense managed *ex ante* as a unified portfolio. Several studies advocate a greater role for the NSTC, OSTP, and/or OMB in setting portfolio guidelines at a higher level than that of the funding agencies as well as actively monitoring fulfillment. A necessary first step to effective prioritization, in other words, is to achieve coordination. Nevertheless, the issue of whether a more unified or better coordinated portfolio is desireable or achieveable has not been adequately debated in the literature and deserves more attention.

A persistent assumption in the literature is that greater coordination is desirable and can be attained by setting high level goals and then proceeding to lower levels of decisionmaking authority. This seems problematic on two counts. First, decisionmaking in this area is embedded in existing institutions and political processes. Setting high-level goals and then rigorously enforcing them as the means for crafting priorities and making allocations on lower levels would, in effect, stand the present system on its head.

Second, such an approach may not accord with the evolving pattern for the commerce of ideas and knowledge management. Modern science is increasingly cross-disciplinary, with major discovery taking place at the interstices of traditional disciplinary categories. Contributing to this trend are increased globalization of effort with geographically dispersed working teams crossing geographic boundaries and an ever denser connectivity of information and ideas.

This is not to suggest that prioritization or coordination are undesirable or that gaining a measure of control is impossible. Rather, it is to suggest that as we proceed further along this line of inquiry we should address the following questions left largely unaddressed by the literature as it stands:

1. What do we mean by the terms "priority" and "coordination"?
2. What do we hope to achieve and how will we improve the public's lot through prioritization and coordination?
3. What are appropriate measures for identifying best practice in priority setting and coordination?
4. What alternative models, not necessarily predicated upon traditional views of either the science process or its effect on the larger society, need we consider to best develop means for achieving a true ability to set priority and the level of coordination we desire?

In order to fully understand the processes that take place within the system that result in the set of activities that the government labels "R&D" or "S&T" the Board needs a better understanding of what is happening in the agencies or in the scientific community in that "vast middle" between high level goals and bottom-up input. The decisions made at the program and project level have not been studied or described in the literature. Insights that could be gained from an examination of these activities may aid the Board in its effort to bring more accountability and coordination to the process.

Annotated Bibliography

AAAS Science and Technology Policy Yearbook 1999. Committee on Science, Engineering, and Public Policy, American Association for the Advancement of Science, Washington, DC, 1999.

Adams, James D., and Suzanne Peck, *A Guide to R&D Data at the Center for Economic Studies,* Washington, D.C.: U.S. Department of Commerce, Bureau of the Census, Center for Economic Studies, August 1994.

This edition of an annual survey of firms' research development expenditures describes R&D data available at the Center for Economic Studies. It covers the years 1972–1992.

America's Basic Research: Prosperity Through Discovery, Committee for Economic Development *AAAS Science and Technology Policy Yearbook 1999.* Washington, D.C.: Committee on Science, Engineering, and Public Policy, American Association for the Advancement of Science, 1999.

Arthur Andersen. *The Costs of Research: Examining Patterns of Expenditures Across Research Sectors.* Report for The Government-University-Industry Research Roundtable, March, 1996.

Arthur Andersen's analyses concluded that the pattern of expenditures incurred for research activities in federal laboratories, universities, and industry are strikingly similar, despite common perceptions that there are wide differences.

Carnegie Commission on Science, Technology, and Government, *Enabling the Future: Linking Science and Technology to Societal Goals,*. New York, NY: Carnegie Commission, September 1992.

This report makes five major recommendations, first among them a call for a nongovernmental national R&D forum to "identify ways in which science and technology can contribute to the definition and refinement of societal objectives and to their realization." In addition, the report recommends that Congress increase its oversight; that congressional research bodies pay more attention to linking S&T to national goals; that OSTP and OMB collaborate more closely in establishing long-term S&T goals; and that agencies pay greater attention to policy analysis and strategic planning.

— *Science, Technology, and Congress: Organizational and Procedural Reforms.* New York, NY: Carnegie Commission, February, 1994.

— *Science, Technology, and Government for a Changing World.* New York, NY: Carnegie Commission, April 1993. 94 p.

— *Environmental Research and Development: Strengthening the Federal Infrastructure*, New York, NY: Carnegie Commission, 1992.

— *Science, Technology, and Congress: Expert Advice and the Decision-Making Process.* New York, NY: Carnegie Commission, 1991.

Chapman, Robert M. *The Machine That Could: PNGV, A Government-Industry Partnership*. RAND MR-1011-DOC. 1998.

Clinton, William J., and Albert Gore, Jr., *Science in the National Interest*, Washington, D.C.: Executive Office of the President, Office of Science and Technology Policy, August 1994.

In laying out the foundation for Clinton administration's support for science, this document lists important national goals to which science can contribute: health, prosperity, national security, environmental responsibility, and improved quality of life. These goals should be met by maintaining leadership across the frontiers of scientific knowledge, enhancing connections between basic research and national goals, stimulating public-private partnerships, ensuring excellence in science education, and raising scientific literacy.

Congressional Research Service, The Committee for the National Institute for the Environment. *Research and Development: Priority Setting and Consolidation in Science Budgeting II*. Issue Brief. Washington, D.C.: Library of Congress, October 1999.

— *Analysis of Ten Selected Science and Technology Policy Studies*, Science Policy Research Division, Library of Congress, September 4, 1997.

CRS Report 97-70, CRS Report 97-382, CRS Report RS20257, and CRS Report 98-224.

The CRS Reports noted that the House Science Committee held hearings in 1996 and 1997 on implementation in the civilian science agencies, and in 1997, the House announced this as a major oversight target. Several committees asked agencies to link FY1999 and FY2000 budget requests to goals expressed in their strategic and performance plans.

Cook-Deegan, Robert Mullan, "Previous Analysis of the U.S. R&D Allocation Process," working paper, Washington, D.C.: National Academy of Sciences, January 1995.

As input to a National Academy of Sciences effort to examine allocation of the federal R&D budget, this report summarizes many of the other reports included in this bibliography.

Committee for Economic Development, *America's Basic Research: Prosperity Through Discovery*. New York, New York: Committee for Economic Development, 1998.

Council on Competitiveness, *Endless Frontier, Limited Resources: U.S. R&D Policy for Competitiveness,* Washington, D.C.: Council on Competitiveness, 1996.

This report addresses the ways in which U.S. industry, government, and academia have been responding to the R&D environment since the end of the Cold War. The council's central finding is that R&D partnerships hold the key to America's future. The report examines the role of partnerships in R&D innovations in the aircraft, automotive, chemical, electronics, information technologies, and pharmaceuticals sectors. Finally, the report provides some policy guidelines for the nation, for industry, for government, and for academia. Specifically, the council states that the distinctions between basic and applied research need to be reevaluated to account for R&D risks in the short, medium, and long terms. It calls for government and industry to work together in choosing future R&D investments. The report also states that federal research should reflect today's missions and budget environment.

Davies, J. Clarence. "Comparing Environmental Risks: Tools for Setting Government Priorities: Resources for the Future" Washington, D.C. 1996.

Davey, Michael E., Genevieve J. Knezo, Richard E. Rowberg, and Wendy H. Schacht, "Exploring Alternative Models of Federal Support for Research and Development," prepared for a Congressional Research Service Workshop, Washington, D.C.: The Library of Congress, October 25, 1995.

This paper covers the history of federal R&D support and the emergence and growth of industrial R&D. The authors suggest four models of federal support for R&D. The first model proposes that federal R&D support would be for defense purposes only, eliminating federal support for all other R&D activities. Private industry would be responsible for funding all R&D not related to defense. In the second model, federal R&D support would cover defense, environmental clean-up, space, and public health; 70 to 80 percent of funds would be for defense R&D with the remainder going toward the other areas. The third model would reduce federal R&D funding by 30 to 50 percent and would treat universities and the private sector as equal partners in R&D enterprise. In the fourth model, federal R&D support would mainly cover basic research, applied R&D would be reduced by 30 percent.

Dutton, John A. and Lawson Crowe, "Setting Priority Among Scientific Initiatives", American Scientist, vol. 76, Nov.-Dec. 1988.

Democratic Staff, U.S. House of Representatives Committee on Science, *The President's Fiscal Year 1997 Budget Request for R&D and Long-Term Outlook for Science*, March 28, 1996.

This analysis presents the House Democratic view of the 1997 R&D budget, comparing the Republican and Democratic budget allocations. It provides a historical graphical overview of past R&D budgets and breaks down the allocations by federal departments and agencies, including the NSF, NASA, NIST, DOE, NOAA, NIH and EPA.

Department of Energy, Office of Science. *Strategic Plan* Washington, D.C: June 1999.

This companion document to DOE's Strategic Plan defines scientific accomplishments and provides priorities and strategies for the future, including how the Office of Science generates priorities in science.

Environmental Protection Agency, Science Advisory Board. *Reducing Risk: Setting Priorities and Strategies for Environmental Protection.* Washington, DC: U.S. Environmental Protection Agency. September 1990.

This report examines strategies for reducing major risks to the environment by improving methodologies for assessing and comparing risk reduction options for the future.

Environmental Protection Agency, Office of Research and Development, *Strategic Plan*, Washington, DC: U.S. Environmental Protection Agency., May 1996.

Executive Office of the President, Office of Science and Technology Policy, "Memorandum for the Heads of Executive Departments and Agencies: FY 2001 Interagency Research and Development Priorities," Neal Lane and Jacob J. Lew, April 22, 1999.

— "Memorandum for the Heads of Executive Departments and Agencies: FY2000 Research and Development (R&D) Priorities, Kerri-Ann Jones and Jacob Lew, June 16, 1998.

— "Memorandum for the Heads of Executive Departments and Agencies: FY1999 Research and Development (R&D) Priorities," John H. Gibbons and Franklin Raines, June 6, 1997.

— S*cience and Technology Shaping the 21st Century*, Washington, D.C., April 1997.

This biennial report from the President to Congress on S&T addresses the administration's portfolio for S&T in security, health, environment and human resources. The report address (1) continuing American leadership in the S&T enterprise; (2) strengthening science, math, and engineering; (3) providing for a sound fiscal and regulatory environment for research; and (4) retaining a long-term commitment to research, education, and innovation.

— "Memorandum for the Heads of Executive Departments and Agencies: FY1998 Research and Development (R&D) Priorities," John H. Gibbons and Alice Rivlin, May 29, 1996.

— "Memorandum for the Heads of Executive Departments and Agencies: FY1997 Research and Development (R&D) Priorities," John H. Gibbons and Alice Rivlin, April 28, 1995.

— Presidential White Paper, Technology and Economic Growth: Producing Real Results for the American People, 1995.

— "Memorandum for the Heads of Executive Departments and Agencies: FY1996 Research and Development (R&D) Priorities," John H. Gibbons and Leon E. Panetta, May 6, 1994.

— Establishment of the National Science and Technology Council, Executive Order 12881, 23 November 1993.

— President's Committee of Advisors on Science and Technology (PCAST) Executive Order and Amendments, Executive Order 12882, 23 November 1993.

Gebbie, Katherine. "Prepared Statement of Katherine Gebbie, Director, Physics Laboratory, National Institute of Standards and Technology Before the House Committee on Science Subcommittee on Technology." May 2, 1996.

In her testimony, Katherine Gebbie provides several ways in which NIST sets priorities among its R&D investments. Specifically, she provides a model in which NIST looks to two nonprofit councils, composed of government, industry and academe, to advise it on setting priorities while also discussing another model that is survey driven and involves customer feedback.

General Accounting Office. Measuring Performance: Strengths and Limitations of Research Indicators, RCED-97-91

The Research Roundtable, an HHS-led interagency group, developed guidance for R&D performance measures. The GAO described the difficulties of developing research outcomes measures.

Glauthier, T. J., "Research and Development Priorities and Reinventing Government," *AAAS Science and Technology Policy Yearbook 1995*, Washington D.C.: American Association for the Advancement of Science, 1995, pp. 57-62.

This article examines the current pressures on the federal budget and the Clinton administration's efforts toward reinventing government. Specifically, the article recommends that the science community (1) identify the implications and priorities of all programs being put together, which programs work and which do not; (2) explain these programs in laymen's terms, for congressional and public consumption; and (3) reinvent programs by including industry, universities, and government in the decisionmaking process.

Hertzfeld, Henry R. "An Assessment of Studies of the Contribution of Fundamental Research," draft submitted to the National Science Foundation, Directorate for Science, Technology, and International Affairs, Division of Policy Research and Analysis, October, 1990. [photocopy dated May 11, 1992]

Hill, Christopher T., "On the Allocation of Federal R&D Funds," working paper, Fairfax, Va.: The Institute of Public Policy, George Mason University, January 1995.

This paper covers a broad overview of present-day allocation of federal R&D funds among national purposes, performers, and federal agencies. It describes the historical processes that have helped shape R&D allocation. R&D spending responds to national crises; political and budgetary imperatives; and occasionally, to determined efforts of highly committed interests pursuing long-term visions of a different future. Rarely does the R&D portfolio reflect a carefully considered balance among national needs, and it does not appear to take account of the overall vitality of the national R&D enterprise.

Knezo, Genevieve J., *Research and Development Funding in a Constrained Budget Environment: Alternative Support Sources and Streamlined Funding Mechanisms*, report for Congress, Washington, D.C.: Congressional Research Service, The Library of Congress, April 5, 1996.

This report summarizes cuts made in federal R&D funds, proposals to increase nonfederal sources of funding, proposals to improve R&D priority-setting, and ways to streamline and alter existing R&D award processes to make them more efficient. Specific topics include limiting federal R&D support to targeted areas; creating a Department of Science and Technology to coordinate federal R&D funding; expanding support to such alternatives as lotteries, state funding, and foundations; revising the tax code to promote R&D; modifying grant mechanisms to conserve resources; and eliminating conservation of peer-reviewed science.

— *Research and Development: Priority Setting and Consolidation in Science Budgeting*. The Committee for the National Institute for the Environment, Research and Development: Priority Setting and Consolidation in Science Budgeting II. October, 1999.

— "Defense Basic Research Priorities: Funding and Policy Issues, CRS Report for Congress , Washington, DC. Congressional Research Service, Oct. 24, 1990.

Kostoff, Ronald N. Handbook of Research Impact Assessment, 7th Edition, DTIC Report No. ADA296021, Summer 1997.

Lederman, Leon M., *Science: The End of the Frontier?* Washington, D.C.: American Association for the Advancement of Science, January 1991.

This is a formal survey conducted to gauge the state of academic research in U.S. universities. University faculty were asked about their experiences with research funding. Questions were asked about research funding in the scientist's own research area, the relative ease or difficulty of obtaining funding, experiences with research funding for the future, and factors influencing the ability of scientists to conduct research in their current settings. The results show that academic research is in trouble; research funding is diminishing; and morale is flagging. According to the

AAAS, university funding, when corrected for inflation, was only slightly higher in 1990 than it was in 1968. The report concludes that, to balance the complexity of science, the United States should be spending twice the amount it was investing in 1968, or $10 billion/ year, and this investment should increase least 4 percent per year. The report further recommends establishing a commission to deal with this issue, consisting of representatives from the Executive and Legislative Branches of the federal government, industry, the financial community, and the academic community.

Levine, Candice S., “Reorienting for Sustainable Development: Support for a National Science and Technology Policy,” *Journal of International Affairs*, Spring 1998.

This article discusses R&D funding as it pertains to the environment. In general, the articles states that poor coordination among federal agencies and inconsistent support from national leaders result in a poor national science policy that will hinder sustainable development.

McLoughlin, Glenn J., *International Science and Technology: Issues For U.S. Policymakers,* Report for Congress, Washington, D.C.: Congressional Research Service, The Library of Congress, September 16, 1994.

This report presents a comparison of national R&D funding issues and options, how other nations set S&T priorities, fund research and development (R&D) programs, and address similar S&T issues. Each nations' R&D funding figures are presented in current U.S. dollars in several major R&D categories. Other R&D funding categories may be found in the chapters on each nation (US, Germany, Japan, India, Australia, UK, New Zealand, and the EU).

— *International Science and Technology Issues: Summary of a Report to the Committee on Science*. Report to Congress, Washington, D.C.: Congressional Research Service, Science, Technology, and Medicine Division, April 20, 1998, 15p.

This report is a summary of a comparative study on international science and technology, prepared at the request of the Committee on Science of the House of Represents. It provides a digest of analysis and findings on the science and technology policies, civilian research and development funding, and relevant policy issues of 13 countries and the European Union. It also provides a description of why these findings and issues may be of interest to U.S. policymakers, as well as an analysis of issues and concerns about U.S. data collection and information.

— and R. E. Rowberg, *Linkages between Federal Research and Development Funding and Economic Growth*. A Report in the Series Economic Policymaking in Congress: Trends and Prospects. Report for Congress, Washington, D.C.: Congressional Research Service, The Library of Congress, 1992. 19 p.

This report provides information on other forms of "direct" (R&D) and "indirect" (other areas) S&T policies in the United States). The report examines the contribution of Federal R&D to economic growth. It addresses the question about a more direct Federal role in the context of international economic competition. Finally, policy considerations are presented which could affect the relationship between mission agency R&D and economic growth, and the issues surrounding a more direct Federal role.

McGeary, Michael, "Where Does the Federal Dollar for Basic Research Go?" working paper, submitted to the National Academy of Sciences Committee on Criteria for Federal Support of Research and Development meeting held on March 30-April 1, 1995, in Washington, D.C.

This paper provides information on federally funded basic research. Using NSF 1994 S&T data, the paper discusses who provides the funds for basic research and why, describes which mechanisms are used to provide support, and discusses which agencies and departments conduct basic research and in which areas. It also provides a general overview and breakout of indirect costs paid to universities and other extramural research institutions.

Merrill, Stephen A., and Michael McGeary, "Balancing the Federal Research Portfolio: Who's Deciding and Why?" working paper, Washington, D.C.: National Research Council, National Academy of Sciences, August 11, 1999.

The authors take issue with congressional claims that the current R&D budgeting process results in a well-balanced portfolio. By examining NSF data, the paper identifies 15 areas of R&D in which funds have declined during the 1990s. The authors note that no one agency is responsible for ensuring that this drop in R&D funding is not harming the national interest. They call for (1) a bottom-up evaluation of these cuts, (2) a more open discussion of national S&T priorities, and (3) principle policymaking bodies to make adjustments to the funding portfolio when there appears to be a serious shortfall in desirable investment.

National Academy of Sciences. National Research Council, *Evaluating Federal Research Programs: Research and the Government Performance and Results Act*. Washington, D.C.: National Academy Press, February 1999.

The NRC released report recommended that federal agencies develop performance measures for research, and issued "benchmarking" reports comparing the status of U.S. science to other countries for mathematics, materials science and engineering, and immunology. The agencies submitted strategic plans to the Congress in September 1997 and delivered annual performance plans with FY1999 budget justifications.

— National Research Council, *Harnessing Science and Technology for America's Economic Future: National And Regional Priorities*. Washington DC: National Academy Press, 1999.

Report makes recommendations to develop new mechanisms for international research collaboration to advance fundamental knowledge, drawing on the experience of recent years. After the federal government, the academic institutions performing research and development (R&D) provided the second largest share of academic R&D support. The NRC report noted that much of this funding comes from state governments, but is counted as institutional funding because the university has discretion over whether it will be spent on research or in other ways. Industrial R&D support for academic institutions has grown more rapidly than support from other sources since 1980 (i.e., in constant dollars, industrial-financed R&D increased by an estimated 250% from 1980 to 1995, and industry's share grew from 3.9% to 6.9%) (NRC, 1999). More extensive university-industry collaboration on long-term issues of interest to industry could help to alleviate the funding pressures being faced by universities (NRC, 1999).

— National Research Council. *An Assessment of the National Institute of Standards and Technology Measurement and Standards Laboratories.* Washington DC: National Academy Press, 1998.

Each year since 1959, the National Research Council has assessed the programs of the National Institute of Standards and Technology (NIST), and its predecessor, the National Bureau of Standards. Assessments are currently performed by about 150 leading scientists and engineers, equally from U.S. industry and academe, appointed by the National Research Council (NRC), and administered by the NRC's Board on Assessment of NIST Programs. There are currently seven major Panels that assess the major organizational areas: electronics and electrical engineering, manufacturing engineering, chemical science and technology, physics, materials science and engineering, building and fire research, and information technology.

— National Research Council. "International Benchmarking of US Materials Science and Engineering Research," Committee on Science, Engineering and Public Policy. Washington, DC: National Academies Press, 1998.

— Observations on the President's Fiscal Year 1999 Federal Science and Technology Budget, Washington, DC: National Academies Press, April 1998.

— Institute of Medicine, *Scientific Opportunities and Public Needs: Improving Priority Setting and Public Input at the National Institute of Health*, Washington, D.C.: National Academy Press, 1998.

This report examines the way in which NIH sets priorities and provides a few recommendations for improvement. The report states that NIH's objectives should revolve around identifying the public's health needs, extending basic research and. The report recommends that NIH continue to use its current method for criteria setting, but implement a more systematic use and analysis of data sources for input in priority setting . The report also recommends an increased role for NIH's Advisory Committee as well as the establishment of a Public Liaison Office.

— National Research Council, *A New Science Strategy for Space Astronomy and Astrophysics*, Washington, D.C.: National Academy Press, 1997.

This update to the 1991 report, The Decade of Discovery in Astronomy and Astrophysics, uses priority-setting methods established in 1991 to provide a strategy for space astronomy and astrophysics. In doing its priority setting, the Task Group on Space Astronomy and Astrophysics, the community (1) concentrated on the scientific objectives rather than the method; (2) prioritized scientific questions according to whole classes of astronomical objects, rather than to individual observing bands; and (3) looked realistically at cost and technical feasibility.

— National Research Council. *Understanding Risk: Informing Decisions in a Democratic Society.* Washington, D.C. National Academy Press, 1996.

— Board on Environmental Studies and Toxicology. "Interim Report of the Committee on Research and Peer Review at EPA." Washington, D.C. National Academy Press, 1995.

— Committee on Criteria for Federal Support of Research and Development, *Allocating Federal Funds for Science and Technology*, Washington, D.C.: National Academy Press, 1995.

The Committee on Criteria for Federal Support of R&D provides an overview of how R&D is defined within the federal government and describes the current process of allocating R&D funds through federal departments and agencies. Based on this information and a literature review, the committee recommends three policy initiatives for allocating federal funds: (1) The President should present an annual comprehensive FS&T budget; (2) the departments and agencies should make FS&T allocation decisions based on clearly articulated criteria that are congruent with those that the Executive Office of the President and Congress use; and (3) Congress should create a process that examines the entire Federal Science & Technology budget before the total federal budget is disaggregated.

— National Research Council. *Science and Judgement in Risk Assessment.* Washington, D.C.: National Academy Press, 1994.

— *Science, Technology, and the Federal Government: National Goals for a New Era.* Washington D.C.: National Academy Press, 1993.

This report recommends tying S&T goals to two overarching principles: (1) The U.S. should be among the world leaders in all major areas of S&T, and (2) the U.S. should maintain clear dominance in scientific fields likely to contribute to substantially important economic, social, or cultural objectives. Further, government should cooperate with the private sector to maintain U.S. leadership in technologies that promise to have major influence on industrial and economic performance and that could lead to new industries, based on principles of cost-sharing, insulation from distributional politics, and stable support.

— National Research Council, Astronomy and Astrophysics Survey Committee, *The Decade of Discovery in Astronomy and Astrophysics.* Washington, D.C.: National Academy Press, 1991.

This report discusses the results of a survey conducted by the Astronomy and Astrophysics Survey Committee of the NRC. The study was commissioned to provide an overview of what is going on in astronomy and to recommend initiatives for the coming decade. The committee was tasked to provide a prioritized list of instruments for the coming decade, evaluate the existing infrastructure, explore the consequences of the computer revolution for astronomy, prepare a popular summary of opportunities for scientific advances in astronomy, and suggest possible areas for developing new observational technologies.

— Presidents of the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, *Federal Science and Technology Budget Priorities*. Washington, D.C.: National Academy Press, 1988.

This report notes that the absence of a coordinated national R&D budget and lack of suitable criteria for making global R&D budget decisions hinders effective use of federal dollars. The report notes that priority-setting within agency missions is adequate and that a pluralistic approach to budgeting has been a strength of the U.S. system. In three classes of activity, however, special attention is needed: (1) initiatives contributing to the science base, (2) initiatives tied to presidential or congressional directives, and (3) major "megascience" projects slated for rapid growth or large pieces of the budget.

—*Risk Assessment in the Federal Government: Managing the Process.* Washington, D.C.: National Academy Press, 1983.

National Institutes of Health. *Setting Priorities at the National Institutes of Health* . Washington, D.C.: Department of Health and Human Services, September 1997.

NIH's Working Group on Priority Setting provides a description of the way that the NIH set's priorities. According to the Group, the NIH provides funding to programs by 1) responding to public health needs 2) following a stringent peer review system and 3) diversifying its research portfolio to include a variety of research. Input into which research programs NIH will pursue depends on a the advise of a variety of actors from the extramural science community to Congress and the Administration.

National Institutes of Health. *NCRR. A Catalyst for Discovery. A Plan for the National Center for Research Resources 1998-2003.* Bethesda, MD: Office of Science Policy, NCRR/NIH, 1998.

National Science Board, "Government Funding of Scientific Research," working paper, Washington, D.C.: U.S. Government Printing Office, NSB-97-186, 1997.

The NSB report calls for mandatory priority setting and coordination of federal R&D. Report provides a follow up to its

1997 announcement that NSB would play a larger role in setting national S&T priorities and policy. Separate House and Senate science policy efforts are also described under the FY1999 budget section.

— "Overview: Science and Technology in Transition to the 21st Century," in *Science and Engineering Indic*ators, Washington, D.C.: National Science Foundation, 1998.

National Aeronautics and Space Administration. "NASA Performance Plan Fiscal Year 1999." Washington, DC: U.S. Government Printing Office, February 1999.

This GPRA document describes performance measures for FY99 Budget activities.

National Science Foundation. "FY1999 GPRA Performance Plan", Washington, DC: National Science Foundation, January 1999.

— GPRA Strategic Plan FY1997-FY2003. Washington, DC: National Science Foundation, September 1997.

National Science and Technology Council. *National Nanotechnology Initiative: Leading to the Next Industrial Revolution.* February 2000.

— *Strategic Planning Document – Transportation R&D. National Science and Technology Council* (NSTC) 1995 Strategic Planning Documents, March, 1995.

This summary report of Federal transportation research and development priorities was prepared for the National Science and Technology Council (NSTC) by the NSTC Interagency Coordinating Committee on Transportation R&D and the Office of Science and Technology Policy. The strategic plan reflects the initial efforts of the Committee to assess Federal research and to develop long-term R&D programs integrated across agencies in specific transportation-related areas of common interest. It is based primarily on materials developed by the subcommittees and working groups, working within the framework established by the full committee in its Strategic Budget Guidance report presented to NSTC in April, 1994.

The summary report was compiled from subcommittee submissions by staff of DOT's Volpe National Transportation Systems Center under the direction of Noah Rifkin, Executive Secretary of the Committee and DOT Director of Technology Deployment and by the White House Office of Science and Technology Policy. The subcommittee report contains extensive additional detail concerning agency programs, goals, issues and resources. Efforts of the Committee in 1994, summarized in this document, focused on identification of perceived R&D gaps and opportunities. They provide the foundation for generation in 1995 of a detailed and comprehensive description of Federal transportation R&D goals, plans, measures, budgets and priorities, including active coordination with other NSTC Committees.

—*1998 Annual Report*, Washington, D.C.: National Science and Technology Council Program Office, 1998.

—-*1997 Annual Report*, Washington, D.C.: National Science and Technology Council Program Office, 1997.

Office of Technology Assessment, *Federally Funded Research: Decisions for a Decade*, Washington, D.C.: U.S. Government Printing Office, OTA-SET-490, May 1991.

This study suggests that the criteria used to set priorities for various areas of research lack explicit guidelines, particularly at the highest levels of allocation, leading to widely varying criteria and outcomes. OTA also commented that the lack of a mechanism for evaluating the total research portfolio of the federal government in terms of progress toward many national objectives results in S&T being only loosely tied to needs. Finally, the federal S&T enterprise should seek to include criteria beyond scientific merit and mission relevance when judging the worth of a research program. The report calls for OSTP to disclose the criteria by which federal S&T priorities are set.

President's Committee of Advisors on Science and Technology, Review of the Proposed National Nanotechnology Initiative, November 1999.

— Letter to President, 6 December 1996.

— PCAST Fusion Review Panel, The U.S. Program of Fusion Energy Research and Development, 11 July 1995.

Popper, Steven W., "Policy Perspectives on Measuring the Economic and Social Benefits of Fundamental Science," RAND MR-1130-STPI. Santa Monica, CA: RAND, September 1999.

Press, Frank, "Criteria for the Choice of Federal Support," *AAAS Science and Technology Policy Yearbook 1996/1997*, Washington D.C.: American Association for the Advancement of Science, 1997, pp. 171-178.

Frank Press, chair of the committee that published a report entitled Allocating Federal Funds for Science and Technology, builds upon and reacts to ideas put forth in the report. The articles states that we need to make the idea of a federal science and technology budget a reality, one that not only contains budget numbers and definitions but also provides a process for upgrading the S&T portfolios of agencies by forcing trade-offs. Appropriations for this budget can be debated within a new subcommittee created for the specific purpose of evaluating the FS&T budget. This type of structure, however, has come under criticism for several reasons (1) it might make the FS&T budget vulnerable during times of budget deficits, (2) it may result in a decrease in the overall budget pool for S&T, and (3) it may create conflict within the science community to increase the budget instead of complying with constrictions, and (4) because the NAS report is itself viewed biased in favor of federal labs and universities.

Robinson, David Z., "Think Twice before Overhauling Federal Budgeting," *AAAS Science and Technology Policy Yearbook 1996/1997,* Washington D.C.: American Association for the Advancement of Science, 1997, pp. 217–224.

This article disagrees with the ideas proposed in the NAS report, Allocating Federal Funds for Science and Technology, calling an FS&T budget structure conceptually and practically wrong. Robinson continues to state that trade-offs should not be made between categories of FS&T investment but between S&T and other expenditures within a federal agency. He continues to argue that mechanisms are already in place to review specific areas of R&D duplication. Robinson recommends that, instead, policymakers should determine the appropriate level of support by linking FS&T programs to national goals while making trade-offs between current and future needs.

Saunders, Kenneth V. *et al.*, *Priority-Setting and Strategic Sourcing in the Naval Research, Development, and Technology Infrastructure.* Santa Monica, CA: RAND, 1995.

This report suggests ways in which the Dept. of the Navy might realize more value from its increasingly constrained research, development, and technology (RD&T) dollars. The study was motivated by the Navy's immediate policy needs in connection with the 1995 round of Base Realignment and Closure (BRAC) and its longer-term need to make the best use of its resources. Suggestions are presented in three parts. First, the authors develop and apply a framework for setting funding priorities in the Naval RD&T infrastructure. Second, the authors discuss alternative RD&T procurement arrangements that are seeing increasing use in the private sector and that have been used in various parts of the government. These are commonly called "smart buying," but the authors use the term" strategic sourcing." Third, the authors present a speculative combination of the priority-setting and strategic-sourcing considerations of the first two parts. Using a reinterpretation of the orthogonal plot developed earlier in the report, it suggests a way to help determine which parts of the Naval RD&T infrastructure are best suited for alternative procurement arrangements. It also suggests a way to determine which facilities might be involved.

Science and Government Report, Mar. 1, 1997.

The Vice President for Research at the University of Michigan, proposed a high-level public/governmental commission to assess "`the rationale for investments in research' by...governments, industry and universities...the division of labor among academic, industrial and government laboratories; criteria for setting levels of R&D support, and the implications of current long-term spending projections for research."

Shapley, Willis H., *The Budget Process and R&D.* Washington, D.C.: Carnegie Commission on Science, Technology, and Government, April 1992.

This report describes and discusses the federal budget process with a focus on R&D. Shapley proposes and addresses several concerns that have arisen in creating a federal R&D, including (1) setting priorities and achieving balance, (2) the use of budget data, (3) the stability and continuity of the current budget process, and (4) the fragmentation of R&D in the budget review process in OMB and Congress. Shapley states that (1) R&D funding for programs should not be pitted against each other but rather against the overall federal budget; (2) a comprehensive comparable databank on R&D budgets should be established, as proposed in a 1988 report of the Senate Budget Committee; (3) a partial rather than immediate implementation of a two-year appropriation cycle is more politically saleable and (4) subcommittee hearings for R&D should not be done by a separate committee, because this could make R&D agencies more vulnerable to arbitrary reductions. Finally, Shapley states that there is a significant shortfall in the R&D budget in meeting important needs and grasping important opportunities. The report states that the nature of R&D makes it a necessity to increase funding in certain S&T areas to keep pace with advances; however, this is difficult to accomplish in a deficit-ridden budget.

Smith, Philip M., and Michael McGeary, "Don't Look Back: Science Funding for the Future," *Issues in Science and Technology Online*, Spring 1997.

This article stresses that evolving national priorities and budget constraints call for a new approach to federal spending. Corroborating the NAS report, Allocating Federal Funds for S&T, the article calls for the development and use of a federal S&T budget. It calls on the OMB and OSTP to implement an annual FS&T analysis as a part of the normal budget review. The authors state that using this analysis would help the most productive programs under a tight budget while strengthening the case for making larger investments in R&D.

Teich, Albert, "Choosing Among Disciplines," *AAAS Science and Technology Policy Yearbook 1991*, Washington, D.C.: American Association for the Advancement of Science, 1991, pp. 41-45

Teich discusses the conflicting perceptions that have arisen as a result of priority-setting discussions. The article addresses (1) who should do the priority setting, (2) who would use the results and how, and (3) what the outcomes of the process would be. The articles also states that despite the concerns that have arisen, the budget process would benefit from the change. Furthermore, incorporating priority-setting methods based on technological merit, scientific merit and social merit would greatly improve the process.

The Government Performance and Results Act, P.L. 101-189 and P.L. 100-456

Require the Department of Defense (DOD) and the Office of Science and Technology Policy (OSTP) to identify priorities for critical dual-use technologies for national security and economic prosperity.

Thomas, Eleanor. Strategic Planning at the National Science Foundation. Arlington, VA: National Science Foundation, July 1996.

U.S. Congress, The Senate FY1999 VA/HUD/Independent Agencies Appropriations Report, Washington, DC: Congressional Printing Office, 1999.

The Senate FY1999 report called on NSF to identify quantifiable goals for research. The appropriations act, P.L. 105-276, gave OSTP and OMB authority to seek the NAS study, as in S. 2217 (in the 105th Congress), but did not include the related provisions.

— House Majority Leader Report. Washington, DC: Congressional Printing Office, 1999.

The House Majority Leader issued a report "rating" the FY1999 plans. The House Committee on Government Reform and Oversight and the Senate Committee on Governmental Affairs held hearings on implementation.

— House of Representatives, Committee on Science, *Unlocking Our Future: Toward a New National Science Policy*. Washington, DC: Congressional Printing Office, 1998.

Recognizing that choices about funding R&D must be made in the face of limited federal resources, this report says that priorities for spending on science and engineering will have to be set. Because of its unique role, fundamental research in a broad spectrum of scientific disciplines, administered through the peer review process, should receive priority for federal spending. A "sharp eye" should be kept on possible downstream applications for such research. Mission-oriented research should continue to fund highly relevant, noncommercial, long-term research.

— *The Government Performance and Results Act*, P.L. 103-62. Washington, DC: U.S. Congress Printing Office, 1993.

GRPA requires agencies to define long-term goals, set specific annual performance targets, and report annually on performance. Legislative language noted the difficulty of quantitatively measuring some program outputs and allows alternatives.

Vonortas, Nicholas S., "Prioritizing Long-Term, Strategic R&D Projects in the Public Sector," Washington, D.C. Center for International Science and Technology Policy & Department of Economics, The George Washington University, paper submitted for the National Science and Technology Council's Summit, Innovation: Federal Policy for the New Millennium, to be held on November 30 and December 1, 1999.

This paper proposes a technology-option approach in choosing long-term, risky R&D investments. According to the author, this methodology explicitly accounts for the uncertainty of long-term R&D and captures the value in terms of opening up opportunities for private-sector investment in new technologies. The paper also argues that this approach has the potential of eliminating R&D political battles by focusing on strategic R&D project selections.

Wells, William G., Jr., *Working with Congress: A Practical Guide for Scientists and Engineers*, Washington, D.C.: American Association for the Advancement of Science, 1992.

This book introduces scientists and engineers to the congressional appropriations process.

SRI International

Symposium on International Models of Budget Coordination and Priority Setting for S&T

H. Roberts Coward
Science and Technology Policy Program
SRI International

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Final Report, August 2000

Prepared for the
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Ad hoc Committee on Strategic Policy Issues and Task Force on International Issues in Science and Engineering

Science and Technology Policy Program

This Final Report on a Symposium on "International Models of Budget Coordination and Priority Setting for S&T," held for the National Science Board in November 1999, consists of two volumes. The first consists primarily of an Executive Summary of important themes and issues raised during the two-day Symposium, a brief review of relevant literature, and other background materials on S&T policy-making in the countries represented at the time of the Symposium, prepared by SRI International. (A number of changes have occurred in several countries since that time.) The second volume consists of materials derived from individual presentations representing seven individual countries plus a speaker from the European Commissions Directorate-General for Research. The views expressed in this Report are the responsibility of SRI International and the individual speakers at the Symposium and do not necessarily reflect the views of the National Science Foundation/National Science Board nor of the governments of the individual speakers.

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EXECUTIVE SUMMARY

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SUMMARY OF THEMES

INTRODUCTION

This Executive Summary takes the form of a summary of important themes raised during Symposium discussion in the course of presentations by representatives of seven countries, as well as the European Union, on the ways in which their governments and national systems dealt with establishing R&D budget priorities. There were, as organized here, a number of common themes, although not always shared by all of the countries. Given the range of methods and variety of ways in which they have been applied, it is difficult to identify "best practices" at this point in time.

One of the purposes of the Symposium was to identify unique models, methodologies, or other approaches that had been both successful in a particular country and had potential for being applied in the United States. Again, what is unique is hard to identify, and it is even harder at this point to determine what the few identifiably unique features do for the country involved. The budget making processes described had more in common than they did any strikingly individual characteristics – there seemed to be a spread of overlapping approaches. The two most interesting features that suggest possible emergence of unique efforts are both under development. They are:

1) South Korea's first iteration of a budget process that places great emphasis on broad evaluations of both programs and research fields that is expected to alter the content of research activity in various fields, if not the funding distribution of fields broadly described;

2) The remarkable number of major reorganizations taking place as countries grapple with the questions posed by the Symposium and focus on the centrality of a country's S&T infrastructure to its competitiveness in the global economy.

Methods and Techniques Employed

Consensus, if something of an abstraction, was the strongest theme in terms of the method employed to reach a set of priorities and budget figures. The countries participating were generally pluralistic in the number of government agencies involved in the process, although there were varying degrees of centralization. Korea and Brazil have central "Science Ministries," although they share S&T policy responsibilities with other ministries such as education. Germany, France, and Sweden have combined education and science into a single ministry – although France recently reversed the combination. Britain and Japan currently have several ministries involved and rely more on coordinating councils or other mechanisms to bridge departmental differences. However, S&T policy is concentrated in the Department of Trade and Industry (DTI) in Britain, and an ongoing reorganization in Japan will result in greater concentration in a new Ministry of Education and Science (MEXT).[1] All have sought to develop a ***process*** that brings together the stake-holders in S&T policy to build a consensus that can be implemented in the concrete terms of budget allocations. One participant summarized it as "more process than strong methods."

A target percentage of GDP (Gross Expenditure on R&D [GERD] divided by GDP) invested in R&D is often a goal and probably the strongest theme in terms of a concrete objective. This goes as high as Korea's recently set target of 5% by 2003, but is more commonly in the vicinity of the roughly 2-3% spent in the United States, Sweden, Germany and Britain, although the impact of defense R&D on GERD varies considerably among these countries. Developing countries, such as Brazil, are far from attaining such numbers due to a significant extent to the lack of industry support for R&D.

"Foresight" techniques, typically involving multiple panels engaged in "Delphi" approaches to identify promising areas of research are prominent as a method, but limited in their influence. Britain, Germany and Japan have formal iterative processes that use this approach as an input for science policy, but all emphasize that it is part of the dialogue and process, not an algorithm to set policy. Brazil is embarking on a first round.

Increased productivity and "quality" are earnestly sought through a variety of monitoring and evaluation techniques, commonly including publication and citation counts as part of the assessment of outputs. There is widespread concern that a high quality research base is not adequately contributing to innovation and competitiveness (especially, Britain, Brazil, and the EU as a whole). Much of this concern is based on patent indicators, but patents enjoy a mixed reputation as indicators of productivity and commercialization, particularly given the small proportion of those granted that are actually exploited.

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[1] Although Japan is joining the countries that have joined higher education and science in ministries, France recently reversed its earlier joining of the two to split the ministry back into the education and research components. What seemed to be a secular trend now seems to have become a fragmented one.

While "benchmarking" can play a role, few countries specifically use comparisons with other countries as yardsticks for setting their own priorities. Germany's comparison efforts involve carefully constructed "missions" to examine how a field is being handled in other countries and may lead to contrasting approaches to the field at home. A trend toward involving foreign scientists (Sweden for some time, France, Korea, and Japan moving in this direction) in evaluation exercises or advisory committees implies more foreign benchmark inputs, but these are diffuse, not direct priority influences.

Benchmarking and indicators play a role, but there is strong resistance on the part of the research community to the application of the types of rigorous analysis that typify the rigor of their own tools-of-the-trade to the process of evaluation, monitoring, and priority setting.

"Strategic plans" are required at a variety of levels. These may be individual fields within an organizing bridge institution (e.g., France's plans within the CNRS), particular laboratories or university units, or departments at the ministerial level. Combined with iterative review at higher levels, these tend to serve as further input to the dialogue, not deterministic road maps.

Social Goals

Social goals guide S&T policy. They represent higher level priorities that set parameters for most other policies, including S&T priorities. They can be highly generic, such as "quality of life" (e.g., France) or may derive from specific national circumstances (e.g., the need to address problems of aging populations, especially in Japan and Britain). The EU deliberately poses priority questions in social rather than scientific terms in an effort to force articulation of choices in terms more clearly understood by the political process and politicians involved. Indeed, a shift toward social goals for R&D is now a major emphasis within the Commission (Caracostas and Muldur, 1998). OECD data are being classified, among other categories, into social goals.

Social aspects of the S&T enterprise itself are important factors in shaping priorities and policies. Some countries face an aging population of researchers that must be renewed with younger people, while most industrialized nations, including the United States, Japan, and most European countries, face systemic problems of aging populations that impinge on R&D priorities. This poses recruitment and mobility problems that must be addressed with both policies and funding – for recruitment, education, training, career startups, and the like.

Human Resources

Countries face imbalances in human resources for S&T. France produces more Ph.D.s than it can absorb, but most countries are having trouble attracting enough students to science, math, and engineering to meet their needs. France tends to lose Ph.D. graduates to overseas post-doctoral opportunities, which do not exist at home, and has trouble attracting them back. Koreans and Brazilians who train abroad, however, generally return home. Korea, in particular, has made significant efforts to develop attractive professional opportunities to bring scientists and engineers back.

Nearly all countries face problems in providing for industry's needs. The education system often produces the wrong kind of product, products at the wrong time in terms of career choice, products that cannot be absorbed, or have only limited potential career trajectories in industry.

Specific Fields

The countries show considerable unanimity in terms of specific fields that show up in their listings of priorities. These include:

- Genomic and post-genome bioscience;
- Other bioscience and biotechnologies;
- Information technology and telecommunications;
- Advanced materials science.

The emergence of nanotechnology, one of NSF's specific priority areas, was cited as a priority by several other countries. On the other hand, there was a sense that countries are ill-served if priorities squeeze certain fields, such as nuclear energy, down to the point where there is no capacity to gear up the country's capabilities if there are changes that require rebuilding.

Involving Industry

Non-industrial research institutions are commonly being encouraged to interact with industry through the use of various mechanisms, including tax credits for industrial research, cost-sharing arrangements for contract arrangements with universities and other laboratories, and forced budget targets for funding from external contracts.

Industry is provided with a "place at the table" in important councils influencing overall budgets and processes behind these (Britain's involvement of industry in the Research Councils and the Research Assessment Exercise, a variety of German initiatives for regional development efforts, as well as its more traditional involvement through the Fraunhofer Gesselschaft).

The importance of "relevance," "exploitability," and "spin-off companies" are frequent factors that influence budget priorities. However, clear, functional and fundable mechanisms to effect these desirable ends are not well understood.

There are some promising experiments ongoing, but countries emulate each other in funding various mechanisms to encourage interaction of industry with the non-industrial R&D community. These include centers patterned after NSF's ERC program and establishment of technology parks. The degree to which such initiatives affect budgets for particular fields is not clear. For example, a regional initiative in Germany is said to have stimulated substantial amounts of basic research as well as the desired regional biotechnology focus, but no data were available concerning on its impact on *bund* [federal] and *laender* ["state"] funding. It was noted that the very common theme of the need to assist "small and medium enterprises" (SMEs) seemed less visible at the Symposium than it typically is in many forums on S&T funding and innovation.

Role of the Research Community

Although the community is ultimately the recipient of the funding allocated through the R&D budget process, the community is also intimately involved in the setting of priorities through a variety of mechanisms in which it participates. These include:

- consultative roles in the overall budget process (e.g., Korea and Japan);
- competitive peer review allocation of funds provided to research councils (Britain, Sweden, Brazil's PADCT program, the EU's Framework), or independent funding institutions (Germany's DfG or France's CNRS and INSERM) once an overall budget is set;
- a high degree of autonomy in peer reviewed funding allocations within programmatic parameters;
- international peer review as part of the monitoring and evaluation process (France and Sweden, with Japan and Korea implementing such a process).

International Cooperation

International cooperation is on the increase by all empirical measures available. This is partially a function of the information revolution, in which virtual laboratories come into existence via the internet (and are encouraged both intra- and internationally by governments). It is also related to various megaprojects that cannot be sustained by a single country. Finally, the tradition of PI cooperation across national boundaries, in addition to being facilitated by the internet, continues to be supported by various nationally funded programs.

EU cooperation in S&T, especially its five-year Framework programs, is the third largest category of expenditure for the EU (although a quite distant third at 4-5% of the budget). The Framework program is worked out in extensive democratic consultation among the members, and is intended to complement, not substitute for national R&D. It does not conduct basic research (a national function), nor does it do applied research that addresses specific national problems.

Several countries (Sweden, France, Korea, and the EU) have programs intended to support S&T in developing countries. They include training grants, fellowships, exchanges, and some research funding, but are not major investments.

For industrialized countries, mega-projects and selected fields that are not viable on a national basis are the primary motivation for formal cooperation. Mega-projects include the international space station and some large-scale astronomical instruments, as well as cooperation on the human genome effort. The latter, however, is now seen as a prologue to an important new priority area that, itself, has nearly attained completion under ongoing national or industrial efforts. Meanwhile, Germany has, effectively, ceded all of its fusion energy research to the program administered by the EU.

I. Background and Objective of the Symposium

In its Working paper on *Government Funding of Scientific Research* (NSB-97-186), the National Science Board identified a national interest in "some form of 'comprehensive' and 'coherent' coordination of Federally-financed research," which would first require the development of "guidelines to provide clear direction on setting priorities within the Federal research budget." The Strategic Plan of the National Science Board states that: "...the development of an intellectually well founded and broadly accepted methodology for setting priorities across fields of science and engineering is a prerequisite for a coherent and comprehensive Federal allocation process for research." In recent years, stakeholders in both the Administration and the Congress have urged better coordination for the Federal budget for research, and the development of a methodology for priority setting across fields of science and agencies to further that objective.

As a consequence, the *Ad Hoc* Committee on Strategic Science and Engineering Policy Issues, acting in concert with the NSB Task Force on International Issues in Science and Engineering, undertook the arrangement of a "Symposium on International Models for S&T Budget Coordination and Priority Setting. The objective of the Symposium and its background preparations was to provide a review of the relevant literature, as well as hearing the views of a number of active R&D policy makers across a variety of internationally representative countries. The Symposium was held on November 19-20, 1999, in the NSF Board Room, where Committee and Task Force members heard presentations and engaged in dialogue with representatives of seven countries and one international entity, the European Union, on the topic.

The participating countries were selected on the basis of the following criteria:

- Does the country have sufficient experience to serve as a model?
- Does the methodology or aspects of it have potential for application to the U.S.?
- Is the methodology sufficiently different from others to offer special lessons?
- Does inclusion of the country need to be considered for political or representational reasons?
- Are excellent presenters/spokespersons for the country's system likely to be available?
- Does the system for government support of research appear to contribute positively to the scientific and engineering strength of the country?

The countries selected for participation included three large European nations – France, Germany, and the United Kingdom, as well as the European Union, which is a major sponsor of research. Two other industrialized nations, Japan, a major Asian industrial nation, and Sweden, a smaller but scientifically highly advanced country were included. One "Newly Industrialized Economy," the Republic of Korea, and Brazil, the largest scientific presence in Latin America, filled out the roster of participants.

SRI International, a contractor, was asked to identify as potential speakers individuals with roles like that of the U.S. science advisor: in government; intimately knowledgeable about how the process works; and at a high level. Normally that would not be the minister of science or equivalent, who are often in office very briefly and who cannot speak from extensive experience about their government's funding for R&D. Countries vary, but the individuals invited were all at a high level in government and very knowledgeable about how the research budget is actually developed.

The following framework for presentations was provided to the invited guests of the National Science Board:

Guidelines for Speakers

Your presentation should be limited to approximately 25 minutes, followed by a question and answer period with members of the Committee and the Task Force.

Board members will have received a briefing document on your country's R&D budget process prior to the Symposium, outlining the general structure and procedures for your national system as they are described in the published literature. We will be supplying you with a copy of that background document. We ask, therefore, that you assume that Board members are familiar with the background material and address your presentation to the following questions, as appropriate to your national system.

Questions to Address on R&D Budget Coordination and Priority Setting

Q1: What needs are targeted in your country's R&D budget—government, in dustry, society as a whole? International cooperative R&D for activities such as megascience projects, major instrumentation, databases, or human resource capacity building?

Q2: In planning for your government's budget for R&D, how are appropriate levels of support determined for the budget as a whole and for programs and activities funded through the R&D budget?

Q3: Are the research activities of other countries a significant factor in developing your R&D budget? How do you evaluate research supported by other countries? Which other countries? How is this information used in your budgeting activities?

Q4: Please describe the priority setting process in detail.

- What are the key organizations or individuals involved in the priority setting process for the R&D budget? What measures or indicators, models or methodologies are employed in weighing alternative prospects for government investments in R&D?
- How is the priority setting process applied to government support for ***fundamental*** research?

Q5: How do you determine that an area is worth pursuing as a national priority, or whether it should be left to other countries? How do you decide which areas should be pursued collaboratively?

- Do multinational themes, e.g. in the environment, enter into the process for determining national priorities for R&D?
- How are international collaborations supported: direct funding, in-kind contributions, other means?
- Does your government make any specific or special provisions for scientific cooperation with developing countries? If so, are these handled out of your science ministry or equivalent or some other part of the government?

Q6: What mechanisms and tools do you use to assess the benefits of scientific research and development and its contributions to your society?

- What units of analysis are used in measuring the return on government investment? e.g., government agencies and their programs; nongovernmental organizations or sectors that receive government support, such as universities or research institutes; scientific fields of study/disciplines; industrial research and technologies; occupational groups; geographic/political units?

Q7: What data are available for measuring R&D investments and returns on your country's investments? Are these sources available in published or electronic form?

II. Overview of International Practices on Priority Setting and Budget Coordination for S&T

A. Introduction

There is worldwide interest, from highly industrialized nations to the least developed countries and international institutions, such as the World Bank and the European Community, in setting priorities for investment in science and technology. Competitiveness in the emerging global economy, the importance of "knowledge-based societies" and their ability to engage in "created comparative advantage," as well as the desire to address a variety of social problems and values drives this interest.

Despite this, there is very little literature that deals with general models or methodologies for priority setting and budget coordination processes in science and technology (S&T) policy. Most of what can be gleaned from the literature relates to the experiments, some of which are quite similar or represent imitation, by individual countries in their efforts to improve the efficiency of their public S&T investments, as well as the conversion of new knowledge into innovation.[1] The bibliography and review in this report are therefore primarily organized by country.

Perhaps one of the most telling aspects of the Symposium was the eagerness of the invited representatives of other countries to learn from the United States. Representatives of systems that would generally be perceived as more centralized seemed to believe that the U.S. system, long perceived to be decentralized, rich, and in no need of setting priorities, had something to teach other countries.

[1] Although it, too, is based on a series of seven country case studies, SRI International's Science and Public Policy Program is currently working on the final stages of a cross-national comparison project entitled "Strategic Plans and Priorities for Science and Technology: Indicators for a Comparative International Assessment" funded by an NSF grant from the Division of Science Resources Studies. The results should be available some time during the first half of 2001.

B. General Literature

To refer to them as "models" or "methodologies" overstates the amount of rigor involved, but four approaches to priority setting and budget coordination stand out as being widely tried and/or accepted across a number of countries. These are:

- GDP targets
- "Foresight" models or techniques;
- Links to industry;
- Monitoring and evaluation; and
- High level coordination.

Briefly on each of these topics, the United States is roughly at the norm for industrialized countries of 3% of Gross Domestic Product (GDP) as Gross Expenditure on Research and Development (GERD, in terms of OECD Frascati Manual terminology), and on an upward trend. With respect to "Foresight" techniques, the United States has engaged in "Critical Technology" exercises, but Foresight has smacked of "picking winners," anathema to Republicans, not an objective for Democrats. Monitoring and evaluation has not been strongly supported in the United States until the Government Performance and Results Act began to put pressures on agencies for metrics on their performance and outputs. The U.S. science policy apparatus has never had nor been hospitable to a centralized or highly coordinated approach.

The U.S. GERD figure has generally been high, although it has not been a specific target, and, until the end of the Cold War, was strongly affected by the high proportion of defense spending involved. This is now declining, but remains high with respect to international comparisons. The GERD figure has been rising in recent years despite the fact that R&D spending (aside from defense, which is now under pressure) is part of the discretionary budget. Although a limited proportion of the federal budget falls into this category, there has been bipartisan support for R&D spending. Both the Reagan and Clinton administrations have been kind to the research community in their budgets, and Congress has followed their lead – indeed, seized the reins in providing increases in funding for health research. At 2.9% in 1999, the GERD percentage is expected to continue rising given the Administration's boost in R&D budgets for FY2001 and an expected continuing increase in industry's investment in R&D, which accounts for about 70% of GERD in the United States[1].

Internationally, while the U.S. figure has run close to that of Japan and somewhat above the figures for the aggregate of OECD and European Union countries (see the graph in the Swedish presentation, Volume II of this report), Sweden is higher – currently about 4%. The figure for developing countries is generally

[1] Payson, Steven. "R&D as a Percentage of GDP Continues Upward Climb." Division of Science Resources Studies Data Brief. National Science Foundation, 1999.

less than 1%, often despite higher goals. However, India has recently increased its emphasis on science and technology and announced a goal of 2% by 200**, while South Korea, a Newly Industrializing[ed] Economy (NIE) has announced goals of 3% by 2001 and a very high 5% by 2003 (see South Korean presentation, Vol. II).

In terms of policy, GERD is a composite figure over which most governments have only partial control. Governments invest in both civilian and defense research, but the level at which industry chooses to invest in R&D is an independent decision. Government policies, such as the U.S. R&D tax credit and similar programs in other countries, can seek to influence private decision-making. The degree to which such policies actually increase private R&D spending, or even end up paying for R&D investment that would have been done without the incentive is not clear. While private firms typically account for a high percentage of GERD in industrial countries, there is not a tradition in many developing countries of industryial spending on R&D, and many have great difficulty in stimulating such investment. The public R&D budget in Brazil, for example, cannot be greatly expanded at this point and the country's desire to get GERD over 1% is largely dependent on stimulating investment by industry (Brazilian Symposium presentation).

Finally, GERD figures say little about the distribution of funds among fields. Aside from the need to judge the impact of defense spending, the figures primarily suggest the overall emphasis given to R&D by the country as a whole. Breakdown figures by field provided by the OECD are quite broad, and do not provide numbers within the category of "natural and biological sciences" (OECD – Basic Indicators). The greatest current significance of GERD in terms of policy is the broad consensus that the figure should be at least 3% of GDP and that most countries are struggling with ways of increasing their current figure.

Foresight is the approach that can most accurately be referred to as a "model," although its practice varies sufficiently from one country to another that the term "model" is compromised. Both countries and corporations have long attempted to assess prospective developments in science and technology through efforts such as the identification of "critical technologies" and technology forecasting. Distinctions came to be made between "forecasting" (assigning some probability to a specific anticipated outcome), and "Foresight":

"... the ***process*** [emphasis added] involved in systematically attempting to look into the longer-term future of science, technology, the economy and society with the aim of identifying the areas of strategic research and the emerging generic technologies likely to yield the greatest economic and social benefits." *—(Martin, 1995, p.140).*

"Process" is emphasized because Foresight exercises are increasingly treated as part of a national dialogue on national priorities, whereas they initially were viewed, optimistically, as producing clearer road maps to priorities than most countries are willing treat them now. This was reinforced by presentations at the Symposium.

However, what have come to be referred to as “Research Foresight” techniques in a formal sense began to be developed toward the “notional” internationally utilized methods during the 1980s, initially in Canada and the United Kingdom, then in the Netherlands (Elzinga, 1983; Irvine and Martin, 1989; Martin, 1995). The most significant dynamic behind this was the influence of the Thatcher Government in Britain, with its budget cutting and “value for money” outlook. Indeed, the impact of the Thatcher approach to S&T policy and the generally stringent budgetary circumstances of many countries during the 1980s had an impact across many countries (Cozzens *et. al.*, 1990).

The U.K. policy process includes what is probably the most formal incorporation of Foresight in a national policy process (Georghiou, 1996, add). Aspects of the approach are widespread, and there have been an number of cooperative efforts among nations, (Martin, 1995; and German presentation, Vol. II).

Monitoring and evaluation of research programs has long been a factor in S&T policy. Monitoring in the sense of periodic reports and audits is a fact of government support, but site visits to large projects, especially, raise this process to new levels of intensity. Moreover, most U.S. evaluation efforts have been embodied in the *ex ante* process of peer/merit review prior to an award. Although *post hoc* evaluations have been sanctioned, even with funding guidelines of about 2%, by Congress, such guidelines have been more honored in the breach than the observance. The passage of GPRA has concentrated minds mightly on the construction of metrics or the development of alternative, usually qualitative, methods to meet the need for evaluating outputs of government programs, including research.

The evaluation of research programs is a difficult and complex process – and it is generally quite costly. A multidimensional approach is usually called for, one that may include literature review, bibliometrics, expert panels, surveys and focus groups, and site visits. Smaller countries, with Sweden a pioneer (e.g., NFR, September 1997), and larger countries, now increasingly, are bringing foreign scientists into evaluation processes (e.g., Ciba Foundation, 1989; Anderson and Fears, 1996). Thus, this practice is becoming more widespread and is often a formalized part of national priority and budget setting practices (see the Symposium presentations from the United Kingdom and the Republic of Korea, as well as Sweden in Volume II of this report).

GENERAL BIBLIOGRAPHY

Caracostas, Paraskevas, and U. Muldur. *Society, The Endless Frontier.* (European Commission, Brussels, Belgium, 1998).

Commission of the European Communities. *Research and Technological Development Activities of the European Union: 1999 Annual Report.* (Commission of the European Communities, Brussels, Belgium, 1999).

Cozzens, Susan E., P. Healey, A. Rip, and J. Ziman, (ed.) *The Research System in Transition.* (Kluwer Academic Publishers, Dordrecht, The Netherlands, 1990).

De Marchi, M. et al. *Changing Structure, Organisation and Nature of PSR Systems*. (CNR, Rome, 1998).

Ergas, Henry. "Does Technology Policy Matter?" *Technology and Global Industry: Companies and Nations in the World Economy.* B. Guile and H. Brooks, (ed.) (National Academy Press, Washington DC, 1987, pp. 191-245).

European Union Research Organisations Heads of Research Councils. *(report). Reports on the Strengths and Weaknesses of European Science.* (European Union Research Organisations Heads of Research Councils, 1997).

Evered, David and S. Harnett (ed.) *The Evaluation of Scientific Research.* Ciba Foundation Conference. (John Wiley & Sons, Chichester, UK, 1989).

Future National Research Policies Within the Industrialized Nations, (Report of a Symposium). Government-University-Industry Research Roundtable. (National Academy Press, Washington DC, 1992).

Indicators and Data for European Analysis (IDEA). (further information available at: http://www.step.no/Projectarea/IDEA/papers.htm)

Intangible Assets (publication list) available at: http://www.oecd.org/dsti/sti/industry/indcomp/prod/intang.htm

Koenig, Robert. "E.U. Grabs Food Safety by the Horns". *Science*. (Vol. 287, Jan. 21, 2000, pp. 403-405).

Koenig, Robert. "Research Chief Wants to Make Science Matter". *Science*. (Vol. 286, Dec. 10, 1999, pp. 2065-2067).

Koenig, Robert. "Tough Questions Greet New Research Chief". *Science*. (Vol. 285, Sep. 17, 1999, pp. 1829-1830).

Martin, Ben R. "Foresight in Science and Technology". *Technology Analysis & Strategic Management*. (Vol. 7, No. 2, 1995, pp. 139-168).

Martin, Ben R., and J. Irvine. *Research Foresight: Priority Setting in Science.* (Pinter Publishers, London, 1989).

Martin, Ben R., and J. Irvine. *Research Foresight: Creating the Future.* (Netherlands Ministry of Education and Science, The Hague, 1989).

McLoughlin, Glenn J. *International Science and Technology: A Comparative Study*. (report, prepared at the request of the Committee on Science, House of Representatives). 1997.

Measuring and Reporting Intellectual Capital: Experience, Issues and Prospects. (meeting symposium). (further information available at: http://www.oecd.org/dsti/sti/industry/indcomp/act/Ams-conf/symposium.htm).

Munoz, E., M.J. Santesmases, and J. Espinosa de los Monteros. *European Comparison of Public Research Systems. The Dynamics of PSR in Spain and Portugal.* (IESA, CSIC, Madrid, 1999).

Nelson, Richard R. (ed.) *National Innovation Systems: A Comparative Analysis.* (Oxford University Press, New York, NY, 1993).

Policy Evaluation in Innovation and Technology. (further information available at: http://www.oecd.org/dsti/sti/stat-ana/prod/evaluation.htm).

Research and Technological Development policy (RTD), (further information available at http://europa.eu.int/pol/rd/index_en.htm)

Rothwell, Roy and W. Zegveld. *Industrial Innovation and Public Policy: Preparing for the 1980s and the 1990s.* (Greenwood Press, Westport, Connecticut, 1981).

Senker, J. *Changing Structure, Organisation and Nature of European PSR Systems. Synthesis Report.* (SPRU, University of Sussex, Brighton, 1999).

Senker, J. et al. *European Comparison of Public Research Systems*. (SPRU, University of Sussex, Brighton, 1999).

Schimank, U., and M. Winnes. *Public Sector Research in Europe: Comparative Case Studies on the Organisation of Human Genetics Research*. (Max Planck Institute for the Study of Societies, Koln, March 1999)

Science, Technology and Innovation (working papers) available at: http://www.oecd.org/dsti/sti/s_t/inte/prod/online.htm.

Skoie, H. *The Scandinavian Countries and their Systems of Public Research.* (NIFU, Oslo, 1998).

Vig, Norman J., and H. Paschen, (ed.) *Parliaments and Technology: The Development of Technology Assessment in Europe.* (State University Press, Ithaca, NY, 1999).

Ziegler, J. Nicholas. *Governing Ideas: Strategies for Innovation in France and Germany.* (Cornell University Press, Ithaca, NY, 1997).

III. National Case Studies

A. Introduction

This section represents individual case studies based on selections from the current literature available on each of the countries (and the European Union) represented at the Symposium. For each country a short narrative brief was developed, intended to distill the S&T policy-making process – summarizing where it has been, methodologies or models that have influenced its practices, and the importance that each country ascribes to efforts to set priorities, especially among scientific fields. In each case, the narrative piece describes the stakeholders, government policy-making and funding organization, and the research performing infrastructure of the country.

Wherever possible, a summary organization chart was either taken from the available literature or compiled based on available descriptions of circumstances in late 1999. The objective was to provide an overall chart showing institutional stakeholders in the S&T policy and budget process for each country. Efforts were made to present the organization charts in a particular manner, showing:

1) S&T policy-making and budget setting organizations at the top;
2) Research funding organizations in the middle; and
3) Research performing organizations at the bottom.

Preparations for the Symposium made it clear that many countries share an interest in priority-setting models and that there are changes afoot in many countries in an effort to improve the process of priority setting and budget coordination. The NSB's interest in the topic is most timely, with the invited foreign participants as interested in learning from the United States as in imparting their own countries' experiences.

Many countries are in the process of making major changes in their S&T system, and presentations at the Symposium often displayed changed organizations or contemplated changes to their institutions that already have or will make the charts shown here obsolete.

The most difficult task in considering the ways in which countries set priorities is to discern the balance between “top-down” efforts of governmental agencies to establish priority fields and allocate funding accordingly, and the more traditional “bottom-up” way in which individual fields develop their own priorities and seek the funding that has increasingly come from national governments, especially for basic science. Each of the countries participating in the Symposium has developed ways in which the government and funding agencies seek to influence priorities in order to develop what are perceived as desirable areas of scientific strengths that will typically contribute to competitiveness in the global economy and other social goals, including health and defense. For mission agencies, in fact, the relationship of their research portfolio to such goals, particularly competitiveness, has become an important new dimension of funding criteria. Even the most proactive national efforts, however, have been limited in the degree to which they have attempted to divert their national scientific research effort from a strong reliance on the evolving interests and ideas of their scientific community.

B. Federal Republic of Germany

The system for the conduct of scientific research in Germany is pluralistic and decentralized, with a diversity of performer organizations, each of which has a relatively large degree of autonomy in selecting, managing and directing its own research activities. German public R&D financing has a strong regional dimension. The central government (*Bund*) and the states (*Laender)* accounted for a ratio of 53% - 47% of public R&D expenditures in 1995. Laender funding is concentrated on university research, whereas Bund financial support focuses more on non-university, industrial, and international research. However, with both the Bund and Laender providing funds for R&D, the system of funding is a dual one. It operates quite differently, however, from the dual system in place in the United Kingdom. Rather than two channels of funding from the central government flowing downward toward research institutions, the German system provides two lateral flows of funding – one through Bund and one through Laender mechanisms, a reflection of its more pluralistic character. The system has been complicated in recent years by the effort to assimilate the research infrastructure of the former East Germany, generally patterned on the Soviet Academy model.

The Science Council is a science policy advisory body set up in 1957 to advise the German federal and state governments on all matters of higher education and research policy. Its main function is to prepare reports and recommendations on the structural development of higher educational institutions and research institutes, taking into account the cultural and socio-economic needs of the country. Although the Science Council can only give non-binding statements and recommendations, it has had a decisive influence on the development of the research system, since its resolutions are based on voluntary agreed compromises among the central actors in the system.

The Federal Ministry of Education and Research (BMBF or BMB+F) was established in 1994 by a fusion of the former Ministry for Education and Science and the Ministry for Research and Technology. The Ministry has the overall responsibility for higher education and S&T policy of the central government. BMBF accounts for about 65% of federal expenditures on R&D. BMBF also administers most of the federal priority programs in selected areas of research and technology. Other Ministries that have a significant role in R&D financing are the Ministry of Defense and the Ministry of Economics. (See the flow chart in Vol. II, Ch. II, p.8.)

The German Research Association (Deutsche Forschungsgemeinschaft – DFG) provides most of the outside support for basic research in the universities. The DFG is a non-governmental organization, even though its funds are received almost entirely from the federal and state governments. There are in addition some 900 foundations offering private sources of support for higher education and research. Among the largest of these are the Robert Bosch Foundation, the Humboldt Foundation, and the Volkswagen Foundation.

R&D performer organizations in Germany include higher educational establishments, government research laboratories and institutes, and industry. Included within the higher educational sector are a variety of forms of institutions, including comprehensive universities, technical colleges/universities, colleges of education, art colleges, and polytechnics. As in the United States, the universities in Germany are the major performers of basic research, both in volume of effort and number of research personnel. Also as in the United States, research is closely coupled with teaching in the universities (the “Humboldt principle”). Essentially all higher educational institutions are state institutions financed by the Laender governments, with some additional federal support. However, higher educational institutions in Germany are *by law* independent bodies that are free from any government domination.

Government research organizations include research institutes subordinate to independent coordinating organizations, such as the Max Planck Society and the Fraunhofer Society, which receive all or a substantial portion of their funding from the federal and state governments; “big science” national laboratories supported by the BMBF; and research establishments subordinate the federal or Lnder ministries or both (federal-state research institutes, usually referred to as the “Blue List”). Blue List institutions are independent research institutions whose functions are of national importance and in the interest of national science policy. The Hermann von Helmholtz Association of National Research Centers (HGF) employs multidisciplinary research and development capacities for the solution of long-terms problems entailing economic risk. The national research centers are legally independent bodies, and have a fair amount of autonomy to determine their research priorities. However, the federal government (mainly BMBF) provides guidelines, and BMBF’s priority programs influence the process of priority setting with each of the centers. Delphi approaches to Foresight techniques have been practiced, but their results have largely been handed over to the scientific community, which is left to respond as it will. An effort to broaden and democratize the Foresight exercises known as "Futur" is now underway (see the materials in Vol. II, Ch. II).

BIBLIOGRAPHY: GERMANY

Abramson, H.N., J. Encarnacao, P. P. Reid, and U. Schmoch (ed.) *Technology Transfer Systems in the United States and Germany*. (National Academy Press, Washington, DC, 1997).

Balzs, Katalin. *Strategic Priority-Setting in Science: Germany*. (draft). Report for SRI International (Arlington, VA, January 1999).

Federal Ministry of Education and Research (BMBF). *Basic and Structural Data 1998/99*. (part of a series). (BMBF, Bonn, 1998).

Federal Ministry of Education and Research (BMBF). *Facts and Figures 1998* (abridged). (part of a series). (BMBF, Bonn, 1998).

Federal Ministry of Education and Research (BMBF). *Faktenbericht 1998*. (part of a series). (BMBF, Bonn, 1998).

Federal Ministry of Education and Research (BMBF). *Numerical Barometer 1998/99*. (part of a series). (BMBF, Bonn, 1998).

Federal Ministry of Education and Research (BMBF). *Report of the Federal Government on Research* (abridged). (part of a series). (BMBF, Bonn, 1996).

Germany's Technological Performance: updated and expanded report. (Summary). (BMBF, 1996).

Koenig, Robert. "10 Years After the Wall, Science Revives in Eastern Germany." *Science*. (**Vol. 286**, Oct. 15, 1999, pp. 392-395).

Krull, W., and F. Meyer-Krahmer, (ed.) *Science and Technology in Germany.* (Cartermill, London, 1996).

Lundvall, Bengt-Ake. (ed.) *National Systems of Innovation.* (Pinter Publishers, London, 1992).

Martin, Ben R. and J. Irvine. "Research Foresight in Germany" in: *Research Foresight Priority-Setting in Science.* (1989).

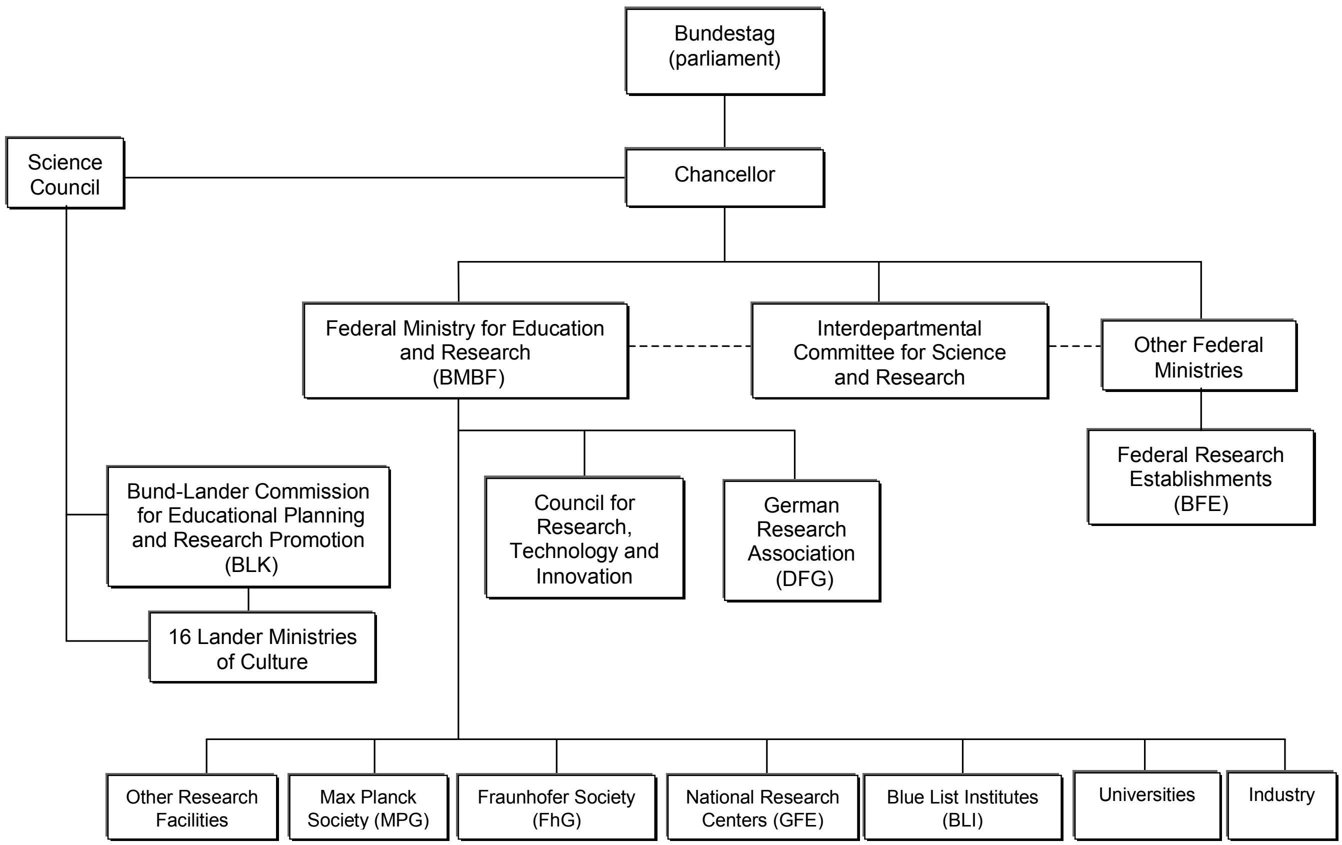
Parthier, Benno. *Transformation of Science After the Reunification of Germany*. (Web site). (http://biology.anu.edu.au/rsbsweb/conferences/NatConf/Natpap11.html)

Reger, G., and S. Kuhlman. *European Technology Policy in Germany.* Physica Verlag 1995.

Schimank, U. and M. Winnes. *National Report. Federal Republic of Germany*. (Max-Planck-Institut fur Gesellschaft, Koln, 1999).

www.aif.de
www.bmbf.de
www.fhg.de
www.mpg.de

Germany


Bundestag (parliament)
Chancellor
Science Council
Federal Ministry for Education and Research (BMBF)
Interdepartmental Committee for Science and Research
Other Federal Ministries
Federal Research Establishments (BFE)
Bund-Lander Commission for Educational Planning and Research Promotion (BLK)
Council for Research, Technology and Innovation
German Research Association (DFG)
16 Lander Ministries of Culture
Other Research Facilities
Max Planck Society (MPG)
Fraunhofer Society (FhG)
National Research Centers (GFE)
Blue List Institutes (BLI)
Universities
Industry

C. FRANCE

Advance background materials from the literature concerning the process of budgeting and priority setting in France are limited and largely in French. This section relies heavily on a report by Laredo and de Laat (1998), part of a European Commission funded cross-national study. It also draws upon the official annual publication on French S&T policy, the so-called "*Jaune*" (because of its yellow covers: *Projet de loi de finances pour 2000: Etat de la recherche et du developpement technologique*). See Vol. II, Ch. III for further materials in the Symposium presentation on France).

The S&T system is unusual in that there are no research councils on the model of most European countries, but the system of R&D funding bears some resemblance to the duality of the British system. Research is partially funded through the university system, which has enjoyed a growing research capability in recent years, and partially through government research institutions, in particular, the Centre National de Recherche Scientific (CNRS) and a set of "Organismes Public de Recherche" (OPRs). The CNRS has had both independent labs and ones collocated with universities, with which it is now strengthening its ties. The CNRS focuses on fundamental research, while the OPRs are sectorally oriented and more focused on applied research in areas such as atomic energy (CEA), health and medical research (INSERM), agriculture (INRA), etc.

The system has been undergoing a series of important changes. Some are strategic and long term in terms of efforts to join the academic to other research sectors and focus public research on innovation-oriented activities. At the same time, until very recently, the Ministry of National Education and Research and Technology, formed by merging two ministries in 1995, was the major policy maker for S&T, as well as higher education. However, in March of 2000, a ministerial shakeup dismissed the Minister and restored the separation between Research and Higher Education as separate Ministries. A number of the previous minister's aggressive efforts at reforming the system were successfully implemented, some held in abeyance, and some stand to be reversed by the new Minister (Balter, *Science,* January 28, 2000 *).*

Laredo and de Laat (1998) note that there have been four characteristics of French research policy historically:

1) until recently, the military represented about 30% of publicly funded research, now declining;

2) deriving from the 1960s, a series of "Grands Programmes," designed to support "national champion" corporations' competitiveness in advanced technological areas, which have in recent years declined in public funding to the point of no longer being major factors due to privatization and other factors;

3) the large share of research conducted by the mission-oriented OPRs; and

4) a separation of fundamental research conducted by the CNRS from that combined with education in the universities.

The declining support of military and industrial-oriented research, has been accompanied by increases in the staffing of both the CNRS and INSERM, as well as in the universities. Recent policies have sought to develop closer ties and a convergence of research strategies between the universities and the OPRs, including the CNRS and INSERM, as well an increased ties to industry.

The public research sector in France is quite large. There are nearly 70,000 FTE research scientists and engineers in a total of about 135,000 FTE research staff, third after Germany and the UK. The annual expenditure on GERD in 1998 was about 188 billion French francs, representing about 2.2% of GDP – a decline from nearly 2.5% in 1993. Just over half comes from industry, which has been increasing its investment in R&D. The military's share of research funding has dropped from about 30% to 20% and now ranks behind public funding of basic research.

The Grands Programmes represented public expenditures on research in several industrial sectors aimed at assisting French corporations like GS Thomson, Alcatel, Airbus, or Aerospatiale to attain global competitiveness. Historically five in number (space, electronuclear, civil aeronautics, computer and electronics, and telecommunications), they initially represented costs in the billions of French francs, but movement away from public support in these areas and the substitution of internal industry funds for research in these sectors has reduced most of them to a shadow of their former selves. Privatization of France Telecom and the rise of Alcatel has placed most telecommunications research in the private sector, and most of the others are much reduced in funding. Only the Space Programme has remained "grand" with some increases in its budget.

The OPRs – mission-oriented agencies with laboratories active in specific fields – have remained stable over the past two decades. As noted, these dominate publicly funded research, and their mission-orientation means that their funds are devoted to problem areas more than fields of research. However, a number of them have been considered since a 1982 law, "public establishments of a scientific and technological character," and are required to conduct a core of scientific research. The CNRS and INSERM are generally considered separately and are more oriented toward funding basic research. Like the CNRS, the OPRs are subject to peer-review evaluation procedures, and there has been a rapid increase in their collaboration with industry in the form of contract research. In this sense, they have shifted from their original links with various professions to the development of close ties to industrial sectors.

The CNRS was established after World War II as the functional equivalent of the OPRs for the conduct of basic research. One effect of this was that, despite the fact that research was part of the mission of the universities, very little was carried on in that sector until recently. From the mid-sixties, "associated," or "mixed" research units developed in which personnel worked in joint units where CNRS, INSERM, and university personnel collaborated in laboratories, frequently co-located with the involved universities. More recently, Ministerial policy has been to reinforce these ties with four-year contracts, certification of the joint institutes by the CNRS, and quadrennial evaluations by the CNRS. In 1997, university FTE research personnel outnumbered those of the CNRS and INSERM combined by about three-to-one. The Grand Ecoles, too, have been drawn into the web of research partners being forged in France.

Priority setting and budget coordination are also affected by the institution of several new instruments for managing the public research sector, which are referred to under the rubric of "managing at a distance". These include:

1) broader contractualization arrangements between the government and research organizations than have been thus far mentioned;
2) "forward looks" by the executive and parliament;
3) institualization of evaluation; and
4) the influence of upcoming social issues on research policy.

Contractualization is a relatively recently phenomenon that began in 1994 and includes the OPRs, as well as the universities. With the OPRs, the contracts focus on ensuring that government objectives are taken into account in planning the research program of the organization. The contracts are monitored on an annual basis. For universities, where nearly 90% of research funding falls under contracts, the objective is the unification of education and research, as well as relating efforts to strategic aspects of national R&D policy. The contracts often involve the CNRS as well as the Ministry and university. The research institutions commit to the support of policy goals such quality control, evaluation, and doctoral training changes, while the government provides new permanent positions and the organization's budgetary allotment.

France, with its tradition of "plannification" and "La prospective," was a major source of the development of future studies and "Foresight" techniques. Under Minister Chevenement in the 1980s a national process of dialogue, first regional, a *Colloque National Recherche et Technologie"* in early 1982 was held to develop a national strategy for S&T. Similar exercises, although not so prominent nor influential, have been held in the 1990s. Delphi techniques and cooperative efforts with Germany and Japan have been included in Foresight exercises. A considerable portion of these national consultations focused on harnessing the nation's R&D efforts to industrial innovation, especially in support of small and medium enterprises (SMEs). Efforts to support SMEs and others have also taken the form of establishing "Technopoles" (technology park-like campuses). The French Parliament established an office roughly comparable to the now defunct U.S. Congress' Office of Technology Assessment. Under this, the Parliament refused to accept a scientific consensus concerning nuclear waste disposal and insisted on research on three alternatives.

Three approaches have been taken to evaluation. A National Committee for evaluation (CNE) supervises the evaluation of university research. It reports directly to the President (i.e., is independent of the Ministry) and currently evaluates more than twenty universities per year, and plays a role in the renewal of contractualization agreements. The National Committee for Evaluation of Research (CNER) is similarly independent and evaluates the OPRs, national programs, and such R&D related policies as research tax credits. Its approach has emphasized the use of evaluative techniques individually adapted to the program under consideration.

Both the CNE and the CNER have been the subject of criticism in national dialogues, while their existence has seemed to lead to a parallel proactive effort by the OPRs to establish their own evaluation techniques. These tend to focus on long term strategies, rather the *post hoc* evaluation of previous efforts. The evolution of such efforts has increasingly focused on the contractualization agreements.

Both for evaluation, policy studies, and the production of science and engineering indicators, France has established an "Observatoire des Sciences et des Techniques," which publishes the French equivalent of the U.S. *Science and Engineering Indicators* report (L'Observatoire…, 2000) in addition to a variety of individual studies not unlike NSF/SRS, but as an independent institution and with a larger original research component. The "Observatory" concept is generating interest in other countries and several imitative institutions have been set up in Latin America.

The poor handling of new major social problems such as AIDS and the accompanying scandal over the problem of contaminated blood supplies has recently led to greater emphasis and the establishment of mechanisms to grapple with the public interest on emerging areas of research. The mechanisms are not yet well established, but it is intended that once such issues have been examined in this venue, they be handed back to the traditional research organizations with appropriate recommendations concerning the nation's research agenda. Special efforts are being made to support the humanities and social sciences.

Two other factors influence priority setting are the emergence of emphasis on deconcentration and devolution of efforts and powers to regions away from the Paris area, and the influence of the European Community as a source of funding under the Framework program. A general policy of empowering regional areas in France through the redistribution of important national institutions has had its impact on the S&T infrastructure, with many research positions having been transferred to more peripheral institutions. Efforts are also being made to provide for greater institutional mobility among French researchers and support for young researchers (see French presentation, Vol. II, Ch. III).

Bibliography: France

Balter, Michael. "Street Protests Keep the Pressure on Allegre". *Science*. (**Vol. 287**, Feb. 4, 2000, p. 781).

Balter, Michael. "New Chief Promises Renewal and Openness". *Science*. (**Vol. 287**, Jan. 28, 2000, p. 567).

Commasariat General du Plan, *Recherche et innovation: la France dans la competition mondiale* (Paris: La Documentation Francaise, October 1999).

Laredo, P. and B. de Laat. *Changing Structures, Organisation and Nature of PSR* [Public Sector Research] *Systems: FRANCE*, Synthesis Report (Paris: Centre de Sociologie de l'Innovation, Ecole Nationale Superieure des Mines de Paris, June 1998)

OST, *Science & Technologie – Indicateurs Edition 2000* Rapport de l'Observatoire de Science et des Techniques (Paris: Editions ECONOMICA, 2000).

Projet de Loi de Finances Pour 2000: Etat de la Recherche et du Developpement Technologique. (annual report of the Government of France to Parliament). (Paris Imprimerie Nationale, Paris, 1999).

D. Japan

The Japanese S&T policy structure and process is undergoing significant change. The system has been divided in responsibility among the two primary Ministries, the Ministry for Education ("Monbusho"), and the Ministry for Trade and Industry ("MITI") with a coordinating agency, the Office of Science and Technology (OST), as well as a Science and Technology Agency (STA) within the Prime Minister's Office. NISTEP, the National Institute for Science and Technology Policy, is a research organization affiliated with the STA. The system will become more centralized in 2001.

Recent policy has been based on a White Paper published in 1996, "Science and Technology Basic Plan," due to be updated in 2001. The Basic Plan concluded that greater concentration on basic research capabilities and expanded visibility of Japanese research in the international research community was a major priority. The plan pledged significant support for the development of university research infrastructure, including instrumentation, as well as human resource support for researchers. In terms of priority fields, however, the Basic Plan largely anticipated that the agenda would be set by individual researchers, who were to be afforded a variety of funding sources, primarily aimed at "diversifying" the research base. More recent reports have examined the Japanese R&D system in terms of a number of international indicators, and generally concluded that Japan still needs to pursue the goals of increasing its basic research base and visibility, but needs also to relate its S&T efforts to social and economic goals.

More recently, S&T have come to be viewed as one of the potentially important contributions to efforts to stimulate and modernize the faltering Japanese economy. In addition to providing added funding to the overall S&T budget, special "Millennial Projects" in information technology, genetics, and environmental studies will be injected into the system. How these funds will be distributed in terms of specific institutions and projects is not yet clear, but they will tilt priorities in the direction of the indicated fields, especially since the R&D budget is not expected to rise much further otherwise (see Vol. II, Ch. IV).

In terms of the S&T policy organization, important changes will be phased in over the coming year. These will raise the visibility and coordination of S&T policy at the highest level of government. The position of the Minister for Science and Technology Policy, formally a junior minister, is now in flux, but is expected to become part of a Cabinet Office level operation that will include the Office of Science and Technology, and a more broadly empowered "General Science and Technology Council." More monitoring and evaluation are anticipated, and various working groups are involved in developing a new "basic plan."

BIBLIOGRAPHY: JAPAN

Council for Science and Technology. (Web site) http://www.sta.go.jp/shimon/98cs.html (1998).

National Science Foundation, Tokyo Regional Office. *A Radical Restructuring of Japan's Postwar S&T Policy and Institutions: The Politics and Rationality of the New Century*. (National Science Foundation, Tokyo, 2000)

National Science Foundation, Tokyo Regional Office. *Follow-up of the Science and Technology Basic Plan: An Interim Summary*. (National Science Foundation, Tokyo, 2000)

NISTEP. (Web site). (http://www.nistep.go.jp/top-e.html).

Normile, Dennis. (in Science Scope) "Arima Out." *Science*. (Vol. 286, Oct. 8, 1999, p. 209).

Normile, Dennis. "Blue Laser Pioneer Seeks Greener Pastures." *Science*. (Vol. 287, Feb. 4, 2000, p. 782).

Science and Technology Basic Plan. (Web site) http://www.sta.go.jp/policy/kihonkeikaku/basicplan.html (1996).

Tanaka, Yoichi, and R. Hirasawa. "Features of Policy-Making Processes in Japan's Council for Science and Technology". *Research Policy*. (Vol. 25, 1996, pp. 999-1011).

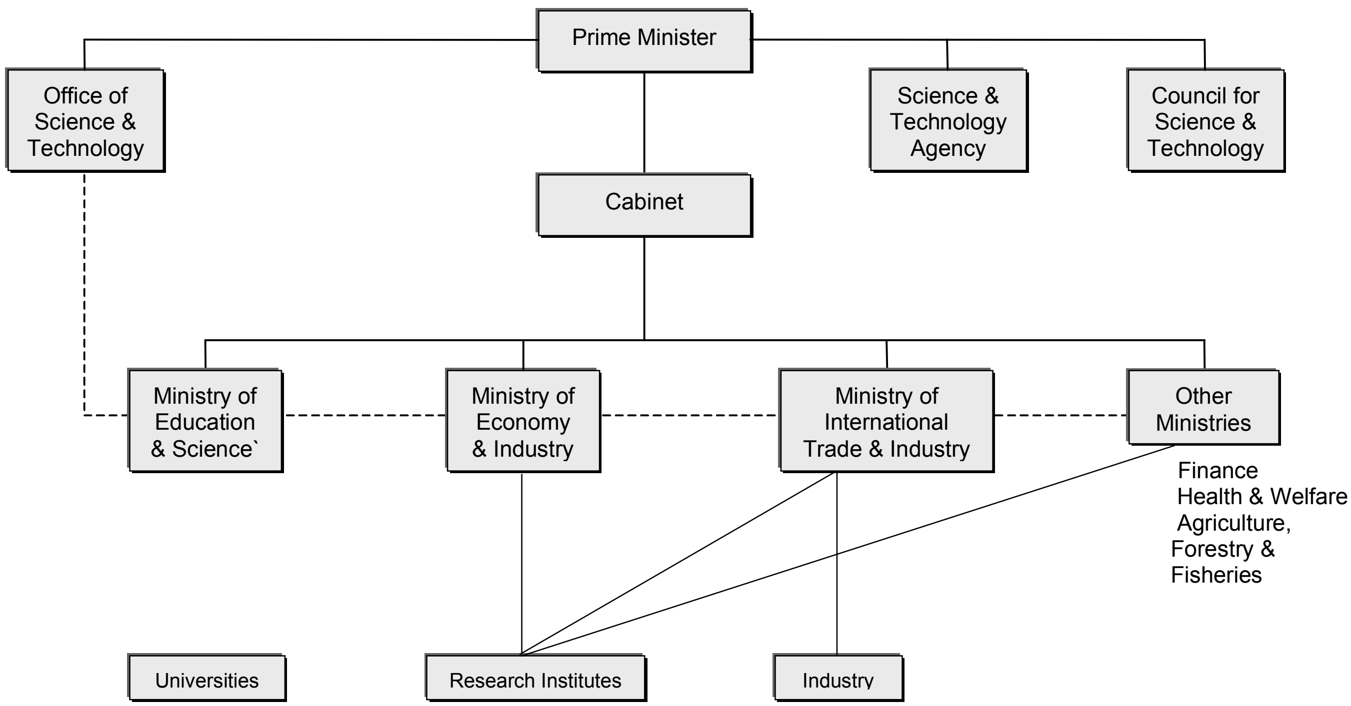
Tanaka, Yoichi. "Effect of Japan's Advisory Councils on Science and Technology Policy". *Technology in Science*. (Vol. 17, No. 2, 1995, pp. 159-173).

Tanaka, Yoichi. "Science and Technology Policy-Making Process in the Japanese Government". *International Journal of Technology Management*. (Vol. 8, No. 6/7/8, 1993, pp. 676-686).

The Science and Technology Resources of Japan: A Comparison with the United States. (Web site) (http://www.nsf.gov/sbe/srs/nsf97324/hilites.htm).

White Paper on Science and Technology. (Web site) http://www.sta.go.jp/policy/seisaku/e9806_5.html (1998).

JAPAN


Prime Minister
Office of Science & Technology
Science & Technology Agency
Council for Science & Technology
Cabinet
Ministry of Education & Science`
Ministry of Economy & Industry
Ministry of International Trade & Industry
Other Ministries
Finance
Health & Welfare
Agriculture, Forestry & Fisheries
Universities
Research Institutes
Industry

E. European Union

The European Union (EU) is not a single national state, but an organization in which individual member countries are involved in decision processes that, among other activities, attempt to establish a number of research programs that are funded by the budget of its governing body. It does not fund basic research for the sake of simply advancing knowledge, but seeks to shape its research programs around two main objectives:

1) strengthening the S&T base of European industry in support of its international competitiveness; and
2) promoting research that supports other EU policies.

The EU's "Research and Technological Development" initiative is primarily operated by The Research DG, but includes other Directorates-General concerned with Enterprise, Agriculture, Transport and Energy, Information Society, and Fisheries, as well as the Joint Research Centers.All the EU's research effort is channeled through the "Framework" program, which is operated over a four-to-five year cycle involving an extensive democratic dialogue among the members in establishing its content and budget. The 5th Framework Program was adopted by the European Parliament and Council at the end of 1998 and covers the years from 1998 to 2002, with a budget of nearly 15 billion Euro. While the program definition process may include some specific field-oriented actions (e.g., the Parliament expanded the budget proposed for the 5th Program, but indicated a strong desire that increased resources be devoted to the life sciences), the overall structural categories of the program's budget are expressed largely in terms of social and economic goals. These include, for example:

- Quality of life and management of living resources;
- User-friendly information society;
- Competitive and sustainable growth; and
- Energy, environment and sustainable development.[1]

In addition to these "thematic" programs, "horizontal" programs deal with the international role of community research, promoting innovation and participation of SMEs, and improving the socio-economic knowledge base. Euratom research falls within the purview of the Framework Program, and particular attention is paid to involving "less favored" regions in the program. Collaboration includes that among Community members, as well as other international collaboration; in particular, the central and eastern European candidates for EU membership as well as Norway, Iceland, Liechtenstein, Israel, Cyprus, and, shortly, Switzerland are all fully paid-up participants in the Frameowrk Program. Most of the Framework program and other scientific activities are administered by the Research DG, with the Information Society DG an important part of the program, although, as noted above, other Directorates-Generals are involved.Once programs are established and approved by the European Parliament, most priority setting takes place within the process of issuing calls for proposals for each program and the evaluation of the resulting proposals. To summarize, it appears that the EU process sets priorities on broad themes in an elaborate consultative process among its members and interested sectors, or stake-holders, and seeks to match these with competitively evaluated proposals that are largely concentrated in applied areas of research.

Organization Chart

No official R&D organization chart is available for the European Union. Web site http://europa.org provides a directory listing Directorates and subdivisions with personnel, but no chart. is included. The major R&D activity, the Framework Program is largely developed and primarily carried out by the Directorate of Research, although the DG for the Information Society and other Directorates-General administers some of the research programs.

Bibliography: European Union

European Commission. *Second European Report on S&T Indicators 1997*. December 1997. EUR 17639.

"Towards a European research area." Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions. January 2000.

www.europa.eu.int

www.cordis.lu

F. United Kingdom

The United Kingdom (UK) has served as one of the leaders in efforts to develop models to assist in the development of government priorities for S&T. As early as the 1960s, the autonomy of government-funded researchers began to be questioned and the need for prioritization raised due to the high cost of research. By the 1970s, there was considerable concern about the ways in which government institutions impacted the balance between basic, "strategic," and applied research. By the next decade under the Thatcher government, the issues began to focus on two areas: 1) the need for the nation to be selective in its efforts due to limited resources, including setting priorities in basic research fields; and 2) the need to couple Britain's basic research effort, perceived to be of excellent quality, to the country's increasingly obvious problems of economic competitiveness, more broadly related to other social goals, especially health. The relationship of mission agency research to economic competitiveness became an important part of each agency's definition of its portfolio. Accountability and evaluation became important themes. A government agency report in 1986, *Exploitable Areas of Science*, led to efforts to develop mechanisms for "technology foresight," that are now formally imbedded in the UK policy process.

A major landmark in the development of the current system was the 1993 White Paper, *Realizing our potential: a strategy for science, engineering and technology*. The result of a massive consultation effort across the stakeholders in the S&T system, the White Paper sought a reversal of the Rothschild approach adopted in the 1970s, in which government departments pursued their individual interests and left industry and academia largely alone on the matter of priorities. The White Paper recommended that partnerships among government, academic, and industrial science be pursued and subjected to tests of relevance to two national objectives: wealth creation and the quality of life – with the emphasis on the former.

The main points of the 1993 White Paper were:

1) The need for priorities;
2) The need to better engage industrial firms;
3) The need for better co-ordination of government funded S&T; and
4) Reorganization of the research councils.

Priorities, it was argued, needed to be set because countries could not sustain a presence in all of the growing fields of science, and could include a healthy dose of relevance without compromising excellence. With a keen eye on economic competitiveness, the Paper sought more effective innovation on the part of industry, especially through greater awareness and access to S&T, to be facilitated by a national Technology Foresight Program that jointly involved industry and the S&E communities. Government coordination was to be improved through the annual publication of a "*Forward Look*" that would provide the industrial and research communities with a current statement of government strategy. This would be prepared by the Office of Science and Technology (OST, moved from the Cabinet Office into DTI in 1995). Also responsible for the Technology Foresight Program and the research councils, OST represents the primary central coordinating agency, working with individual departments and with the ministerial advisory Committee on Science and Technology (CST). Some adjustments in field allocation were made, and the resulting six councils' activities coordinated by a Director-General of the Research Councils under the OST.

The British S&T system remains highly pluralistic, both in terms of the number of institutions and government agencies involved, and the variety of sources of public funding. In particular, funding for basic and "strategic" science is dual in character, flowing partially from the Department of Education and Employment, which provides funds for infrastructure, faculty salaries, and a core research agenda via the Higher Education Funding Councils (HEFCs) – under devolution, one for each part of the UK: England, Scotland, Wales, and Northern Ireland. The HEFCs provide funding to the universities for two purposes: teaching and research. While the universities enjoy a high degree of autonomy in spending the HEFC research funds, their programs are subject to a periodic Research Assessment Exercise (RAE) that examines work in particular fields. In terms of models developed by the United Kingdom, there appears to be increased international interest in the HEFC's REA exercises (Hagman, *Science*, January 28, 2000).

The second flow stems from the Department of Trade and Industry (DTI) through the Research Councils. For these funds, university researchers engage in competitive, merit-reviewed bidding for funds that come from the science budget of DTI/OST. The Councils' impact on priorities is relatively subtle: they are mission-oriented in the sense that they are field-defined, and can "nudge" applicants for funding in terms of program definitions. However, the governing boards include representatives from industry, giving them a voice in shaping programs. Each research council includes "users" – including industry – on its governing board (the Council), and is involved in various efforts to align their agendas and make them accessible to user interests. Otherwise, they have each developed their own operational approaches to priority setting.

Other funds may be derived from various government departments, industry, foundations, and international organizations. Thus, both the HEFCs and the Research Councils are in a position to influence priorities among fields, while there is a strong effort to link S&T to economic competitiveness through the influence of mission agencies and national exercises such as the Foresight exercise. Overall, in response to the Thatcher Government's concern that British science lacked clear direction and measures of achievement, a number of mechanisms have been embedded in the policy process that aim at setting objectives, coordinating policies, and evaluating outcomes.

The outcome of these efforts is reflected by the complex organization chart shown for the United Kingdom. Formally, UK science policy has several high level agencies with input at the highest levels of government. Most important is the Office of Science and Technology (OST), which is officially part of the Department of Trade and Industry (DTI). It is responsible for the science budget, the direct work of the seven research councils, the Council for Science and Technology, and the Technology Foresight Steering Group. It produces an annual *Forward Look of Government Funded Science, Engineering, and Technology*.

Two of the key players in setting and coordinating the S&T budget are attached to the OST: the Chief Science Advisor, and the Director General of the Research Councils. The Transdepartmental Science and Technology Group deals with coordinating cross-departmental matters for the Science Advisor and plays an important role in developing a large picture of trends that might have an impact on priorities and budget coordination.

Since the White Paper's recommendations were implemented, there have been some minor organizational changes made aside from moving OST into DTI. The Labour Government initially placed ministerial oversight of science in the hands of the President of the Board of Trade and elevated S&T affairs from a junior minister to the level of a Minister of State. Initially responsible for both science and energy, there is now an independent Minister for Science. The Labour Government has generally moved S&T policy up in the political hierarchy and increased the visibility of the CST. Supported by OST, the CST is made up of representatives from academia, business, finance, and foundations concerned with scientific research. It provides advice on strategic policies and the overall framework of S&T in Britain, but is quite distant from priority setting among scientific fields.

BIBLIOGRAPHY: UNITED KINGDOM

Anderson, J. and R. Fears (ed.) *Valuing and evaluating: assessment of the value of R&D in creating national and corporate prosperity.* (report on a symposium). (Moller Centre, Cambridge, UK, 1996).

"Competitiveness: Forging Ahead". (HMSO, May 1995, Cm 2867).

Georghiou, Luke. "The UK Technology Foresight Programme". *Futures*. (Vol. 28, No. 4, 1996, pp. 359-377).

Hagmann, Michael. "Support Grows for British Exercise to Allocate University Funds". In article: Mervis, Jeffrey. "Graduate Educators Struggle to Grade Themselves". *Science*. (Vol. 287, Jan. 28, 2000, pp. 568-570).

Healey, Peter and H. Rothman. Strategic Priority-setting in Science: The United Kingdom. (draft). (October 1998).

HMSO. *Annual Review of Government Funded Research & Development*. (series). (HMSO, London, 1991 *et seq.*).

Office of Science and Technology. *Forward Look of Government-funded Science, Engineering and Technology.* (Department of Trade and Industry, London, 1996 *et seq.*).

Office of Science and Technology. *Science, Engineering and Technology Statistics.* (Department of Trade and Industry, London, 1998).

Office of Science and Technology. *The Future in Focus: A Summary of National Foresight Programmes.* (Office of Science and Technology, Department of Trade and Industry, London, 1997).

Office of Science and Technology. *Winning through Foresight: Report on the Whitehall Audit of the Foresight Programme.* (Department of Trade and Industry, London, 1997).

Parliamentary Office of Science and Technology. *Science Shaping the Future?* (report summary). (Parliamentary Office of Science and Technology, London, 1997).

"Realising Our Potential: A Strategy for Science, Engineering and Technology". (HMSO, May 1993, Cm 2250).

Science and Technology in the United Kingdom. (Web site). http://strategis.ic.gc.ca/ssg/bi18164e.html

Senker, J. *Changing Structure, Organisation and Nature of European PSR Systems. United Kingdom: A Report for the European Commission.* (SPRU, University of Sussex, Brighton, 1998).

The Royal Academy of Engineering. *Measuring Excellence in Engineering Research.* (The Royal Academy of Engineering, Westminster, London, 2000).

White Papers:

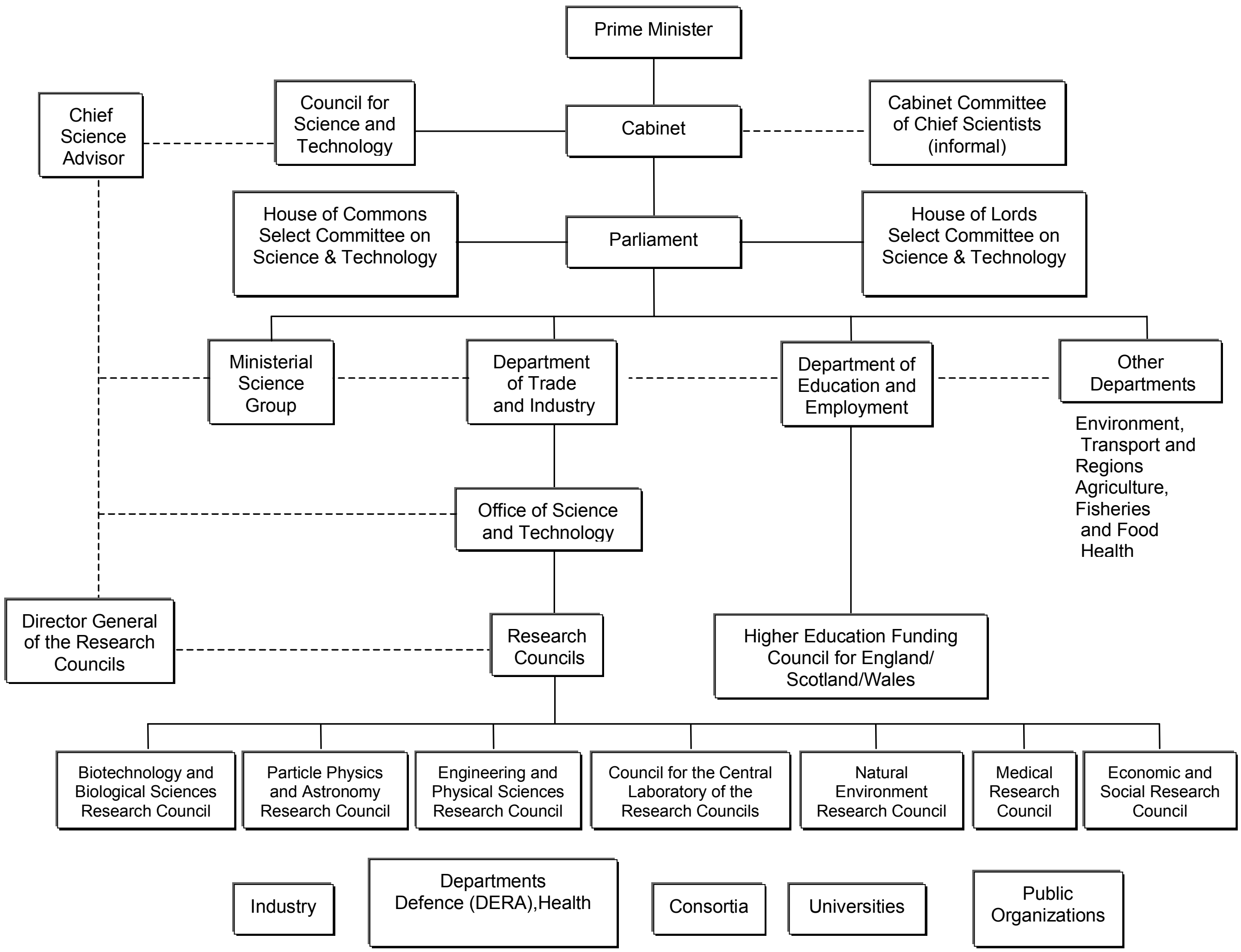
Realising Our Potential: A Strategy for Science, Engineering and Technology, Cm 2250 (London: HMSO, May 1993).

Competitiveness: Forging Ahead, Cm 2867 (London: HMSO, May 1995).

Excellence and Opportunity–A Science and Innovation Strategy for the 21st Century.(London: HMSO, 2000)

www.dti.gov.uk/scienceind/index.htm

UNITED KINGDOM



G. Republic of Korea

Like a number of countries, especially in Asia, the Korean S&T system is undergoing important changes. Some have their roots in the recognition by several countries – including Japan – that the original Japanese technology development model, with its heavy emphasis on reverse engineering and applied research, lacked the important dimension of a fundamental research base. Some time before S&T were elevated as a priority aspect of solving recent economic problems by the current government, the Koreans had funded a "Creative Research Initiative" (CRI) program intended to foster the development of a basic research culture as part of the R&D infrastructure. (Both Japan and China are involved in similar efforts.) Other ministries are involved in encouraging basic research, and efforts are being made to link industrial participation to this aspect of the research enterprise.

Prior to the 1990s, government efforts were concentrated in the Government Supported Research Institutes (GSRIs), primarily focused on individual industrial priorities. The GSRIs are subject to periodic evaluation and, in principle, have had the right to set their own priorities, although the government maintained a strong influence in consultation with industry. In the early 1990s, the Ministry of Science and Technology (MOST) initiated the "HAN Project" (Highly Advanced National Project), aimed at developing next generation technologies in a variety of high tech fields, such as semiconductor technology, nuclear reactor technology, functional bio-materials, environmental technology, advanced manufacturing system technology, and advanced materials for information, electronics and energy. Unlike the ensuing CRI program, the HAN efforts were more of a priority setting exercise in critical technologies that represented a logical follow-on to the GSRIs.

In the institutional configuration that existed until last year, the Science and Technology Policy Institute (STEPI) operated under MOST carrying out three basic functions. These included S&T policy research, support of international activities, and the distribution of research funds from the government budget in accordance with program guidelines by means that included grants, contracts, and institutional support.

Recent changes have spun off the Korea Institute of S&T Evaluation and Planning (KISTEP) from STEPI, retaining it under MOST with responsibility for research funding and R&D Evaluation. The other policy aspects of STEPI report to the office of the Prime Minister. Three advisory councils have been elevated from the level of the Prime Minister and Cabinet to the Presidential level. During the past year, KISTEP has led MOST through the first round of a comprehensively evaluative budget process that is expected, in time, to alter the content of the country's research portfolio significantly, although it is unlikely to alter greatly the distribution of funds among broad scientific fields or disciplines. A detailed description of this process is provided in Vol. II, Ch. VII.

BIBLIOGRAPHY: REPUBLIC OF KOREA

Baker, Michael. "Laid-Off Satellite Group Sets Up Shop". *Science.* (Vol. 287, Jan. 21, 2000, p. 409).

Ministry of Science and Technology. *Science and Technology in Korea.* (The Technology Cooperation Bureau, Ministry of Science and Technology, Gwacheon, Korea, 1996).

Organisation for Economic Co-operation and Development. *Reviews of National Science and Technology Policy: Republic of Korea.* (OECD, Paris, 1996).

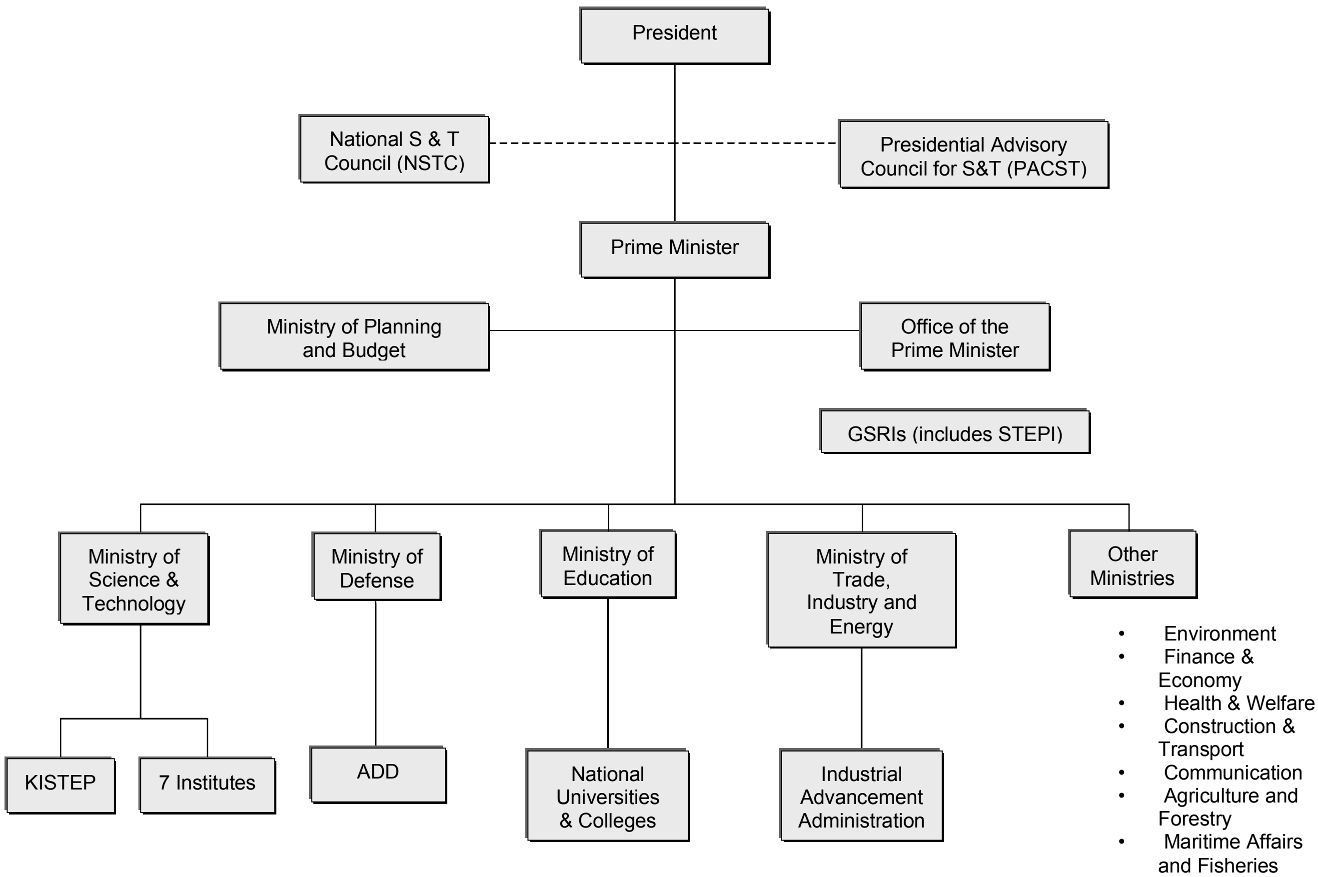
Park, Young-Il, Y. Lim, Z. Bae, and J. Lee. "Innovation in Korea". *Science and Public Policy.* (Vol. 23, April 1996, pp. 77-90).

Science and Technology Policy Institute. *Report on the Survey of Research and Development in Science and Technology.* (Ministry of S&T, Korea, 1996).

Science and Technology Policy Institute. *Review of Science and Technology Policy for Industrial Competitiveness in Korea.* (Ministry of Foreign Affairs and Association of South-East Asian Nations, Seoul, Korea, 1995).

Wilson, David and J. Wilson. *Korea: A Science and Technology Profile.* (series). (The British Council, Manchester, UK, 1996).

Korea


President
National S & T Council (NSTC)
Presidential Advisory Council for S&T (PACST)
Prime Minister
Ministry of Planning and Budget
Office of the Prime Minister
GSRIs (includes STEPI)
Ministry of Science & Technology
Ministry of Defense
Ministry of Education
Ministry of Trade, Industry and Energy
Other Ministries
KISTEP
7 Institutes
ADD
National Universities & Colleges
Industrial Advancement Administration
• Environment
• Finance & Economy
• Health & Welfare
• Construction & Transport
• Communication
• Agriculture and Forestry
• Maritime Affairs and Fisheries

H. Sweden

Sweden is a small country whose scientific community enjoys a high reputation in international science and receives a high proportion of GDP investment (3.7%). It has a tradition of international peer evaluation of scientific programs and has sought to establish various mechanisms to link research to industrial innovation. Recent years have brought a number of changes to the structure of the Swedish S&T system, and it is now on the verge of further change as the consequence of a major examination of the structure of research funding that reported about one year ago (the "Hagstrom Report"). The government is now acting on report recommendations, as outlined in Vol. II, Ch. VIII.

It is difficult to characterize the nature of priority-setting in the Swedish S&T system and its recent evolution. Although the recent report emphasizes the need to place greater emphasis on the control of a basic research agenda by the nation's scientific community, substantial autonomy already exists. Three elements of the S&T structure impinge on the perception of priority setting:

1) the evolution of an agency from what was known as STU to NUTEK;
2) the addition of a Research Council for Engineering Science; and
3) the establishment of a set of foundations that are currently very well funded, but lack a clear mission and direction from public authorities in their legislated mission to support research.

NUTEK, the Swedish National Board for Industrial and Technical Development, is the successor organization to the STU, which wielded substantial funds in aid of industrially oriented research and the transformation of basic knowledge into innovation in the 1980s. NUTEK remains a major source of funds for research in universities and other research institutions, and is technologically oriented, but appears to be less directive in its perception of its mission than was STU and includes a strong engineering and science policy studies element.

In addition, a Research Council for Engineering Sciences exists alongside the more traditional Councils for Medical Science and the Natural Sciences. The Research Councils operate primarily on the model of investigator-initiated, merit-reviewed proposals and do little in the way of imposing priorities on the research community.

The Foundations were legislated into existence by a center-right/liberal government in the early 1990s and funded by the dissolution of funds derived from an industrial profits tax, where the funds were originally intended to provide greater power to wage-earners in the trade unions. The largest of these is the "Foundation for Strategic Science," which has established a program with the goal of defining strategic areas – currently bioscience, information technology, and such other base technologies such as materials science, energy research, and food production that are of importance for Swedish industry. The considerable resources available to the Foundations provide them with substantial leverage in establishing research agendas, and the Committee's report has suggested that the foundations have an excess of political independence. The thrust of the Hagstrom Report appears to recommend increased autonomy on the part of the Swedish scientific community in terms of setting priorities. Some aspects of the government response are outlined in a document included with the Swedish presentation in Volume II.

Bibliography: Sweden

Anderson, John B., et al. *Peers on Peers: Allocation Policy and Review Procedures at the Swedish Research Council for Engineering Sciences.* (Swedish Research Council for Engineering Sciences, Stockholm, 1997).

Brennan, Max, K. Burke, S. Forsen, and T. Stadtman. *Review of the Organisation and Working Methods of the NFR.* (Swedish Natural Science Research Council, Stockholm, 1998).

Nilsson, Annika and J. Rose. "Buffeted Community Braces for More Change". *Science.* (**Vol. 282**, Nov. 20, 1999, pp. 1401-1403).

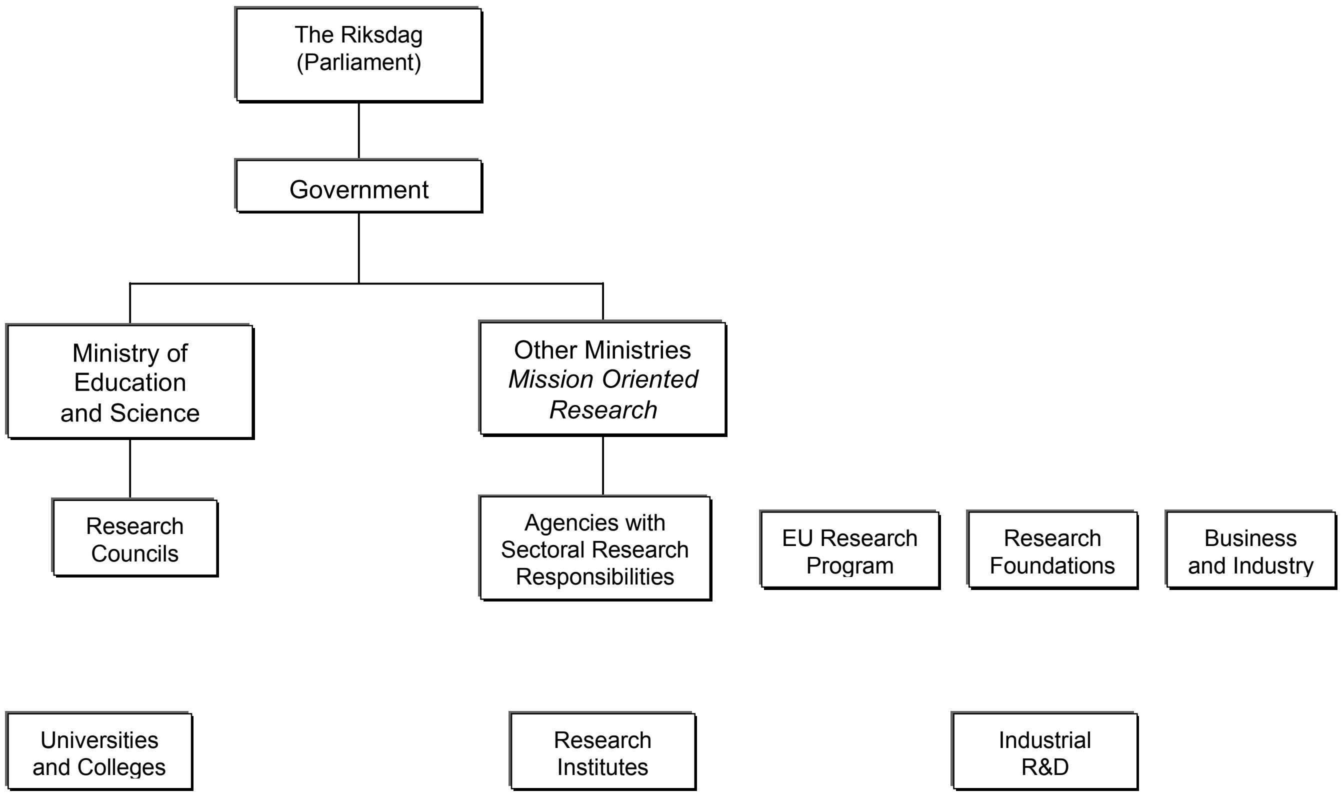
Policy of the Foundation

Swedish Natural Science Research Council. *International Evaluation of Plasma and Space Physics.* (series). (Swedish Natural Research Council, 1997).

Swedish Research Council for Engineering Sciences. (brochure). (Stockholm).

Swedish Research Foundations. *Stiftelsen for strategisk forskning: Policy of the Foundation.* (Stockholm, 1995).

SWEDEN


The Riksdag
(Parliament)
Government
Ministry of
Education
and Science
Other Ministries
*Mission Oriented
Research*
Research
Councils
Agencies with
Sectoral Research
Responsibilities
EU Research
Program
Research
Foundations
Business
and Industry
Universities
and Colleges
Research
Institutes
Industrial
R&D

I. Brazil

Brazil is the only country in the Americas that has a Ministry of Science and Technology (MCT) with broad oversight and policy functions at the national level. Its scientific infrastructure suffered badly during the “lost decade” of economic disarray. While Brazil’s economic situation is still precarious, it has weathered fairly well the more recent financial crisess among developing countries during the 1990s.

Despite the centralizing influence of the MCT, the Brazilian system of S&T research remains dispersed among three agencies. Substantial funding is provided by CAPES under the Ministry of Education, largely in the form of scholarships, fellowships and post-doctoral funding. FINEP, which nominally funds research infrastructure (instruments, laboratory equipment, and the like), and the CNPq (National Council for the Development of Science and Technology – the Brazilian equivalent of the NSF) are both responsible to the MCT. In addition, the federal system of Brazil offers a state-based source of support for research. In principle, each state has a Foundation funded by a small percentage of its tax receipts intended to fund research projects. The most notable of these is that of the wealthiest state, Sao Paolo, FAPESP. It is a very well-funded and extremely efficient dispenser of research support (proposals reputedly are typically merit-reviewed in less than two months), but only operates within the state of Sao Paolo. Its recent achievements in the area of genomics are well recognized internationally. Other States are seeking to invigorate their state foundations in order to enhance regional development.

An important initiative of the Federal Government in S&T was the PADCT program (roughly translatable as “Program for the Development of Science and Technology”), carried out with a combination of national funds and loans from the World Bank. The initial phase of the Program (1985-1990) was of major significance in helping the Brazilian research community to weather bad economic times. During the second phase (1991-1996), however, the Program’s primary objective of fostering a transparent merit review program was combined with a set of several priority fields. The program in now embarking on its third phase, PADCT III. The new phase has three foci: 1) continued support for merit-reviewed basic research in selected fields; 2) a major effort to involve Brazilian industry in cooperative efforts, especially with universities, in research efforts; 3) an enhanced capability on the part of Brazil to meet OECD standards in efforts at the monitoring and evaluation of research programs, including the production of international standard science and technology indicators.

In recent years, the fragmented nature of the support system has meant that many research projects had to be “shopped” from one support source to another: a piece of equipment from FINEP, a post-doctoral position from CAPES or the CNPq, etc. In this piece-meal situation, priority setting was essentially non-existent. A “one-stop shopping” component of PADCT III is an effort of unify projects and place them in a field-oriented setting for the review process. In fact, the most significant priority setting effort in Brazil emerged from the PADCT program itself, where it was determined to focus on seven scientific areas in the funding of research:

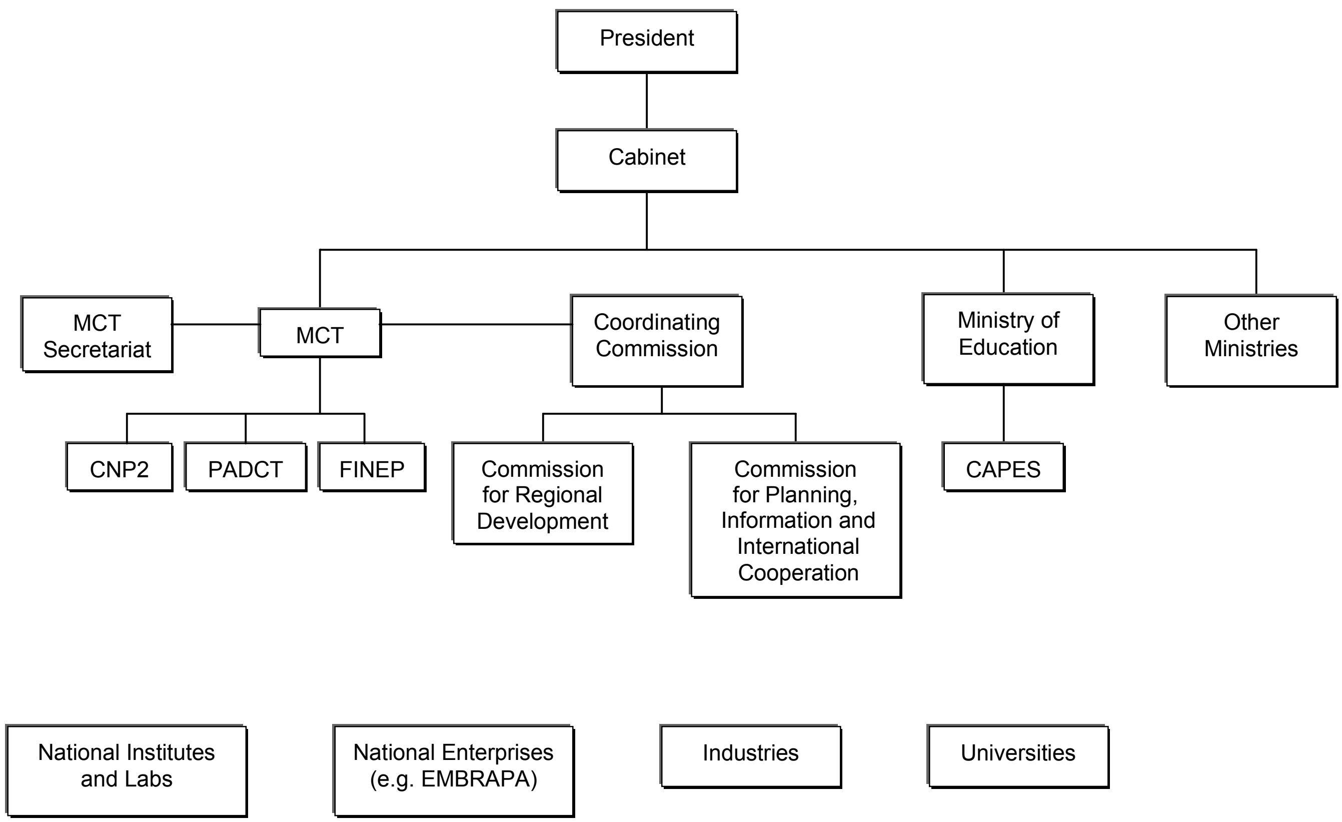
1) Environmental Sciences
2) Geosciences and Mineral Technology
3) Biotechnology
4) Chemistry and Chemical Engineering
5) New Materials
6) Instrumentation, and
7) Science Planning and Management.

A recent bibliometric assessment of publications by PADCT funded researchers during its first two phases suggested that the impact of their research was higher, although not universally so, than other Brazilian research in comparable fields, and generally showed favorable trends in its international impact over time[1]. It is unclear, however, to what degree the program was operated in a manner that created a "self-fulfilling prophesy." Its transparent merit review system meant that the researchers and projects that it funded represented Brazil's best capabilities. However, to the degree that the selection of fields attracted these capabilities to the PADCT program, it represents a field-oriented national priority setting exercise.

Science and technology represent a national priority and have been specifically included in the government's Pluri Annual Plan for 2000 –2003. In addition the Federal Government established recently new specific funds to support the area. [Some of the details are contained in the presentation by the Brazilian Symposium speaker contained in Volume II of this report.]

[1] Coward, H. Roberts, Roland Bardon. The Publication Productivity and Impact of PADCT-Funded Researchers in Brazil: A Bibliometric Analysis. Final Report. SRI International, 1997.

Brazil


President
Cabinet
MCT Secretariat
MCT
Coordinating Commission
Ministry of Education
Other Ministries
CNP2
PADCT
FINEP
Commission for Regional Development
Commission for Planning, Information and International Cooperation
CAPES
National Institutes and Labs
National Enterprises (e.g. EMBRAPA)
Industries
Universities

BIBLIOGRAPHY: OTHER COUNTRIES

UNITED STATES

Government Funding of Scientific Research. (National Science Board, Arlington, VA, 1997). NSB-97-186.

International Partnerships in Large Science Projects. (National Science Board, Arlington, VA, 1995).

Knezo, Genevieve J. *Research and Development: Priority Setting and Consolidation in Science Budgeting.* (issue brief). (Congressional Research Service, Library of Congress, 1998).

Payson, Steve. *R&D as a Percentage of GDP Continues Upward Climb.* (data brief). (Division of Science Resources Studies, National Science Foundation, Arlington, VA, 1999). NSF 99-357.

Roessner, J. David and B. Coward. *An Analytical Synthesis of Empirical Research on U.S. University-Industry and Federal Laboratory-Industry Research Cooperation.* (SRI International, Washington DC, 2000).

National Research Council, Committee on Criteria for Federal Support of Research and Development. *Allocating Federal Funds for Science and Technology.* (National Academy Press, Washington DC, 1995).

National Academy of Sciences, Committee on Science, Engineering, and Public Policy. *Experiments in International Benchmarking of US Research Fields.* (National Academy Press, Washington DC, 2000).

National Academy of Sciences, Committee on Science, Engineering, and Public Policy. *Evaluating Federal Research Programs.* (National Academy Press, Washington DC, 1999).

National Science Foundation, Division of Science Resources Studies, *Data Briefs*, numbered and dated series.

Australia

Australia's Science and Innovation System Background Information. (Web site). (http://www.dist.gov.au/science/pmsec/14meet/bground/s&t-sytm.html).

Australian Science and Technology Council. *Setting Directions for Australian Research.* (Australian Government Publishing Service, Canberra, 1990).

Priority Matters. (A Report to the Minister of Science and Technology). (Department of Industry, Science and Tourism, Canberra, 1997).

Science and Technology Analysis Section, Department of Industry, Science and Resources. *Science and Technology Budget Statement 1999-2000.* (Department of Industry, Science and Resources, Canberra, 1999).

Hungary

Balazs, K. *Changing Structure, Organisation and Nature of Public Research System (PRS) in Hungary.* (Technopolis, Brighton, 1998).