RAND

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

Executive Summary and Annotated Bibliography

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

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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.

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Inquiries regarding the S&T Policy Institute or this document may be directed to:

Bruce W. Don
Director, Science and Technology Policy Institute
1333 H Street NW
Washington, D.C. 20005
Phone: 202-296-5000, ext. 5351
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 constitute 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.

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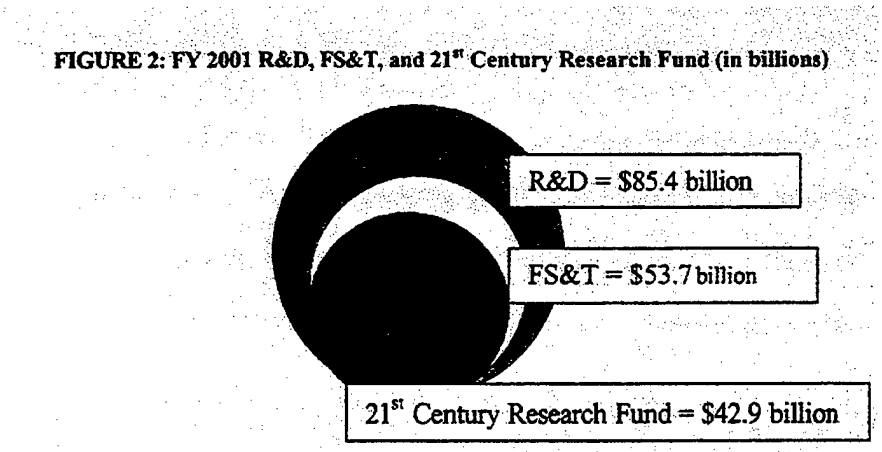
[1] R&D is a budget category that is defined by the Office of Management and Budget (OMB) in Section 25 of Circular A-11.

[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.

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



Source: Research & Development FY20001. Washington, DC: American Association for the Advancement of Science, April 2000.

Defining S&T

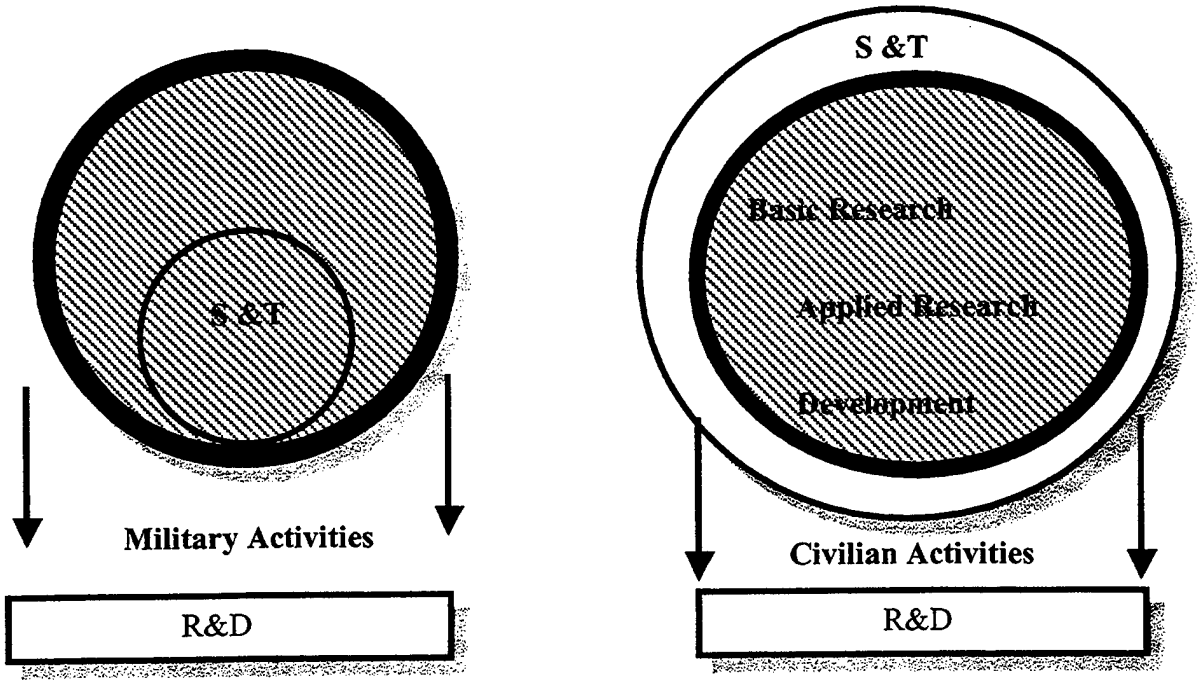
Parallel to the designation of specific federal activities as R&D, there is a simultaneous labeling as to general purpose (i.e., mission) or function activities for S&T. R&D activities are found in every functional category in the federal budget. Of particular interest are the R&D activities in Function 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.

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

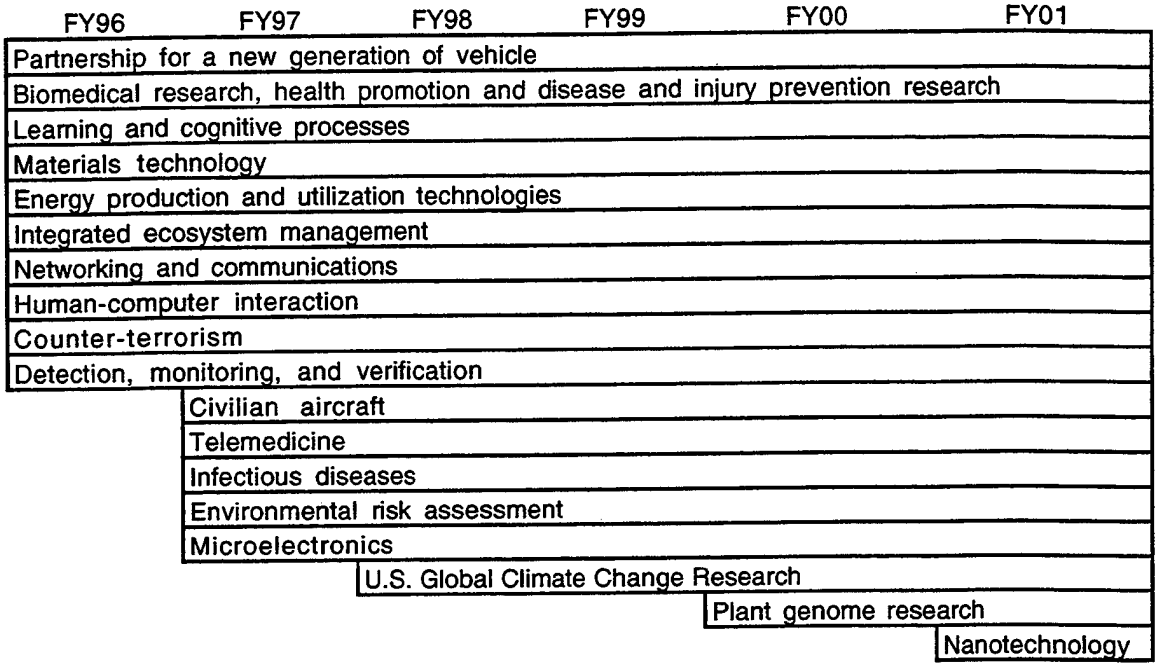
The Executive Office of the President has four offices or councils that advise the President about priority setting in R&D and S&T. These are:

- **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 below.

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: • 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? • 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 unadressed 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 coordiantion to the process.

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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.

— *Science 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 Repor*t, 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.