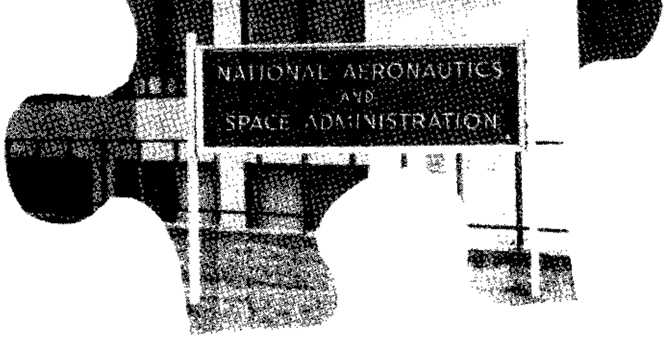
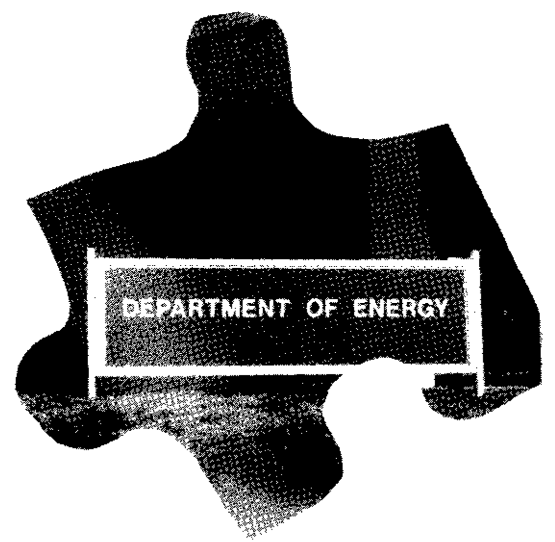



CHAPTER 4

# The Federal Research System: The Research Agencies



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# The Federal Research System: The Research Agencies

## Introduction

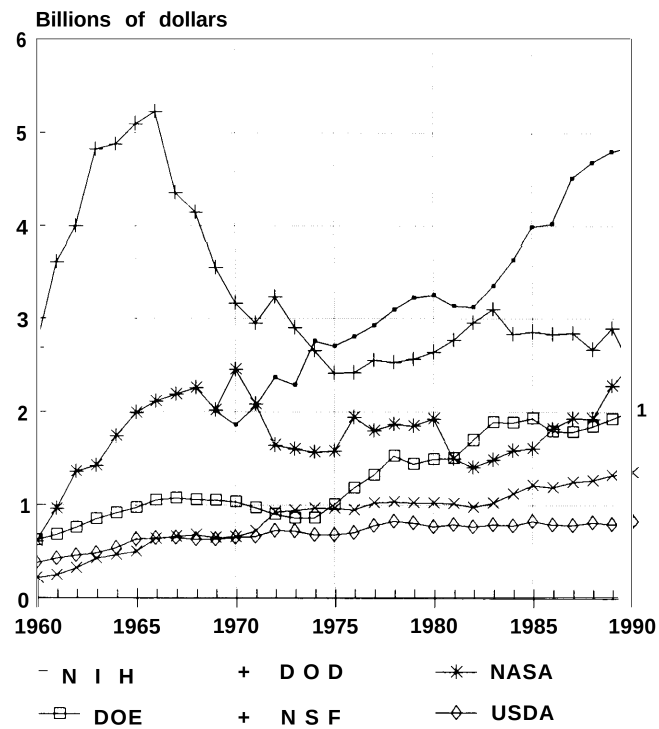
The effective management of the Federal research system depends on the quality of the research agencies and their staff. Over the last 30 years, as research budgets and the system have grown in size, the importance of these agencies in decisionmaking has increased.

Each agency has its own culture, which contributes not only to its success, but also embodies historically the ''way things are done. ' Agency culture is thus a powerful determinant of future directions, with specific goals reflected in the collective knowledge of agency personnel. Pluralism and decentralization characterize each of the research agencies, with many separate programs pursuing diverse objectives. In particular, the lines of decisionmaking within an agency are more complicated than any organizational chart would suggest.

In preparing this report, OTA selected the six Federal agencies that fund most of the Nation's research. They are, in the order of their fiscal support of research (including basic and applied): the National Institutes of Health (NIH), the U.S. Department of Defense (DOD), the National Aeronautics and Space Administration (NASA), the U.S. Department of Energy (DOE), the National Science Foundation (NSF), and the U.S. Department of Agriculture (USDA)[1] (see figure 4-l). OTA reviewed historical budget figures for these agencies and conducted inperson interviews with agency personnel, ranging from top administrators, who interpret and set annual research priorities, to program managers, who disburse the funds. The interviews, 125 in all, yielded information on goal setting in the agency, proposal review, and methods of allocating funds. Interviews with National Academy of Sciences (NAS) staff (who are commissioned by research agencies to perform studies that will enhance decisionmaking) augmented the agency descriptions (see box 4-A).

OTA found that the research agencies generally attempt to follow their missions, as outlined in their founding charters and in subsequent legislation. However, congressional and executive views diverge on what is included in missions. There is also disagreement at many agencies over what constitutes a thoughtful, fiscally prudent, and expeditious

**Figure 4-l-Research Obligations in the Major Research Agencies: Fiscal Years 1960-90 (in billions of 1982 dollars)**




KEY: DOD - U.S. Department of Defense; DOE = U.S. Department of Energy; NASA = National Aeronautics and Space Administration; NIH = National Institutes of Health; NSF = National Science Foundation; USDA = U.S. Department of Agriculture.

NOTE: Research includes both basic and applied. Before 1989, obligations for NIH were not broken out in this source. Figures were converted to constant 1982 dollars using the GNP Implicit Price Deflator. 1990 figures are estimates.

SOURCE: National Science Foundation, *Federal Funds for Research and Development, Detailed Historical Tables: Fiscal Years 1955-1990* (Washington, DC: 1990), table A; and National Science Foundation, *Selected Data on Federal Funds for Research and Development: Fiscal Years 1989, 1990 and 1991* (Washington, DC: December 1990), tables 4 and 5.

[1] Together these agencies supply roughl, 95 percent of the Federal research budget. See Albert H. Teich and Kathleen Gramp, *R&D in the 1980s: A Special Report* (Washington, DC: American Association for the Advancement of Science, September 1988).

**Box 4-A-OTA Interviews at the Federal Agencies**

For this study, OTA sought data on the research goals of the six major Federal agencies that fund basic research: the U.S. Department of Defense (DOD), the U.S. Department of Energy (DOE), the National Institutes of Health, the National Aeronautics and Space Administration, the National Science Foundation, and the U.S. Department of Agriculture. In addition to collecting budget data, OTA performed 125 interviews with agency personnel ranging from top administrators who interpret annual budget priorities to program managers who disburse the funds. Interviews at the National Academy of Sciences and the Office of Management and Budget augmented the agency interviews.

Discussions centered on decisionmaking, priority setting, and funding allocation mechanisms. Typical questions that were asked included:

1. What are the stated goals for agency research monies and programs? What goals are not stated, but are implicit in the agency's mission? How have these goals changed since the 1960s? the 1970s? the early 1980s?
2. What processes (both formal and informal) are used in the agency to set priorities and goals for research monies? How has this process changed in the last 20 years?
3. How do new directions in research that are not anticipated get funded?
4. Does Congress set goals for the money that the agency allocates? Has this changed over time?
5. How do agency divisions coordinate with other parts of government?
6. What mechanisms are used to allocate funds? How do these mechanisms differ for extramural and intramural funding?

To illustrate the scope and depth of the interviews at the agencies, the interviews conducted at DOE can be used as an example. Interviews were conducted in five offices under the Secretary of Energy, and one laboratory was chosen as a case study. Excluding those interviewed at Los Alamos National Laboratory (LANL), four directors of offices at DOE headquarters, eight division directors, and five program managers were interviewed. Since the Office of Energy Research (OER) is the primary supporter of basic research at DOE, the Executive Director of OER, six division directors, and four program managers were interviewed. The Director of the Office of Weapons Research, Development and Testing; the Deputy Assistant Secretary for Renewable Energy; and one program manager in the Office of Conservation and Renewable Energy were interviewed. In addition, departmentwide priority setting was discussed with the Under Secretary for Policy, Planning, and Analysis, and the chief planner for research. Finally, budget data were discussed with the Deputy Director for Research in the Office of the Budget. At LANL, OTA staff toured the facility and interviewed the Deputy Director of LANL, the Director of the Meson Physics Facility, and the Deputy Director of the Health Research Laboratory, as well as a number of scientists and other members of the staff.

In all agencies, the offices that support research were identified, as well as those that participate in departmentwide planning. In addition, one or more inhouse laboratories were chosen for site visits. Summaries of the interview results were prepared and distributed to all interviewees for comment (with the exception of DOD, where a smaller set of reviewers was selected). Because the number of people interviewed had to be limited, the analysis sought only to illuminate the structure and diversity that characterizes executive branch decisionmaking in research. The table of organization was sampled to capture various perspectives on decisionmaking within and across the research agencies.

SOURCE: Office of Technology Asscssment, 1991.

strategic plan to attain specific goals. Goals at the ''macro level' (e.g., a Presidential call for more research and development (R&D) in a specific area) do not necessarily map neatly into agency missions, and some macro level goals cannot be addressed through current agency structures.

Agencies also have a good sense of their research constituencies (i.e., the scientists that receive agency funds), and of what their future directions and needs will be. However, programs managers must often make tough decisions within limited budgets about who to fund, whether to provide money for instrumentation or personnel, and whether to favor disadvantaged groups such as women, minorities, and young investigators. Competing goals of education, equity, and economic activity must be weighed in every program.

OTA found that peer review, manager discretion, and combinations of these methods are used by the research agencies to distribute funds. Since the beginning of the 1980s, the distribution patterns of research funding have been under great scrutiny. It is not only a matter of ***who*** should receive the funds, but how they are allocated (e.g., individual investigator grants or block grants to centers, short-term or long-term projects).

In this chapter, the major research agencies are described, their priority-setting mechanisms outlined and compared, and their funding allocation mechanisms discussed. Agency planning efforts and direction from other agencies of the Federal Government and the scientific community are analyzed.

## Priority Setting in the Federal Agencies

Federal agencies initiate, manage, and terminate programs. At each step in the process, agency personnel must decide which program, or component of a program, will take precedence. What follows is a brief introduction to each of the major research agencies and to their priority-setting mechanisms for research. The agencies are presented in descending order of their annual research budgets.

### National Institutes of Health

**NIH is the** largest research agency in the Federal Government in terms of dollars awarded to basic and applied research. It is the principal biomedical research arm of the U.S. Department of Health and Human Services (HHS), funding biomedical and basic research related to a broad spectrum of diseases and health problems both in its own research facilities (the NIH laboratories) and in external organizations.

The missions of the institutes are reflected in their titles. There are categorical, or disease-oriented, institutes, such as the National Cancer Institute (NCI) or the National Heart, Lung, and Blood Institute (NHLBI). And there are institutes with a population-based research focus that is population based, such the National Institute on Aging. The exception to these categorizations is the National Institute of General Medical Sciences (NIGMS), which has no targeted responsibility other than general basic research.

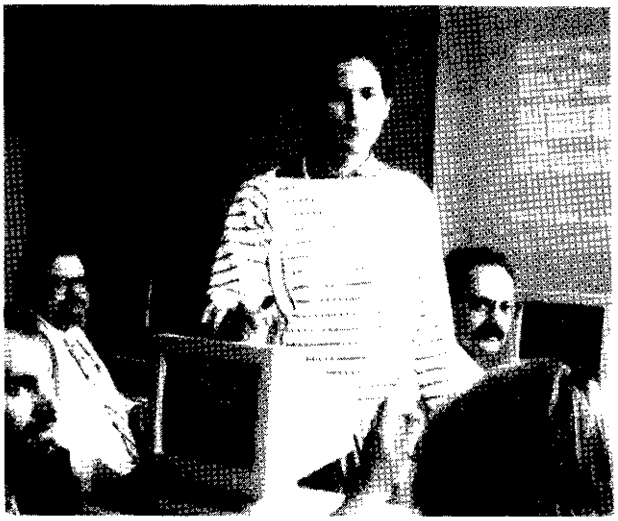


*Photo credit: Research Triangle Institute*

**Researcher trains hospital staff for a National Institutes of Health (NIH)-sponsored clinical trial of medical therapies. Clinical trials are an integral part of NIH applied research.**

**NIH is part of the Public Health Service, so its** work is very much tied to public health issues. Although NIGMS is devoted primarily to basic research, the categorical institutes conduct a range of research from basic to applied to development. For example, NCI's mission is to implement programs on the cause, diagnosis, prevention, and treatment of cancer. Often, the missions of the institutes overlap with each other or with other agencies. In these cases, a lead institute will coordinate. Because many of the institutes are categorical, NIH and Congress tend to set their research agendas epidemiologically, focusing their mission on diseases of highest prevalence. Critics of NIH question this approach, saying that it focuses the research agendas too much on the diseases of the majority, skewing research that could lead to health improvements in other areas.

Since the 1960s, the goals and justifications for health research have been fairly constant-improving the health of the American people, curing particular chronic diseases, and contributing to the economic well-being of the Nation by producing a healthier work force. However, particular emphases have shifted. During the early 1960s, mental retardation was emphasized by President Kennedy. In the 1970s, cancer and heart disease, which had been prominent research areas for decades, became even more important as President Nixon declared the War on Cancer in 1971. Vast sums of money were dedicated to attempts to eradicate these families of disease with mixed success. Although levels of funding remained high, by the late 1970s, the role of the environment in creating and reducing cancer risk replaced the earlier research focus on viral etiology and understanding cellular mechanisms.[2]

During the mid- 1970s, the discovery of recombinant DNA shifted the emphasis of research once again, this time to biotechnology, which received increasing attention throughout the Reagan Administration. Most recently, treating and curing AIDS has been a dominant goal of NIH research. It first appears in the 1983 NIH budget authorization testimony,[3] and every year since then AIDS has received the largest increases in research funding within the NIH budget.

The fiscal year 1991 appropriation to NIH was just over $7.4 billion. NCI has the largest appropriation at $1.7 billion, followed by NHLBI at $1.1 billion. The National Institute on Deafness and Other Communication Disorders had the smallest appropriation at $135 million. See table 4-1 for budget histories of the various institutes from 1970 to 1990.

Each institute has an advisory council, which is appointed through HHS and is made up of scientists and lay people. Program officers must go before the council to present ideas for new programs, and councils review program balance. Each institute may also form advisory committees with programmatic foci; for example, NHBLI has six committees to assist in specific fields. Committees help develop new initiatives. It should be noted, however, that the council is only advisory, except for its ability to approve or disapprove grant applications.

When institute staff notice evidence of an emerging area of research, they assess the importance of the new field and gauge interest and capabilities. They can then convene a meeting or workshop, write up a proposal for a new program, and go to their council for approval. If the program does not have a known constituency, an institute will often issue a request for applications.

Some observers have criticized NIH in its response time to new research needs, such as AIDS and the Human Genome project. On the other hand, some scientists said NIH responded too quickly with its AIDS agenda. Interestingly, AIDS was incorporated into the existing NIH structure, with the National Institute of Allergy and Infectious Diseases (NIAID) taking the lead. The Human Genome project, which some argued belonged in NIGMS, was placed in the Office of the Director. Both approaches have been simultaneously criticized and hailed.[4] To date, there has been no mechanism for centralized planning at NIH. However, NIH, for the first time, is developing a strategic plan that cuts across all institutes. In addition, each institute submits its annual plan to the Office of the Director along with the budget. However, the Director has little authority to redirect the agenda of any institute. Through the budget process, Congress provides a coordinating function.

Despite growth in funding over the last decade, NIH views itself as being in a "steady state" and under enormous strain. After experiencing phenomenal growth (virtually a doubling of the budget in real terms during the 1980s), including an intramural budget that exceeds $900 million today, managers still feel they must juggle priorities, reorient existing programs, and make small, incremental changes in other programs-both intramural and extramural.[5] But there are exceptions: NIAID rose from seventh place among institute budgets to third place (from

[2] Richard A. Rettig, *Cancer* Crusade: *The Story of the National Cancer Act of 1971* (Princeton, NJ: Princeton University Press, 1977); and Stephen Strickland, *Politics, Science, and Dread Disease* (Cambridge, MA: Harvard University Press, 1972).

[3] Mark Pollack, "Basic Research Goals: Perceptions of Key Political Figures, " OTA contractor report, June 1990. Available through the National Technical Information Service, see app. F,

[4] With matrix management, some National Institutes of Health staffers said (in OTA interviews during the spring of 1990), the best way to respond to a new research initiative is to create a new associate director in the Office of the Director to coordinate efforts among the institutes. Also see Institute of Medicine, *The AIDS Research Program of the National Institutes of Health* (Washington, *DC:* National Academy Press, 1991); and Janice Long, "AIDS Research: More Funds, Coherent Strategy Needed, " *Chemical & Engineering News, vol. 69, Mar.* 11, 1991, p. 4.

[5] Problems cited as besetting the National Institutes of Health (NIH) are: noncompetitive wages (especially for young researchers), increased politicization (notably over fetal tissue research and the use of animals for experimentation), "accountability fever" (centering on congressional investigations of purported misconduct in research and complaints about NIH's own process of inquiry), excessive paperwork to document research-related decisions, and lack of direction (the difference between an "acting' and a presidentially nominated, Senate-approved director). See Rick Weiss, ''NIH: The Price of Neglect,'' *Science,* vol. 251, Feb. 1, 1991, pp. 508-511. The confirmation in March 1991 of Bernadine Healy as NIH Director filled a vacancy that existed since August 1989. See Larry Thompson, ''NIH Gets Its First Woman Director,'' *The Washington Post,* Health section, Mar. 26, 1991, p. 8.

**Table 4-1—National Institutes of Health History of Congressional Appropriations: Fiscal Years 1970-90** (In millions of constant 1982 dollars)

| | 1970 | 1972 | 1974 | 1976 | 1978 | 1980 | 1982 | 1984 | 1986 | 1988 | 1990 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NCI | $432.1 | $814.6 | $976.9 | $1,207.1 | $1,208.3 | $1.166.7 | $986.6 | $1,004.3 | $1,103.8 | $ ,211.3 | $1,243.8 |
| NHLBI | 382.4 | 500.2 | 536.3 | 586.4 | 620.4 | 615.5 | 559.6 | 654.5 | 754.3 | 796.0 | 816.1 |
| NIDR | 68.6 | 93.3 | 81.5 | 81.3 | 85.5 | 79.7 | 72.0 | 82.4 | 90.7 | 104.1 | 103.3 |
| NIDDK | 313.8 | 329.7 | 284.4 | 284.5 | 360.5 | 398.1 | 368.2 | 430.8 | 499.8 | 440.8 | 442.5 |
| NINDS | 231.7 | 251.0 | 224.8 | 228.8 | 247.1 | 282.4 | 265.9 | 311.9 | 380.5 | 440.8 | 373.2 |
| NIAID | 231.7 | 234.6 | 205.7 | 201.1 | 224.8 | 251.3 | 235.9 | 296.8 | 336.7 | 526.6 | [illegible]33.9 |
| NIGMS | 353.1 | 373.1 | 311.7 | 296.8 | 319.7 | 364.6 | 339.9 | 386.2 | 452.0 | 521.6 | [illegible]18.9 |
| NICHD | 181.2 | 250.3 | 232.4 | 216.2 | 230.5 | 243.9 | 226.3 | 256.3 | 282.5 | 327.1 | [illegible]37.[illegible] |
| NEI | 54.3 | 79.8 | 76.3 | 79.6 | 118.3 | 131.9 | 127.4 | 144.0 | 171.3 | 185.4 | [illegible] |
| NIEHS | 41.4 | 56.8 | 52.6 | 59.7 | 88.9 | 97.9 | 106.3 | 167.7 | 173.4 | 177.8 | [illegible] |
| NIA | n/a | n/a | n/a | 30.6 | 51.7 | 81.7 | 81.9 | 107.1 | 137.4 | 160.6 | 182.3 |
| NIAMS | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 121.8 | 128.5 |
| NIDCD | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 89.5 |
| NCNR | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 19.3 | 25.5 |
| NCHGR | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 45.3 |
| Other | 236.0 | 255.3 | 333.5 | 376.2 | 382.0 | 287.6 | 270.3 | 331.4 | 445.1 | 462.9 | 471.5 |
| Total | 2,526.2 | 3,239.1 | 3,315.6 | 3.648.3 | 3.937.5 | 4.001.1 | 3.640.2 | 4.172.3 | 4,620.0[a] | 5,496.0 | 5,765.9[a] |

KEY:

| | |
|---|---|
| NCI | National Cancer Institute |
| NHLBI | National Heart, Lung, and Blood Institute |
| NIDR | National Institute of Dental Research |
| NIDDK | National Institute of Diabetes and Digestive and Kidney Diseases |
| NINDS | National Institute of Neurological Disorders and Stroke |
| NIAID | National Institute of Allergy and Infectious Diseases |
| NIGMS | National Institute of General Medical Science |
| NICHD | National Institute of Child Health and Human Development |
| NEI | National Eye Institute |
| NIEHS | National Institute of Environmental Health Sciences |
| NIA | National Institute on Aging |
| NIAMS | National Institute of Arthritis and Musculoskeletal and Skin Diseases |
| NIDCD | National Institute on Deafness and Other Communication Disorders |
| NCNR | National Center for Nursing Research |
| NCHGR | National Center for Human Genome Research |

[a]Reflects enacted administrative reduction and sequestration.

NOTE: N/A=not applicable

SOURCE: National Institutes of Health, unpublished, February 1990 almost **$375** million to over **$907** million) between fiscal years 1984 and 1991. AIDS research funds account for this increase, with one-half of the current NIAID budget devoted to research on the disease. AIDS funds are new money, and are not taken from other biomedical budgets.

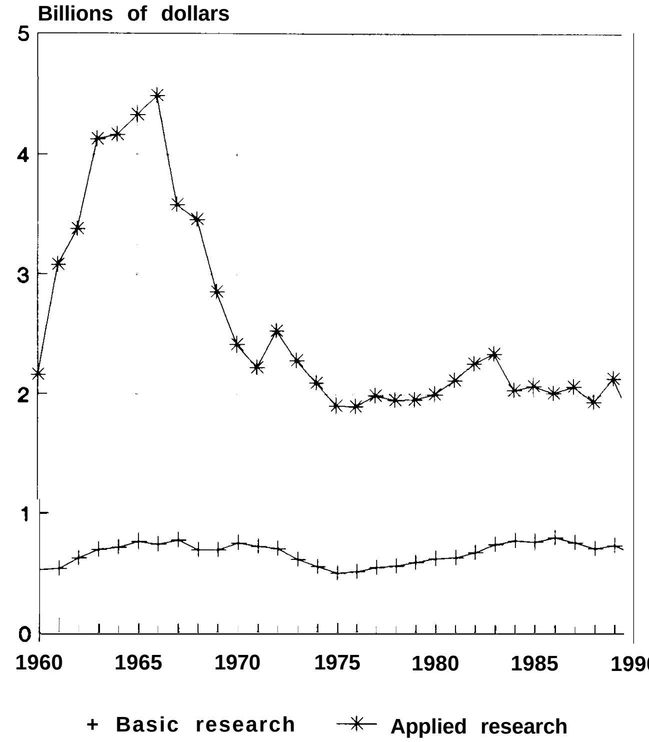
NIH is perpetually struggling to balance its research and public health missions. Some institutes are more responsive to one or the other, and therefore are oriented to individual investigators (and basic research) or centers (and clinical, disease-focused work), but all seek to serve both missions. What has been especially inconsistent is the NIH approach to public health or research crises. As noted above, while the AIDS initiative was assigned to one institute, Human Genome, originally assigned to the Office of the Director, is now a separate National Center for Human Genome Research that is not part of the Office of the Director. Many argue that one approach or the other responds better to crises while remaining supportive of, and responsive to, developments in basic research. Perhaps new efforts aimed toward a strategic plan could be used to better address public health and research crises.[6]

### Department of Defense

DOD is the second largest source of basic and applied research funds in the Federal Government. Justification for defense R&D throughout the last three decades has been to stay ahead of the Soviet Union in the development of new military technologies. However, defense research is also inextricably linked to the expansion of knowledge and bolstering the overall U.S. technological base.

The military funds research through three categories: 6. l—research of the most fundamental nature; 6.2—applied research and exploratory development; and 6.3A—the initial stages of advanced development.[7] Research within DOD can be characterized by two phrases: "technology-push" and ''requirements-pull. Knowledge gained from research creates areas for potential advancement, some of which were unforeseen when the research began.

**Figure 4-2—Basic and Applied Research Funds for DOD: Fiscal Years 1960-90** (in billions of 1982 dollars)




NOTE: Figures were converted to constant 1982 dollars using the GNP Implicit Price Deflator. 1990 figures are estimates.

SOURCE: National Science Foundation, *Federal Funds for Research and Development, Detailed Historical Tables: Fiscal Years 1955-1990* (Washington, DC: 1990), table A; and National Science Foundation, *Selected Data on Federal Funds for Research and Development: Fiscal Years 1989, 1990 and 1991* (Washington, DC: December 1990), tables 4 and 5.

This new knowledge nudges the system to incorporate new ideas and thereby gain a greater level of capability (technology-push). At the same time, identified needs define areas for research and technological results to enhance the military. These requirements shape the directions of research and set the level of effort to be pursued (requirements-pull).

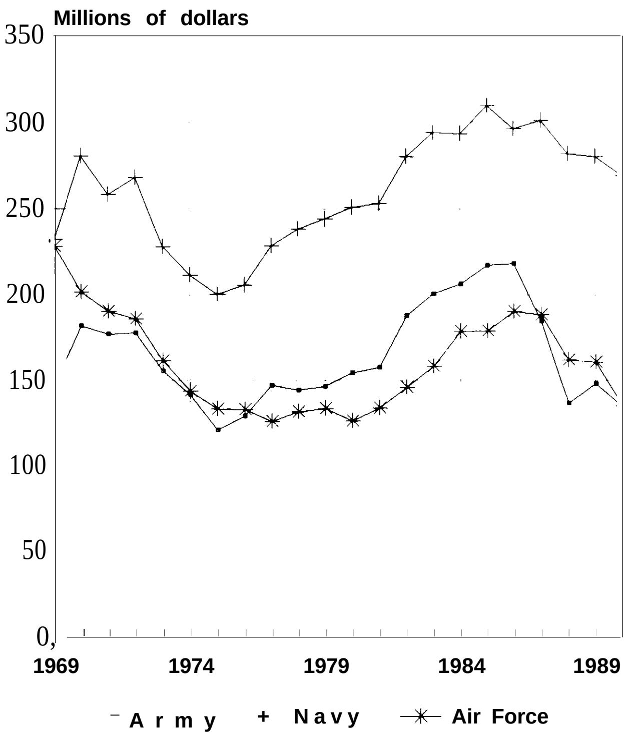
Figure 4-2 presents the basic and applied (corresponding roughly to 6.1 and 6.2) research funds authorized for DOD from 1960 to the present.[8] Figure 4-3 graphs basic research funding in constant

[6] See Institute of Medicine, *Funding Health Sciences Research: A Strategy to Restore Balance,* Floyd E. Bloom and Mark A. Randolph (eds.) (Washington, DC: National Academy Press, November 1990).

[7] The rest of the 6.3 category is devoted to more advanced development. U.S. Congress, Office of Technology Assessment, Holding the *Edge: Maintaining the Defense Technology Base,* OTA-ISC-420 (Washington, DC: U.S. Government Printing Office, March 1989).

[8] These data were collected by the National Science Foundation (NSF). Although some of the research agencies report problems with the NSF survey (discussed below), the Department of Defense already categorizes its research with 6.1 and 6.2 budget designation. Funds reported as "basic" and "applied" correspond to 6.1 and 6.2 funds, and their interpretation is fairly straightforward.

**Figure 4-3-Basic Research in DOD by Service: Fiscal Years 1969-90** (in millions of 1982 dollars)

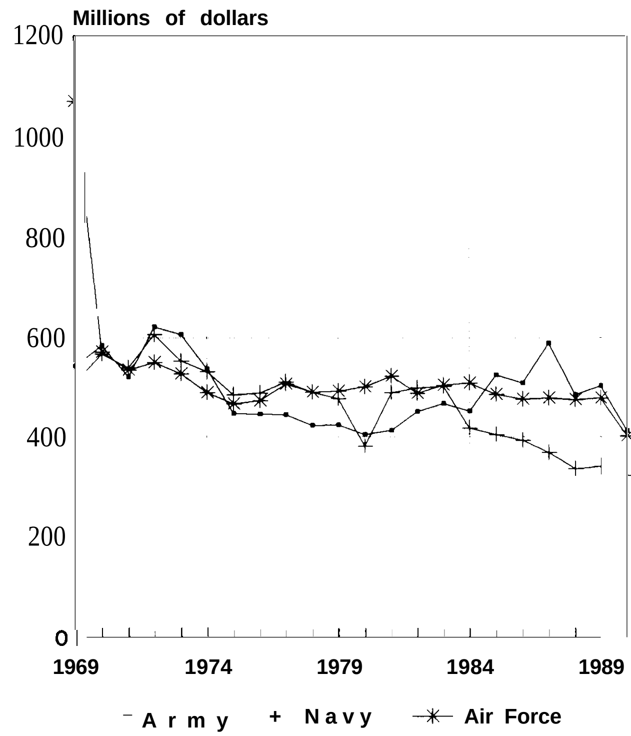



KEY: DOD = U.S. Department of Defense.

NOTE: Figures were converted to constant 1982 dollars using the GNP Implicit Price Deflator. 1990 figures are estimates.

SOURCES: National Science Foundation, *Federal Funds for Research and Development, Detailed Historical Tables: Fiscal Years 1955-1990* (Washington, DC: 1990), table A; and National Science Foundation, Selected *Data on Federal Funds for Research and Development: Fiscal Years 1989, 1990 and 1991* (Washington, DC: December 1990), tables 4 and 5.

**Figure 4-4—Applied Research in DOD by Service: Fiscal Years 1969-90** (in millions of 1982 dollars)




KEY: DOD = U.S. Department of Defense.

NOTE: Figures were converted to constant 1982 dollars using the GNP Implicit Price Deflator. 1990 figures are estimates.

SOURCES: National Science Foundation, *Federal Funds for Research and Development, Detailed Historical Tables: Fiscal Years 1955-1990* (Washington, DC: 1990), table A; and National Science Foundation, Selected *Data on Federal Funds for Research and Development: Fiscal Years 1989, 1990 and 1991* (Washington, DC: December 1990), tables 4 and 5.

dollars for the three services, and figure 4-4 presents applied research funds by service from 1969 to the present. Compared with basic research funding for other research agencies, the services show remarkably little fluctuation in allocated finds, adjusted for inflation. The Navy has been consistently awarded more funds than either of the other services, roughly twice that of the Army or Air Force. Although applied research funding decreased in the late 1960s, it has remained even more constant than basic research in the 1970s and 1980s, and the three services have received almost identical levels of funding for applied research since 1970. Basic and applied research is also supported by the Strategic Defense Initiative Organization (SDIO-although SDIO funds are technically categorized as 6.3A) and the Defense Advanced Research Projects Agency (DARPA). These two organizations often cooperate with the three services to fund and operate research projects.

As recently stated by the Congressional Research Service:

> Although military basic research funding totals almost $1 billion annually, it (together with military applied research funding) has decreased since the mid- 1960s in real dollar terms and relative to increases in total research, development, testing, and evaluation. Despite recent congressional action to increase military research budgets, executive branch decisionmakers have not sought large increases for research funding. As a result, critics say, too much attention goes to weapons development and too little to "creative" science needed to produce knowledge

vital to U.S. national security. Some allege that because of funding cutbacks the quantity and quality of military research may be decreasing.[9]

Recently each of the services concluded that a published strategic plan, explicitly covering their individual projections for the future technology base, would both aid in policy formulation and positively influence the budget for research. In the Air Force, it was called 'Project Forecast II;' in the Navy, "Navy 21;" and, in the Army, "Army 21." Some of these plans take into account the "new reality" for the future: the decreasing likelihood of a European war, the increasing likelihood of low-intensity conflict (especially in the Third World and/or connected with drugs), increasing global economic and technological competition, the decreasing U.S. defense industry and R&D base, the decreasing supply of U.S. citizen scientists and engineers, and finally, decreasing defense budgets. Based on this future scenario, the plans identify key emerging technologies and areas for enhanced research.

The three services differ in the degree of centralization in the dispersal of 6.1 money. In the Air Force and the Navy, almost all 6.1 research monies flow through the Air Force Office of Scientific Research (AFOSR) or the Office of Naval Research (ONR), respectively. In the Army, 6.1 funds are more decentralized.

### Army

Much of Army research is closely linked to priority setting for all of the R&D funds in the Army's laboratories and institutes. Laboratories in the Army act independently, although they determine priorities in relation to overall directives from Laboratory Command. With this independence comes requirements for a high level of accountability, and laboratories are reviewed regularly. Most are ''industrially funded' '-competing for funds from sources within and without the Army.

In addition, the mission of the Army Research Office (ARO) is to ". . . develop the Army Materiel Command research program for mathematics, and the physical, engineering, atmospheric, terrestrial, and biological sciences according to Army-wide requirements.[10] Eighty-three percent of the research contract program monies go to universities, 10 percent to industrial laboratories, and 7 percent to Federally Funded Research and Development Centers and not-for-profits.[11] ARO receives guidance from its parent Army Materiel Command, which provides focus to its research programs. ARO has also come to rely on informal types of outside input, especially from the scientists that it supports. The Medical Research and Development Command recently developed an Army Medical Technology Base Plan, which provides guidance to the medical research community within the Army. Finally, the mission of the Army Research Institute for the Behavioral and Social Sciences is to focus on ". . . the acquisition, training, development, utilization and retention of the Army's personnel resources.[12] Three laboratories and many university contracts support this goal.

### Navy

Almost all of the 6.1 research dollars in the Navy are disbursed by the Office of Naval Research. Over one-half of ONR funds go to universities, one-fifth to ONR laboratories, over 10 percent to other Navy laboratories, and the final 10 percent to industry and other government research organizations. ONR funding is spread among disciplines, with a little less than one-half devoted to areas of explicit Navy emphasis, such as ocean and atmospheric sciences, computers, and materials. Other areas of support are linked closely to broader defense interests: astronomy and astrophysics; biological, medical, cognitive, and neural sciences; general physics, chemistry, and mathematics; and energy conversion, radiation sciences, and electronics.

In addition to Navy 21, ONR relies on inhouse personnel (including personnel from the ONR laboratories), foreign field offices, and outside experts and panels (including NAS) to help set priorities. This type of planning is relatively new for the Navy. Before 1970, a primary research criterion was the quality of the science. Most of the research was not

9Genevieve J. Knezo, "Defense Basic Research Priorities: Funding and Policy Issues,'' *CRS Report for Congress* (Washington, DC: Congressional Research Service, Oct. 24, 1990), p. 38.

10Army Research Office briefing materials prepared for OTA, May 1990.

11Ibid.

12Ibid.

multidisciplinary and minimal advice was requested from the external scientific community. Now, due in part to the 1970 Mansfield Amendment, mission relevance is a strong criterion; multidisciplinary programs are enhanced and are greater in number; some programs can be put on a "fast-track"; and substantial input is sought from the external scientific Community.

### Air Force

Before 1974, inhouse Air Force laboratories controlled most 6.1 monies. After 1974, the Air Force consolidated the disbursal of 6.1 monies into one unit, the Air Force Office of Scientific Research. Each laboratory still has a portion of 6.1 monies, but the bulk are distributed by AFOSR. Air Force laboratories compete for these funds along with universities and other performers. In addition to Project Forecast II, each year key personnel in the Air Force research system and managers of the science and technology areas discuss the "macro strategy" for the next year. A report is then sent to the separate parts of the Air Force research system, such as AFOSR, which reinterprets its programs in terms of these goals.

Even though there is a significant amount of ''top-down' direction in the distribution of Air Force 6.1 money, it is still primarily a bottom-up process. The influence of top-down management is viewed as adding discipline to the management of research programs, which still respond primarily to scientific community concerns about the direction of research. The balance of top-down and bottom-up management seems intermediate to that in the Army where the management is more decentralized and bottom up, and to the Navy where ONR provides greater top-down management.

### DARPA and SDIO

Project selection in research at DARPA is very different from that at other DOD research agencies. Project managers state that they are not attempting to maintain strength across a field, rather they are funding good *ideas* that are on the forefront of technology development to meet desired objectives (see box 4-B).

In the Strategic Defense Initiative Organization, the Innovative Science and Technology Office (ISTO) is the core unit that funds basic and applied research for SDIO. Within the overall mission of developing space surveillance, weapons, and communications technologies, ISTO determines future directions for research. ISTO includes an eight-person research management team, which sets goals and works to see that these goals are achieved. The measure of success is ISTO's impact on SDIO.

At present the three services, SDIO, and DARPA set their own research agendas, gaining the usual advantages of pluralism. In a previous report, OTA also found disadvantages to pluralism, which included ''. . . wasteful duplication of efforts, lack of critical mass to solve common problems, fractionated efforts, and inattention to areas that are on no component's agenda. It also risks failing to identify areas of common or overarching significance. ' '[13] In a mission-oriented organization like DOD, these disadvantages seem too large to ignore. OTA also found previously that the inability to define the products of research has limited DOD's use of quantitative decision support and evaluation methods like those used in industry .[14]

From 1989 to 1990, DOD prepared for a downturn in funding. After a period of phenomenal growth in the 1980s, DOD projected that such funding could not continue, and that a real decline in funds was therefore likely. DOD set in motion planning activities to construct useful options in such a funding scenario, such as the consolidation of several research laboratories, and many of the priorities embodied in these plans have been implemented in the DOD budget. The consequences of these decisions have yet to be evaluated.

## National Aeronautics and Space Administration

NASA is now the third largest source of research funds (both basic and applied) in the Federal Government. NASA was created in 1958, 1 year after the launch of Sputnik, and took over the National Advisory Committee on Aeronautics' laboratories. In fiscal year 1960, the research budget was slightly over $0.5 billion (in constant 1982

[13] Office of Technology Assessment, op. Cit., footnote 7.

[14] U.S. Congress, Office of Technology Assessment, ' 'Evaluating Defense Department Research,'' background paper of the International Security and Commerce Program, June 1990.

### Box 4-B—The Defense Advanced Research Projects Agency

Because the creation of new technologies is often interdisciplinary and involves risky research ventures, President Eisenhower felt that ". . . a different type of organization was needed with unique business practices."[1] The mission of the Defense Advanced Research Projects Agency (DARPA), created m 1958, is to ". . . develop 'revolutionary' technologies that can make a significant impact on the future of the United States' defense posture, and to ensure that those technologies effectively enter the appropriate forces and supporting industry base. '

The "unique business practices" that now prevail at DARPA involve program managers directly with the projects that they fund and manage. Managers typically create a portfolio of research projects seeking particular objectives, such as the use of Gallium-Arsenide in new micro circuitry developments, and follow them closely. Programs are expected to last 3 to 5 years; the manager is given almost total discretion over funding allocation; and the success of the manager and the program are judged by the results produced

Managers are also given discretionary money to pursue ideas for future programs, and every year new programs compete for funding. DARPA stresses that this competition is based almost exclusively on the worthiness of a particular idea, not on external considerations such as maintaining U.S. strength in a particular research field. Also, DARPA's contribution must be unique. An "inhouse rule" stresses that 80 percent of the funding in a particular research area must come from DARPA. This targets DARPA's investment in emerging research topics.

DARPA further stresses the importance of allocating enough funds for a project to see it through to completion. Because of funding shifts, many agencies must compromise their programs and projects by allowing only partial funding. At DARPA, programs and projects are routinely terminated to make way for others.

Among the agencies where OTA conducted interviews, DARPA is applauded as the only organization that can effectively trade off agency programs and, if needed stop a project. DARPA allows less than 1 year to switch program direction, whereas research managers in many other agencies state that it takes at least 2 years, and often much longer, to achieve such redirection. DARPA relies foremost on program managers to determine when to halt a program, which is hailed as a key to DARPA's success.[3]

DARPA's accomplishments in high-performance computing, solid state devices, advanced materials, and many other areas have sparked much congressional interest. Attempts to model other agencies after DARPA, particularly a "Civilian Advanced Research Projects Agency," have concentrated on DARPA's novel organizational style.[4] Congress could also consider instructing the Federal research agencies that do not already have programs specializing in high-risk research to adopt select DARPA management techniques.

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[1] *Craig I. Fields, testimony* at *hearings* before the House Committee On *Armed* Services, *Subcommittee* on Research and Development, Mar. 1, 1, 1989, p. 1. 1. 45&! see "The Government's Guiding Hand: An Interview With Ex-DARPA Director Craig Fields," *Technology Review,* February-March 1991, pp. pp. 33

[2] Ibid., p. 1.

[3] See Ted Agres, "DARPA Bets on High-Risk R&D," *Research & Development,* November 1989, pp. pp. 39

[4] See Senate and House bills S. 1978 and H. 3833; and Senate Committee on Governmental Affairs, hearing on S. 1978, Trade Technology and Promotion Act of 1989, June 12, 1990.

dollars) and, by fiscal year 1990, it had surpassed $2 billion (in constant 1982 dollars, see again figure 4-l).

Not unexpectedly, the primary focus of NASA research from 1961 to 1969 was directed at achieving President Kennedy's announced goal of landing men safely on the Moon by the end of the decade. The use of satellites for communications, meteorological observations and research, and Earth resource surveys were also persistent emphases. The investment in space was justified on the basis of perceptions of U.S. leadership in science, technology, and world affairs, and of expanding knowledge of the universe. As the economy tightened and the lunar landing neared, the ostensible practical benefits of space research and of space-related technology received increasing emphasis. The end of the Apollo program produced a need for new priorities both to guide the agency's activities and justify continued high levels of funding. In the mid- 1970s, the Space Shuttle began to move to center stage.

During the 1980s, research priorities at NASA diversified. NASA began to emphasize commercial uses of space (including industrial research), as well

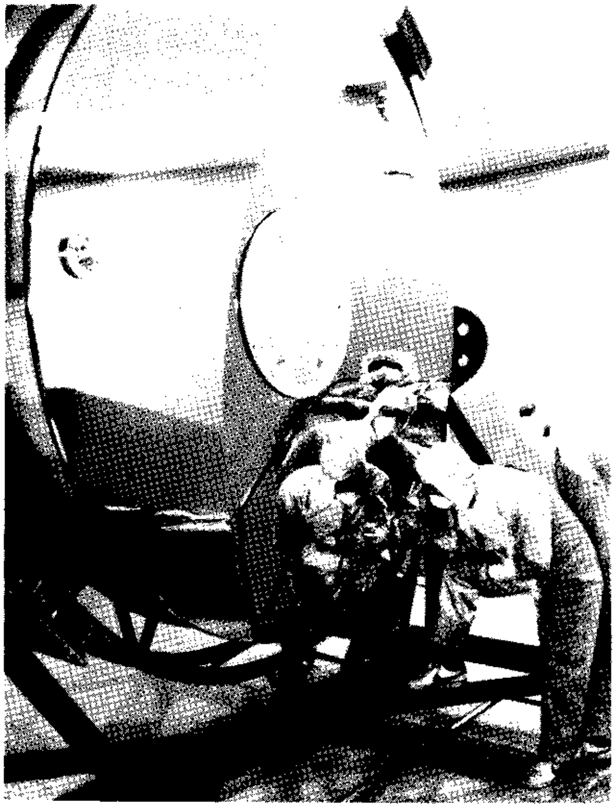


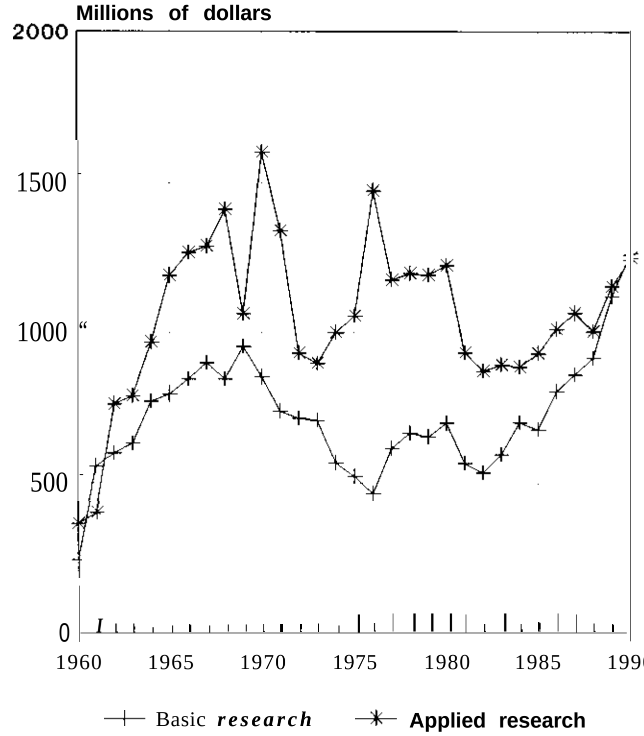
*Photo credit: National Aeronauts and Space Administration*

**Scientists work on a mirror for the Hubble Space Telescope (HST). Building the apparatus for any mission in space, such as the HST, is complex and involves many different components.**

as the use of space for defense. In addition, NASA initiated work on the Earth Observing System to collect much more environmental data than had previously been collected from space. Recently, President Bush has also set a goal to return humans to the Moon and explore Mars.

Basic and applied research management at NASA is split between the Office of Space Science and Applications (OSSA) and the Office of Aeronautics, Exploration, and Technology (OAET). Data on basic and applied research funding at NASA are presented in figure 4-5.[15] Over the last three decades, basic research funding has oscillated slowly, between $600 and $800 million (in constant 1982 dollars). Applied research shows a more active

**Figure 4-5-Basic and Applied Research Funds at NASA: Fiscal Years 1960-90** (in millions of 1982 **dollars)**




KEY: NASA - National Aeronautics and Space Administration.
NOTE: Figures were converted to constant 1982 dollars using the GNP Implicit Price Deflator. 1990 figures are estimates.
SOURCE: National Science Foundation, *Federal Funds for Research and Development, Detailed Historical Tables: Fiscal Years 1955-1990* (Washington, DC: 1990), table A; and National Science Foundation, *Selected Data on Federal Funds for Research and Development: Fiscal Years 1989, 1990 and 1991* (Washington, DC: December 1990), tables 4 and 5.

history, ranging from $0.8 to $1.6 billion (in constant 1982 dollars), but in the 1980s applied research has held fairly constant at nearly $1.0 billion.

OSSA sets priorities in conjunction with the budget process and by selecting specific projects. The process is essentially bottom up with project managers proposing new initiatives. However, when large missions are proposed, such as Space Station Freedom, top-down direction will determine the parameters of the effort. OSSA recently produced its first strategic plan, which emphasized a commitment

[15] OTA notes that many agencies do not find the division into basic, applied, and development useful. Consequently, agency budget Offices believe that the data that they report to the National Science Foundation (NSF) iartificial and prone to errors, The NSF figures also remove the funds for equipment purchase from the research and development (R&D) budget line items and add the support funds from the Research and Program Management appropriation associated with R&D. OTA uses these data only as a general indicator of level of effort in particular areas.

to the Space Station Freedom and the Earth Observing System and to flying a mixture of small and large missions.

The National Research Council (NRC) plays a particularly strong advisory role for OSSA, and the Space Studies Board provides input for most NASA basic research programs. The board is unique at NRC because it has an *institutional* relationship with NASA, i.e., NASA funds the board and requests many studies, but the board can use these resources to initiate studies independently. In fact, the board has been able to preserve its credibility because it has not always agreed with NASA, and has openly disputed it on some occasions. Roughly every 10 years if events do not call for an earlier revision, the board writes a strategic plan for every discipline in OSSA. The Space Studies Board also conducts periodic reviews of the programs and every new mission, and other larger topics such as ''manned' v. ''unmanned' flight are routinely studied.

In addition, OSSA has an internal structure of advisory panels. The panels are usually made up of representatives from academia, industry, Federal laboratories, and other interested groups such as program managers from other agencies. They are consulted at least once or twice each year (sometime quarterly) about future directions for research programs. However, as with NRC, their findings are never binding.

In early 1990, "exploration" was added to the Office of Aeronautics, Exploration, and Technology, formerly the Office of Aeronautics and Space Technology. The new program participates fully in the Administrator's Moon/Mars Initiative, which gives it a new and higher profile within the agency.

The aeronautics work in OAET is almost all basic and applied research, and OAET views its role as the basic research provider in aeronautics for the country. Consequently OAET's advisory committees are primarily composed of and almost always chaired by industry representatives. Generally the decisions of research direction are made by the associate administrator. It is a somewhat open process, in which there is ample chance for those outside NASA to comment.

In the 1970s and into the 1980s, OAET's space technology component asked of project directors: ''what will they need for the future?' In 1986 and 1987, the program changed its philosophy. It focused on short-term problems and attempted to promise system delivery by specific dates. In 1989, the deputy administrator questioned this approach. Now 60 percent of the funding goes to near-term solutions to mission problems; 30 percent to long-term solutions; and 10 percent to high-risk research. The frost 90 percent is developed in conjunction with mission managers, and the rest is decided within the space technology group, and can be used to support risky research, such as studies on '' wormholes' '—shortcuts between distant points in space.

Recent problems have plagued many NASA programs, such as a flaw discovered in the Hubble Space Telescope, the halt of space shuttle flights due to hydrogen leaks, and nagging questions about the Space Station. A reflective look at NASA programs by Congress has been urged, and calls for an overhaul of NASA's management structure have grown louder.[16] Director Truly has cited the need 'or a better match between agency programs and its resources. In addition, many have pointed to the failure of NASA programs to encourage a civilian space industry that also supports research. While NASA has been charged (since 1960) to promote a civilian space capability, it has been successful to a lesser extent than predicted one, two, and three decades ago.[17] An Advisory Committee on the Future of the U.S. Space Program has reviewed NASA's programs and has suggested such goals as building a reliable space transport system, improving NASA's civilian pay structure, and augmenting

[16]For example, see David C. Morrison, ' 'Hill to NASA: Come Down,'' *National Journal,* vol. 22, No. 18, May 5, 1990, pp. 1077-1081; Kathy Sawyer, "Truly: NASA Needs More Flexibility," *The Washington Post,* Sept. 14, 1990, p. A17; and Kathy Sawyer, "NASA: Mission Implausible," *The Washington Post, Nov. 4, 1990,* p. C3.

[17]See Mark R. Oderman, "A Viewpoint on Commercial Space Activities: Realities and Options for the 1990s," *Science, Technology, and the Changing World Order, colloquium* proceedings, Apr. 12-13, 1990, S.D. Sauer (cd.) (Washington, DC: American Association for the Advancement of Science, 1990), pp. 253-264.

NASA facilities.[18] OMB and the National Space Council have been directed to create an implementation plan based on its suggestions.[19]

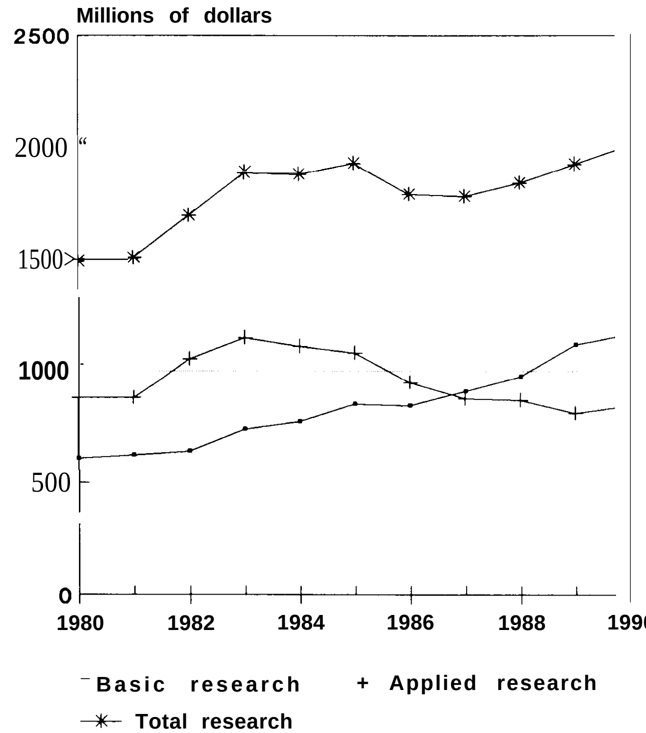
### Department of Energy

DOE is the fourth largest source of basic and applied research funds in the Federal Government. DOE is also the youngest of the six major research agencies. Created by the Carter Administration to succeed the Energy Research and Development Administration, DOE inherited a strong research base from another predecessor, the Atomic Energy Commission, including the national laboratories and a network of university researchers.

When DOE was founded, in the wake of the formation of OPEC and the subsequent Arab oil embargo, its top priority was to lessen U.S. dependency on foreign countries for meeting its energy needs. At the same time, rising concern with environmental issues such as water and air pollution spumed research on developing cleaner, more efficient energy sources. Nuclear power was an avenue frequently stressed, although the accident at Three Mile Island in 1979, compounded by cost concerns, seemed to slow work on fast-breeder reactors. The Carter Administration also placed particular emphasis on achieving short-term results through work on conservation, cleaner burning coal, solar electrical power, and other sources.

The 1980s saw a marked shift in the priorities of DOE, emphasizing long-term rather than short-term research and stressing the role of the Federal Government as a risk-taker, pursuing research projects that, if potentially profitable, are to be turned over to the private sector for demonstration and commercial development. The Reagan Administration emphasized basic research over applied research, cutting the latter in the mid-1980s while increasing basic research markedly over the same period (see figure 4-6).

**Figure 4-6-Basic and Applied Research at the Department of Energy: Fiscal Years 1980-90 (In millions of 1982 dollars)**




NOTE: Figures were converted into constant 1982 dollars using the GNP Implicit Price Deflator. 1990 figures are estimates.

SOURCES: National Science Foundation, *Federal Funds for Research and Development, Detailed Historical Tables: Fiscal Years 1955-1990* (Washington, DC: 1990), table A; and National Science Foundation, *Selected Data on Federal Funds for Research and Development: Fiscal Years 1989, 1990 end 1991* (Washington, DC: December 1990), tables 4 and 5.

In general, priority-setting mechanisms for research at DOE appear to be very much like those at DOD and NASA in the 1960s.[20] However, compared with other agencies, less accountability is required from project to project. This is not to say that accountability does not exist. DOE is responsive to the scientific community and to the rest of the government. Research managers outside of DOE envy DOE's flexibility, but see the tradeoff as a loss of excitement in working toward a defined goal.

[18] See Advisory Committee on the Future of the U.S. Space Program, *Report of the Advisory Committee on the Future of the U.S. Space program* (Washington, DC: U.S. Government Printing Office, December 1990); and Philip C. Abelson, "Future of the U.S. Space Program," *Science*, vol. 251, Feb. 25, 1991, p. 357.

[19] Gene Koprowski, "OMB to Join S- t on Space Report," *Washington Technology*, vol. 5, Dec. 20, 1990, p. 1.

[20] In the defense programs, although nuclear weapons research occurs within both the Department of Energy (DOE) and the Department of Defense (DOD), there is a clear division of labor. DOD builds the delivery systems and DOE produces the nuclear weapons to go inside them. To set goals, every 2 years a document comes from the Pentagon called ' 'Nuclear Weapons Development Guidance." It outlines the requirements of future systems. Based on this document, supplemented with threat assessments and other analyses, the DOE defense group decides the future direction of their research programs. Generally no large redirection is required.

They wonder, too, about DOE's accountability to basic and applied research missions.[21]

Recently, the Secretary of Energy attempted to institute more strategic planning within DOE. In particular, he created a National Energy Strategy (NES) with input from the offices within DOE and from external advisors. The planning process for the NES required planning at all levels of DOE, and Secretary Watkins has sought to maintain and further this planning function at DOE. As it is too early to observe the changes in response to these initiatives, OTA cannot judge their effectiveness, but such planning is reportedly beneficial at other agencies.

In the Office of Energy Research, programs such as Basic Energy Sciences and High Energy and Nuclear Physics use an "iterative" process of priority setting-where ideas are proposed (with origins both within and without DOE), feedback from the scientific community and other parts of government are received, and the proposal is revised—to determine goals. In particular, as national goals are defined and new ideas arise from either within DOE or without, the program will frost consider them internally. If the new initiative would fit into the existing program or complement it, then the idea will be fielded to a wider audience. Sometimes this audience includes only other parts of the agency. DOE may, however, hold public workshops and/or panel meetings to devise a plan of action.

If a plan is codified by the Office of Energy Research (OER) or within one division, it is sent out for review to DOE personnel, academic and industrial representatives, and other interested parties. This method of fielding new ideas requires much responsiveness on the part of DOE to groups outside of the agency, including the scientific and industrial communities. This method also develops strong working relationships with these communities, but it can have its drawbacks. For instance, some managers complain that the scientific community tries to dictate on occasion (and more than at other agencies) plans that could never gain either the finances or the political support necessary to emerge as new programs.

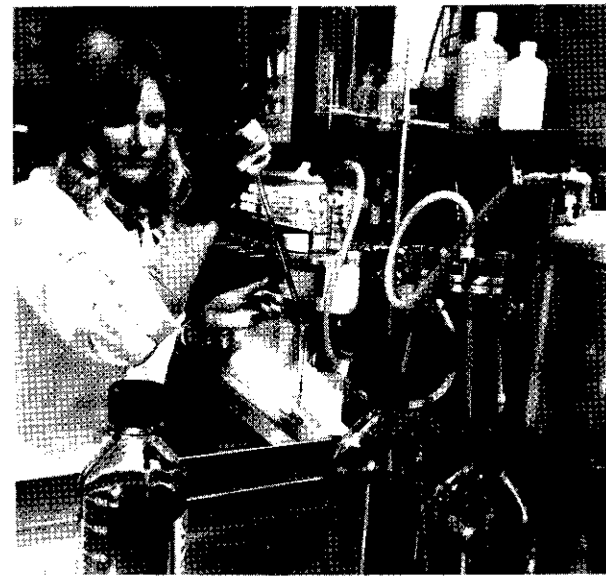


*Photo credit: U.S. Department of Energy*

**Researcher at Oak Ridge National Laboratory studies the health and environmental effects resulting from synthetic fuels conversion processes. The Department of Energy sponsors research in many broad scientific areas.**

Complicating decisions on priorities is the fact that DOE has a very broad research base. For example, under OER, the Basic Energy Sciences program considers its mission similar to NSF. As one manager put it: ''. . . the research that we support is as broad as NSF's, but with a different emphasis. Also, with the major cuts in applied energy research funding during the Reagan Administration, the applied programs in offices outside of OER lost much of their research function. They now may look to OER to develop needed research programs.

In addition, each program has an advisory panel, such as the High Energy Physics Advisory Panel. Until recently there was also an overall advisory committee, the Energy Research Advisory Board (ERAB), which reported to the Director of Energy Research and the Secretary of Energy. This group

[21] Consider for example, the Department's ambivalence over and checkered funding history of the fusion research program. Fusion is seen by many as the best long-term alternative to fossil fuel energy dependence. U.S. participation in a major multinational effort to design a fusion energy test reactor, the International Thermonuclear Experimental Reactor, marks a renewed commitment that is reflected in the Administration's fiscal year 1991 budget. See Mark Crawford, "U.S. Backing for Fusion Project Seen," *Science, vol. 251,* Jan. 25, 1991, p. 371; and Christopher Anderson, "DOE Rallies to Save U.S. Fusion Research Program," *Nature*, vol. 349, Jan. 24, 1991, p. 269.

**was** disbanded in early 1990, and the Secretary has formed the Secretary of Energy's Advisory Board (SEAB), which is already in operation. SEAB's charter has been expanded beyond the scope of ERAB, to include advice on the National Energy Strategy and on the role of the national laboratories.

In the late 1970s and early 1980s, while the Reagan Administration was entertaining notions of abolishing DOE, many interviewees said that the planning for DOE's research was more external to the agency, with NAS and other organizations playing key roles. Program shifts were primarily budget controlled and long-term goals often suffered. Furthermore, many decisions on specific programs were dictated by the scientific community they served. The interviewees state further that the system has now evolved so that DOE can make decisions that balance external as well as internal forces. This is accomplished primarily through the iterative process described above. Differences between programs are due primarily to the constituencies and the types of problems addressed, but differences are also due to historical tradition.

In the applied research offices of DOE, processes of goal setting are also iterative. Most ideas are first taken up internally, and then may be augmented by contractor reports. After much deliberation, they are taken to the public. Five-year plans are written for all new programs and receive extensive review.

In the late 1970s and early 1980s, the process of priority setting for applied research was inward looking. Now with the large consulting process described above and participation by industry, DOE perceives that it is better serving its "client''—the energy industry-and thereby the public. During the Reagan Administration, the emphasis was on funding research that was too risky for industry. Under the Bush Administration, the emphasis seems to have shifted toward projects perceived to have the highest payoff for industry and DOE.[22]

## National Science Foundation

NSF is the fifth largest source of basic and applied research funds in the Federal Government. Established in 1951, it has evolved into an agency composed of eight directorates in addition to the Director's Office. The Director and Deputy Director are appointed by the President and serve 6-year terms. Five of the directorates fund basic and applied science and engineering; another two focus on education, human resources, data, and policy; and one handles NSF's administrative matters. On average, each directorate has five divisions. Each division has several programs.

The primary role of NSF is to support basic research and science education across broad categories of science and engineering. This is done primarily through support for university-based individual investigators, who absorb over 60 percent of the research budget. Aggregate support to groups and centers represents a small portion of the budget (less than 10 percent) and is more sensitive to budget fluctuations.[23] Support for individual investigators is considered the primary mission, even by those managers with portfolios covering group and center support.

A number of research administrators at NSF prefer to use the terminology "fundamental v. directed" rather than "basic v. applied" in making distinctions between categories of research funding.[24] In using the former **terminology, they are** likely to respond that they fund both (but much more fundamental than directed). In using the latter terminology, they are more likely to say they fund only basic research. Most administrators say that they never give a grant with applications in mind, but they are pleased when grantees cite NSF-funded work when seeking patent applications.

In its first operating year, the NSF budget was $151,000. In constant dollars, the budget has grown over NSF's history, although not consistently (see table 4-2). The NSF budget authority for fiscal year 1991 is $2.2 billion. Currently, NSF funding is provided in six separate appropriations: Research and Related Activities (R&RA); Education and Human Resources (EHR, formerly Science and Engineering Education); U.S. Antarctic Program; Facilities, Program Development and Management; and the Office of Inspector General. R&RA has

[22] For example, see Alan Schriesheim, "Toward a Golden Age for Technology Transfer," Issues *in Science& Technology,* vol. 7, winter 1990-91, pp. 52-58.

[23] National Science Foundation, *Report on Funding Trends and Balance of Activities: National Science Foundation 1951-1988*, special report, NSF 88-3 (Washington DC: 1988).

[24] OTA interviews at the National Science Foundation, spring 1990.

**Table 4-2—National Science Foundation Obligations: Fiscal Years 1952-90**
(in millions of constant 1982 dollars)

| Year | Total obligations | Research and related activities |
|---|---|---|
| 1952 . . . . . . . . . . . . . . . | $ 13.6 | $ 7.6 |
| 1954 . . . . . . . . . . . . . . . | 28.6 | 23.1 |
| 1956 . . . . . . . . . . . . . . . | 54.8 | 44.4 |
| 1958 . . . . . . . . . . . . . . . | 159.7 | 102.1 |
| 1960 . . . . . . . . . . . . . . . | 494.1 | 287.0 |
| 1962 . . . . . . . . . . . . . . . | 795.2 | 548.8 |
| 1964 . . . . . . . . . . . . . . . | 1,049.1 | 724.3 |
| 1966 . . . . . . . . . . . . . . . | 1,316.5 | 942.7 |
| 1968 . . . . . . . . . . . . . . . | 1,319.2 | 942.0 |
| 1970 . . . . . . . . . . . . . . . | 1,100.2 | 783.6 |
| 1972 . . . . . . . . . . . . . . . | 1,292.9 | 1,032.2 |
| 1974 . . . . . . . . . . . . . . . | 1,195.7 | 1,000.4 |
| 1976 . . . . . . . . . . . . . . . | 1,148.1 | 972.0 |
| 1978 . . . . . . . . . . . . . . . | 1,187.3 | 1,017.9 |
| 1980 . . . . . . . . . . . . . . . | 1,138.8 | 983.6 |
| 1982 . . . . . . . . . . . . . . . | 999.1 | 909.7 |
| 1984 . . . . . . . . . . . . . . . | 1,213.4 | 1,065.0 |
| 1986 . . . . . . . . . . . . . . . | 1,311.9 | 1,140.0 |
| 1988 . . . . . . . . . . . . . . . | 1,420.1 | 1,202.2 |
| 1990 . . . . . . . . . . . . . . . | 1,586.7 | 1,312.9 |

NOTE: Fiscal year 1990 figures are estimates.

SOURCE: National Science Foundation, *Report on Funding Trends* and *Balance of Activities: National Science Foundation, 1951-1988,* special report, NSF 88-3 (Washington DC: 1988);andNational Science Foundation, press release, PR90-05, Jan.29,1990.

accounted for more than 70 percent of the budget since 1967, and 80 percent or more since 1982. EHR has been the most variable, ranging from 46 percent in 1959 to a low of l.5 percent in 1983. It is also the target of recent increases, approaching an all-time high of $322 million of NSF's $2.2 billion fiscal year 1991 budget.

Within directorates, research funding is very much a bottom-up process. Goals are set by scientific opportunity and the proposal process, as well as in special initiatives from advisory panels. Through its grants program, NSF receives proposals for research spanning the fullest range of science and engineering. The scientific community is NSF's constituency, and program staff project a strong sense of obligation and commitment to that community. There is an explicit ethic pervading the directorates that discourages heavy-handedness in the setting of priorities. Staff serve as interpreters, advocates, and jurors throughout the priority-setting and planning process.

An exception to the above lies in the Engineering Directorate. Created as a separate unit in 1983, Engineering tends to set its priorities around national needs. For example, a recent initiative involved a Request for Proposals in design and manufacturing systems. It was the sense of NSF staff and its advisory committees that there was a need for research in those areas. In addition, the Engineering Directorate tends to address problems more centrally, and many areas of engineering are cross-disciplinary. To this extent, the divisions of Engineering, and the methods by which they set priorities, differ somewhat from the way other directorates operate.

The agency primarily sets priorities and plans through a process described by many as". . . continuous, open, and decentralized. " The decision cycle is keyed to the annual Federal budget and annual appropriation cycles. Eight populations provide formal and informal input into the planning process. They are: 1) the National Science Board (NSB); 2) advisory committees; 3) professional societies; 4) NRC; 5) Visiting Scientists, Engineers, and Educators (also known as "rotators' '); 6) NSF staff; 7) the Inter-Directorate Task Force; and 8) Congress.

Each spring, the advisory committees meet with program managers and division directors to recommend priorities for the current year and years to come. Besides scientific opportunity, staff usually recommend that NSF not fund research already well-supported by other agencies.

Plans are eventually forwarded to NSB for consideration at their June meeting. A strategic plan is developed that must be set against the general recommendations of NSB. For example, in 1989, NSB decided on four general priorities for NSF to pursue-international cooperation in research, education, economic competitiveness, and better methods for leveraging Federal dollars (i.e., to share funding with other-typically State or private-sources). If an organizational unit within the agency proposes a new program that covers all or most of these priorities, it has a very good chance of getting a proportional increase in its budget. For example, in the late 1970s it was decided that there should be more funds for the physical sciences in the 1980s; in the 1980s it was decided that in the 1990s NSF should focus on building strength in engineering and computer sciences. The mid- to late 1990s should bring more funds to environmental sciences and geosciences. National needs are very much a part of the planning process.

In addition to planning conducted on a program basis, there has been increasing attention paid to planning on an activity basis: by whom and how will research be conducted? This has resulted in more support for women and minorities and broader geographic distribution of funds. Between 1985 and 1990, support for the individual investigator went up 25 percent as compared to other research funding modes, such as groups and centers.

NSF faces a daunting task-being all things to all people. The organic act entrusts it with the support of the Nation's basic research and science education. (Thus, every research program at NSF has an impact on human resources.[25]) Within the scientific community, however, there is growing concern that NSF has reduced its flexibility by relying too strongly on traditional mechanisms to set priorities and allocate funds. While not wishing to abandon peer review, NSF has sought some alternatives. A recent report, which addresses these issues of emphasis and process from the perspective of senior staff, stresses that NSF must serve all research performers, streamline the proposal process, and better integrate human resources with research funding considerations.[26]

## Department of Agriculture

USDA is now the sixth largest source of basic and applied research funds in the Federal Government. USDA has a long history of support for research, especially when compared with other government agencies. In 1862, the Merrill Land-Grant College Act recognized the importance of agricultural research and education by setting aside Federal land for agricultural colleges. In 1887, the Hatch Act created the State Agricultural Experiment Stations and assigned administrative responsibility for them to the land-grant institutions. During this time, USDA also grew in power as a research provider, creating an expanding research network.[27]

In the late 1960s, environmental problems began to dominate discussions of research in agriculture, with particular concern expressed for finding alternatives to the use of chemicals as pesticides and in fighting plant and animal disease. Throughout the last three decades, research on human nutrition has been stressed, as well as with finding means for improving the productivity of American farms.

R&D funding levels for USDA since 1955 are tabulated with the other agencies in table 4-3. In constant dollars, USDA R&D funds have hardly grown since 1965. For basic and applied research, the figures are similar. In 1960, USDA research funds totaled just under $0.5 billion. Throughout the 1960s, 1970s, and 1980s, their total grew steadily, but declined from 1985 to slightly under $0.8 billion in fiscal year 1988.

USDA is advised by many groups. Most important is the Joint Council on Food and Agricultural Sciences (JCFAS), created by an act of Congress in 1977 to coordinate and encourage research, extension, and higher education in agriculture. Its members include influential representatives from public and private sectors, producers, industry, and government; as well as directors of research, extension, and higher education activities in universities, agricultural experiment stations, and other centers. While JCFAS has the mandate to evaluate and recommend changes to USDA programs, it cannot direct USDA to institute them. Another advisory body is the Users Advisory Board on Research and Education, with membership selected from those who benefit from research and education. These and other groups advise the various research components of USDA.

### Agricultural Research Service (ARS)

ARS was established in 1953 as USDA's inhouse agricultural research agency.[28] The National Program Staff (NPS) is a core component of ARS headquarters and is responsible to the administrator for planning, developing, and coordinating the ARS

[25] Although the National Science Foundation's (NSF) share of the total Federal research and development budget requested for fiscal year 1992 is only 3 percent, its education and human resources programs represent 23 percent of the total proposed Federal agency effort. Programs such as Research Experiences for Undergraduates (which is slated to support almost 12,000 students) are increasingly visible. See Frederick M. Bernthal, acting director, National Science Foundation testimony at hearings before the House Committee on Science, Space, and Technology, Subcommittee on Science, Feb. 20, 1991, pp. 7-8, 11.

[26] See National Science Foundation Report *of the Merit Review Task Force,* NSF 90-113 (Washington DC: Aug. 23, 1990); and Jeffrey Mervis, "Panel Weighs Overhaul of NSF's Grant System," *The Scientist, vol. 5, No.* 1, Jan. *7,* 1991, pp. 1,6-7, 12.

[27] Lawrence Busch and William B. Lacy, Science, *Agriculture, and the Politics of Research* (Boulder, CO: Westview Press, 1983).

[28] Central offices of the Agricultural Research Service (ARS) are in Washington, DC, and Beltsville, MD. There are approximately 7,000 full-time employees (of which 2,350 are scientists) scattered across the United States, Puerto Rico, the Virgin Islands, and several foreign countries. Research is conducted at 122 domestic and 6 overseas locations by civil service scientists. Last year there were about 1,700 projects ongoing with budgets ranging from $100,000 to $1 million. Much of the work of ARS is conducted in direct cooperation with the State agricultural experiment stations, other State and Federal agencies, and private organizations.

**Table 4-3—Trends in Federal Obligations for Total Research and Development, by Major Agency: Fiscal Years 1955-88 (in millions of constant 1982 dollars)**

| Year | USDA | HHS | NSF | DOE | NASA | All other agencies | Total nondefense agencies | DOD |
|---|---|---|---|---|---|---|---|---|
| 1955 | $347 | $ 327 | $ 46 | $1,574 | $ 207 | $ 325 | $2,586 | $9,591 |
| 1960 | 505 | 1,284 | 300 | 3,059 | 1,483 | 759 | 7,390 | 22,938 |
| 1965 | 788 | 3,050 | 657 | 4,353 | 17,374 | 1,156 | 27,525 | 23,753 |
| 1970 | 738 | 3,205 | 758 | 3,533 | 9,974 | 2,410 | 20,941 | 19,319 |
| 1975 | 728 | 4,155 | 1,031 | 3,548 | 5,311 | 2,603 | 17,376 | 15,620 |
| 1980 | 804 | 4,421 | 1,031 | 5,560 | 3,783 | 2,938 | 18,357 | 16,352 |
| 1985 | 837 | 4,865 | 1,195 | 4,410 | 2,955 | 2,227 | 16,490 | 26,458 |
| 1988 | 778 | 5,079 | 1,379 | 4,027 | 3,636 | 1,862 | 16,761 | 34,489 |
| **Agency Percentage of Total Annual Nondefense R&D Funding** | | | | | | | | |
| 1955 | 13.4 | 12.6 | 1.8 | 60.9 | 8.0 | 12.6 | 100 | |
| 1960 | 6.8 | 17.4 | 4.1 | 41.4 | 20.1 | 10.3 | 100 | |
| 1965 | 2.9 | 11.1 | 2.4 | 15.8 | 63.1 | 4.2 | 100 | |
| 1970 | 3.5 | 15.3 | 3.6 | 16.9 | 47.6 | 11.5 | 100 | |
| 1975 | 4.2 | 23.9 | 5.9 | 20.4 | 30.6 | 15.0 | 100 | |
| 1980 | 4.4 | 24.1 | 5.6 | 30.3 | 20.6 | 16.0 | 100 | |
| 1985 | 5.1 | 29.5 | 7.2 | 26.7 | 17.9 | 13.5 | 100 | |
| 1988 | 4.6 | 30.3 | 8.2 | 24.0 | 21.7 | 11.1 | 100 | |

KEY: USDA=U.S. Department of Agriculture; HHS=U.S. Department of Health and Human Services; NSF=National Science Foundation; DOE=U.S. Department of Energy; NASA=National Aeronautics and Space Administration; DOD=U.S. Department of Defense.

NOTE: Totals are not exact due to rounding.

SOURCE: National Research Council, *Investing in Research: A Proposal to Strengthen the Agricultural, Food, and Environmental System* (Washington, DC: National Academy Press, 1989), table A.l, p.96.

national research program. There are about 30 NPS employees with expertise in a discipline, commodity, or problem. Their role is individually and collectively to plan research programs, set priorities, allocate resources, review and evaluate research progress, and provide coordination.

ARS has a long-range Program Plan-designed in the 1980s—and an Implementation Plan, which describe how the Program Plan is to be operated over a 6-year period. The Program Plan focuses on the goals, objectives, and broad research approaches that ARS will pursue. The current Implementation Plan covers 1986 through 1992 and considers, among other things, how the budget and shifts in research needs relate to the goals and mission of the agency. This strategic planning is relatively new, having started in 1983. Administrators of NPS feel that the development of the Implementation Plan has enabled them to set priorities, helped in redirection of finds, and has increased communication between ARS and groups such as other USDA agencies, Congress, user groups, and scientists.

The Implementation Plan was put together by NPS and the ARS laboratories with input from industry, academia, and regulatory agencies. Because program areas often overlap, NPS works together in planning for the entire research program. NPS, therefore, is very centralized and not only does planning and priority setting, but also makes allocation decisions and performs program reviews.

### Cooperative State Research Service (CSRS)

CSRS is USDA's ". . . principal entree into the university system of the United States for the purpose of conducting agricultural research." It . . . participates in a nationwide system of agricultural research program planning and coordination among the State institutions, USDA, and the agricultural industry of America."[29] Programs of research are jointly developed with the State Agricultural Experiment Stations, forestry schools, 1890 Land-Grant Universities, and other cooperating institutions. The most recent planning exercise resulted in the strategic plan entitled "A Research Agenda for the 1990s. ' This is the first time that such a strategic plan has been developed. It outlines current research efforts and areas of proposed enhancement, including the safety and stability of consumer foods, and the protection of water quality.

[29]Cooperative State Research Service, "Budget Submission for 1990," hearing before the House Subcommittee on Rural Development Agriculture, and Related Agencies Appropriations of the Committee on Appropriations, Part 2, p. 444, 1989.

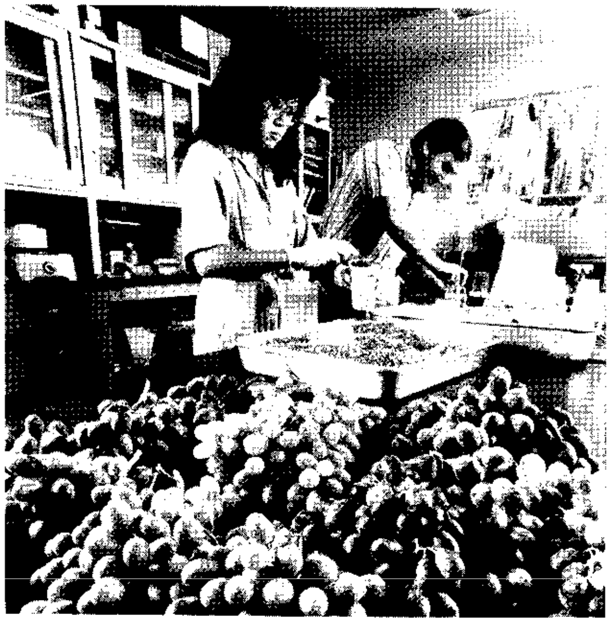


*Photo credit: U.S. Department of Agriculture*

**An Agricultural Research Service scientist (rear) and a graduate student (front) transplant seedless grape varieties. Research and education are intertwined in many research areas.**

The majority of CSRS Federal funds (approximately $200 million out of the $340 million in fiscal year 1989) comprise *formula funds,* which are directly appropriated by specific acts of Congress. *Special Research Grants* amount to another $61 million (fiscal year 1989), and consist mostly of line item appropriations (which many liken to earmarks) requiring oversight from CSRS. Priority setting is negotiated between the cooperating institutions and CSRS. In addition, the *Competitive Research Grants Office* (CRGO) conducts a nationwide competition for basic research funds in specific fields. CRGO began in 1978 with programs in plant science and nutrition and, by 1985, it had expanded to include animal and biotechnology research. NRC, with strong support from USDA, has proposed a National Agriculture Research Initiative, which would enlarge the USDA Grants Program from $45 million to over $500 million. The program would increase research funds in areas not presently supported at USDA, such as global climate change.[30]

## Forest Service

The research mission of the Forest Service is to ". . . serve society by developing and communicating scientific information and technology needed to protect, manage, and use the renewable natural resources of the Nation's 1.6 billion acres of forest and related range lands."[31] Within the structure of USDA, the Forest Service is quite separate from CSRS and ARS, as it reports to the Office of the Assistant Secretary for Natural Resources and Environment rather than the Assistant Secretary for Science and Education. Furthermore, its budget is not considered by the congressional agriculture committees in Congress, but by the interior committees.[32]

The decentralized nature of the Forest Service research work force encourages bottom-up planning.[33] Reently the Forest Service stations have been required to submit budgets at four different funding levels, ranging from 90 percent of the funding level 2 years before to 10 percent over the agency request from the prior year. An iterative process between Washington and the stations adjusts what work will be done at different budget levels. Perhaps the most important trend is that in the early 1980s, and before, the budget process was tightly controlled by the Deputy Chief for Forestry Research. Now the process is much more open, and the stations are more responsive to national problems, such as global change, water quality, and endangered species. For instance, the percentage of funding devoted to national problems rose from 28 percent in fiscal year 1989 to 42 percent in the fiscal year 1991 Presidential request, with new developments funded as special initiatives.

[30] See U.S. Department of Agriculture, Cooperative State Research Service, *National Research Initiative Competitive Grants Program: Program Description* (Washington DC: 1990).

[31] See U.S. Department of Agriculture, "Strategy for the '90s for USDA Forest Service Research," review copy, February 1990.

[32] The Forest Service has eight regional Research Stations and the Forest Products Laboratory (FPL) where researches conducted. Within the 8 stations and FPL, 190 Research Work Units (RWUs) are gathered at 74 locations. Over 700 scientists work in these units with a total budget of nearly $150 million. Extramural research is supported at a low level—approximately $14 million per year, although this is deceptive since many of tlRWUs are located on college campuses.

[33] In practice, Research Work Unit Descriptions (RWUDs) charter work in a particular problem area. They usually prescribe a plan for a 5-year duration and often will build directly on previous work. The Station Director has a large amount of discretion to choose projects at the RWU level, and the RWUDS are reviewed inhouse in the Washington Office to provide balance in a nationally coordinated program.

OTA found in this and earlier studies that investment in research at USDA has lagged behind other agencies, and that USDA has difficulty in clearly stating its mission, planning for the future, or setting priorities in research.[34] Consequently, much of the new agriculture-related science (e.g., biotechnology) is performed by scientists who are not trained in the agricultural sciences and who do not pursue agricultural problems. Many blame the lack of growth in research funding at the agency to the lack of a comprehensive strategic plan.[35]

### Other Agencies

**The six** agencies described above together devote over $11 billion annually to basic research. Also contributing to the research base, but on a much smaller scale, are the following 10 agencies: the Alcohol, Drug Abuse, and Mental Health Administration (in HHS); the U.S. Geological Survey (in the Department of the Interior); the Smithsonian Institution; the Environmental Protection Agency; the National Institute of Standards and Technology and the National Oceanic and Atmospheric Administration (both in the Department of Commerce); the Department of Veterans Affairs; the Department of Education; the Agency for International Development (in the Department of State); and the Department of Transportation. This group of 10 agencies represents approximately 5 percent of the total Federal expenditure on basic research.[36] Although their contribution is comparatively small, these agencies lend breadth and flexibility to the Nation's research capacity.

## Crosscutting Descriptions of Agency Priority Setting

Comparisons of the research agencies reveal the variation and complexity in the Federal research system. While agency cultures are very different, the prospect of transferring methods and standards across agency boundaries deserves consideration. OTA first examines various characteristics of the organization and management of the Federal research system.

### Division of Labor

**The** Federal research system can be thought of as a composite of the various agencies that support research. Each agency has a mission and therefore a purview of research responsibility. NSF and NIH, for example, have the broadest scope in research areas funded. Any project within a discipline that is of high quality and does not clearly fall under any other agency's jurisdiction can be a candidate for funds.[37]

NASA, DOE, DOD, and USDA have more restrictions (than NIH or NSF) on the research areas that they support. NASA supports science that can make use of space (and most often seeks information about space), either through satellites, experiments above the atmosphere, or human exposure to zero gravity. DOE funds research relating to nuclear weapons and all forms of energy and its effects on humans and the environment, which is interpreted broadly in the Department.

Although some claim that because the research areas supported by DOD and USDA are closely tied to their technical missions, the research by definition cannot be basic or fundamental in nature. Indeed, OTA finds that the research supported by these agencies can be as fundamental as that supported by other agencies, such as NIH or NSF. In addition, the amount of funds spent on basic research at these agencies is comparable in size to that disbursed by NSF. Nonetheless, these agencies' priorities shape research goals.

Areas of support among the agencies allow a multitude of questions to be posed and investigated differently within the research system. This also provides some measure of pluralism in research opportunities, i.e., many researchers have two or three agencies (and even more programs) within the

[34] U.S. Congress, Office of Technology Assessment, *Agricultural Research and Technology Transfer Policies for the 1990s*, special report, OTA-F-448 (Washington DC: U.S. Government Printing Office, March 1990).

[35] Ibid.

[36] All budget &I@ reported below are based on National Science Foundation Division of Science Resources Studies, *Federal Funds for Research and Development: Detailed Historical Tables, Fiscal Years 195.5-1990 (Washington DC: 1990);* and National Science Foundation, *SelectedData on Federal Funds for Research and Development: Fiscal Years 1989, 1990, and 1991* (Washington DC: December 1990).

[37] Researchers quickly learn what research is and is not eligible for funding at an agency. Program announcements, Conversations with program officers, and the fate of other submitted proposals convey to the researcher which agency (and program within it) is an appropriate source of funding. This, too, is part of the agency culture, which forms a constituency of extramural research performers.

Federal Government to apply for funds. Pluralism has long been hailed by the scientific community as a strength of the research system in the United States.[38] However, the pursuit of agency missions is not without legislative contention, as Congress consistently asks agency managers, in authorization and appropriations hearings, how specific research programs support the agency mission.[39]

### Coordination

The division of labor among the agencies does not seek to eliminate overlap; indeed, agencies cooperate to fund some areas of mutual interest. Agencies with broad research agendas, such as NSF and NIH, coordinate more routinely with other agencies—more than those, such as USDA, with a more narrow scope.

In addition, because of the size of agencies and departments, coordination *within the* agency or department can be important as well. For example, the services in DOD sometimes attempt to find a niche in a scientific area so there is no overlap with another service. In supercomputers or artificial intelligence, for instance, the Air Force has chosen to rely on the other services. The Air Force in turn takes the lead in other areas, such as mathematical control theory. In areas that require overlap, however, agencywide committees are often employed to coordinate the activities of the services, DARPA, and SDI0.[40]

Coordination among and within Federal agencies occurs at two levels, at the agency program level and at the research performer level. Agency-level coordination generally occurs through committees. One standing coordinating mechanism is the Federal Coordinating Council on Science, Engineering, and Technology in the Office of Science and Technology Policy. It has several subcommittees, such as Global Change and High-Performance Computing, which provide a forum in which agencies can communicate (see chapter 5). Other committees that are not governmentwide also exist, which may coordinate two or more agencies on a specific topic.

Researcher and program manager level coordination occurs through meetings and other communication that is a normal part of the discourse of the scientific community. It is at this level that the separate roles of agencies are most apparent and that researchers accommodate to changing funding levels in the cooperating agencies. An illustration of agency and performer interaction can be found in superconductivity research (see box 4-C).

### Bottom-Up and Top-Down Management, and the Use of External Advice

**One** of the most prevalent styles of management of research has been loosely titled bottom up, which implies that research ideas and priorities originate with researchers who communicate these ideas to their sponsors (agency program managers, for example). These managers in turn talk to their superiors. As ideas percolate, their relative importance is set. Bottom-up management contrasts with top-down management, where the most senior decisionmakers in an agency decide the priorities for the system, or their part of it. These directives are then transmitted down the organizational ladder in consultation with managers, eventually to researchers.

OTA finds that in the research agencies both kinds of management are prevalent and are often mixed. In short, decisionmaking is more complicated. Some agencies employ much stronger top-down direction. In the Agricultural Research Service of USDA, priorities are set by the National Program Staff, and at DOD, managers at all levels exert a great deal of influence over the areas in which they support projects. On the other hand, agencies such as NSF and NIH employ mostly bottom-up management. At NSF, this means that only priorities among areas of support are set at the top (by the Director, the Assistant Directors, and NSB). For example, deci-

[38] As Hunter Dupree observed: "A plural set of government agencies went to a plural set of congressional committees to ask for appropriations, which were then distributed by grant and contract to investigators in a plural set of universities.' Quoted in U.S. Congress, House Committee on Science and Technology, Task Force on Science Policy, *A History of Science Policy in the United States, 1940-1985, 99th* Cong. (Washington, *DC:* U.S. Government Printing Office, September 1986), p. 40.

[39] Overlap in support responsibility among agencies for certain areas of research ensures better diffusion of results into multiple applications, a kind of inadvertent diffusion policy. Harvey Brooks, Harvard University, persona communication, February 1991.

[40] A very good example is the Joint Services Electronics Program, operated continuously since 1945, in about 20 or so universities. The three military services provide equal contributions to each university group, but delegate administration to one service. For example, Harvard University and the Massachusetts Institute of Technology each have such a program administered by the Office of Naval Research. This is a fairly successful interdisciplinary program. Ibid.

### Box 4-C—Coordination of Superconductivity R&D

Major research initiatives are usually executed by one Federal agency, based on the scope of the research and the mission of that agency. There are exceptions, of course, where research on one area is done in several different agencies, and these research areas bring with them the added burden of coordination. In the case of superconductivity, coordination becomes especially important since research is spread among several different agencies, primarily the Departments of Defense (DOD), Energy (DOE), and Commerce, the National Science Foundation, and the National Aeronautics and Space Administration (NASA).[1]

There are two aspects of coordination that require quite different approaches. First, coordination is required to monitor the different programs and make appropriate decisions to ensure an efficient allocation of research funds to all of the agencies. Second, at the researcher and program level, there must be an adequate flow of information between researchers to avoid overlap or duplication of research. Effective coordination at both the national level and the researcher level is vital to a successful research program.

Congress has made several attempts to encourage coordination of superconductivity research and development by the executive branch. Part of the 1988 Omnibus Trade and Competitiveness Act created the National Commission on Superconductivity (NCS) which was to meet, produce a report and then dissolve by December 1989. The Trade Act also mandated an increase in staff for the National Critical Materials Council (NCMC), which at the time had no active members. Finally, the National Superconductivity and Competitiveness Act of 1988 called for cooperation between the Office of Science and Technology Policy (OSTP), NCMC, and NCS in order to produce a 5-year National Action Plan for Superconductivity to be accompanied by annual reports.

The success of these initiatives has been limited. The 5-year National Action Plan was published in December of 1989, but the formation of NCS was delayed, so it did not take part in the plan's formation. Although the plan itself acknowledged the need for better Federal coordination, it lacked both the budget recommendations and the long-term perspective Congress had requested.[2] In addition, the Federal Coordinating Council on Science, Engineering, and Technology Committee on Superconductivity report of March 1989 did little more than assemble agency superconductivity budget data and list various prograrns.[3]

Fortunately, at the researcher and agency program level, the exchange of information has successfully protected superconductivity research from overlap and duplication. Programs at different Federal agencies have aided scientists in the exchange of research information, if not actual coordination of effort. The Ames laboratory distributes the "High-Tc Update," a widely read newsletter; the national laboratories have broadcast nationally several high-temperature superconductivity conferences; and DOE has established a computer database that shares research results with industry. NASA also maintains communication through the Space Systems Technical Advisory Committee, a group with representatives from industry, universities, and government organizations.

The success of the ground-level coordination efforts is promising, but the resistance to priority setting from the administration may inhibit the progress of superconductivity research. In particular, such questions as whether DOD funds too high a percentage of superconductivity research, and whether the Federal laboratories are doing too much of the research relative to other performers are important to the future success of the development of superconductivity. These questions must be addressed through agency-level coordination,

[1]Funding levels at each agency, of course, are a separate and perhaps 'ore pressing issue. See Kim A. McDonald, ''Panel Urges Increased Support for Superconductivity, Recommends Specific Goals for Research in Field,'' *The Chronicle of Higher Education*, VOL 36, No. 48, Aug. 15, 1990, pp. A5, A7.

[2]U.S. Congress, Office of Technology Assessment, *High-Temperature Superconductivity in Perspective*, OTA-E-440 (Washington, DC: U.S. Government Printing Office, April 1990), p. 63.

[3]Ibid., p. 69.

sions are made to support the physics program at one funding level and the chemistry program at another. Bottom-up management at NSF and NIH leads to a different selection mentality than that in other agencies, specifically to reliance on peer review as a formal mechanism for incorporating advice from the scientific community.

Agencies that are more bottom up also tend to employ more panels or to commission more studies from outside of the agency to help set priorities. At NSF, NIH, and NASA, standing external committees, NAS, the National Academy of Engineering, and the Institute of Medicine play significant roles in deciding agency priorities. However, agencies such as DOE, USDA, and DOD employ outside panels to assist in determiningg research directions to a lesser extent.

Another difference between top-down and bottom-up management is the degree to which the agency becomes invested in the success or failure of a project. For example, DOD has a large operational investment in the results of the research it supports. This provides an atmosphere that reminds researchers that DOD has a stake in their success. Consequently, these researchers report favorably that DOD is more realistic about the funds and time needed to complete a project, and program managers are more available during the course of the project to aid with difficulties that may arise.[41] This contrasts with the experience of NSF and NIH researchers where the agency does not have a stake in the success of any *one* project, because there is no expectation of direct ''use' and no timetable for making ''progress.

### intramural and Extramural Research

Five of the agencies that OTA studied support intramural research (NIH, DOE, DOD, NASA, and USDA). Intramural research facilities are most often within laboratories either run directly by the agency or by an outside contractor. Together the Federal research agencies are the primary sponsors of hundreds of laboratories. Some are administered directly by the Federal Government, such as NASA's Goddard Space Flight Center, while others are administered by a university or corporation, such as DOE's national laboratories. Laboratories can be funded *institutionally,* where monies flow from the research agency to support all activities at the laboratory, or *industrially,* where the laboratory competes with other laboratories and research organizations to perform research for clients in number of research agencies. Often there is a mixture between institutional and industrial support within a laboratory, as in many of the DOE national laboratories.

#### Intramural Research

Research in intramural laboratories has many distinct advantages for the Federal Government.


*Photo credit: U.S. Department of Energy*

**Los Alamos National Laboratory (LANL) is one of the oldest intramural laboratories of the Department of Energy. LANL was established in 1943 to develop World War II atomic bombs, and today retains responsibility for conducting defense-related research programs. Research at LANL has also diversified into other fields such as fossil and geothermal energy.**

First, laboratories can maintain a research effort over one or more decades. Second, laboratories can easily incorporate a multidisciplinary approach to problems. Third, DOE managers report that they more often fund ''risky' research-research that has a very good chance of abject failure, but also a good chance of resounding success—at the laboratories, because the laboratories can absorb a setback without jeopardizing graduate students or young faculty. Fourth, project managers can easily maintain their involvement in the projects at a laboratory. Fifth, the research at the laboratories can be put "on the fast track," in the words of one manager, when the results are needed on a timetable. Sixth, there is ample evidence that the laboratories can often perform research at a reduced cost to that performed extramurally. Finally, the laboratories are often the only sensible place to site facilities needed for a project, because access and maintenance can be assured.[42]

Disadvantages of intramural research include problems in recruiting and retaining personnel. The

[41] This suggests that differences in project monitoring more or less create the need for ex post accountability-and the call for evaluation of project outcomes (see ch. 8).

[42] This also makes laboratories important sites of science education. The role of mission agencies and their laboratories in science education has grown noticeably, especially at the Department of Energy. See U.S. Congress, House Committee on Science, Space, arTechnology, Subcommittee on Energy Research and Development, *Role of the Department of Energy's National Laboratories in Science, Engineering and Mathematics Education,* 101st Cong. (Washington DC: U.S. Government Printing Office, June 13, 1990).

government laboratories must pay on the Federal. pay scale, but while salaries have risen in academia and industry for scientists, growth in salaries in the Federal Government has been very slow.[43] Consequently, although research problems addressed at the laboratories and the research environment can be very exciting, researchers are often attracted by much higher paying and more flexible jobs elsewhere.[44] Some critics claim that the pay scale and government cutbacks have limited the quantity and quality of research in the Federal laboratories.[45] In addition, intramural laboratories often do not support graduate students, which are an invigorating part of research.

Another disadvantage is that many laboratories are large organizations. While they were built with a mission (or a set of missions) in mind, the mission may have been achieved or abandoned.[46] The laboratory must then find a new mission or face the prospect of downsizing or phaseout. Laboratories have sometimes moved from mission to mission, but this can lead to great stress in the organization.[47]

### Extramural Research

The advantages of extramural research include competition on the ''open market" for the best research teams for a particular problem. (Note that laboratory teams can often compete for these funds as well.) Extramural researchers are paid competitively and can be solicited for one project. The research performers are top scientists in an area and enjoy access to state-of-the-art equipment.

Disadvantages of relying on extramural research are, frost, that extramural researchers must bid for the project. If a new project is not associated with enough gain (either in money, equipment, or publications), it is difficult to find extramural researchers willing to apply (although this may also be true in some cases for intramural laboratories) .48 In academia, government-sponsored research is also constrained by the academic environment. For example, although DARPA funds university research, on some projects DARPA finds it difficult to work solely with universities. The university structure of research, with a professor and his or her graduate students, often operates too slowly for DARPA's purposes. Also, DARPA reserves the right to terminate at any point, which can be disastrous for a professor and especially for a graduate student.

OTA finds that both intramural and extramural capabilities are important for the advantages they provide the agencies; both should be supported by the Federal Government.[49] At present roughly one-quarter of all research funds are spent intramurally, slightly under one-half extramurally in universities or colleges, one-quarter in industry, and one-twentieth by other performers.[50]

## Issues of Agency Priority Setting

Some priority-setting issues are of particular concern across all of the research agencies. OTA identifies four in particular: 1) risk-taking and conservatism, 2) flexibility, 3) strategic planning, and 4) redirecting the agencies.

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43 U.S. Department of Commerce, Bureau of Economic Analysis Government Division, ''Biomedical Research and Development Price Index,'' report to the National Institutes of Health, Mar. 30, 1990,

'Pepper Leeper, ''NIH Intramural Program: No Radical Changes Needed,' *NewsReport of the National Research Council, December 1988-January 1989, pp. 2-5.*

45 For example, *see* Knezo, op. cit., footnote 9, p. 38. Similar statements were made in several OTA interviews at the research agencies.

46 ''Also, big labs tend t. become bureaucratized as Federal pay policy leads to a gerontocracy, with the least entrepreneurial people staying on. A big disadvantage of intramural research is that it is much easier to do relatively 'boring' but vitally useful research, e.g., spectroscopic tables, and systematic physical and chemical property measurements. ' Brooks, op. cit., footnote 39.

47 Evidence of ferment has been most apparent at the Department of Energy. See Council on Competitiveness, ''National Labs Meet With DOE," *Legislative and Policy Update, vol. 3, No. 2,* Jan. 28, 1991; Mark Crawford, ''Domenici Bill to Broaden Labs' Missions," *The Energy Daily,* vol. 19, No. 14, Jan. 22, 1991, pp. 1-2; and''Roundtable: New Challenges for the National Labs," *Physics Today*, February 1991, pp. 24-35.

48 This problem could be compounded by the recent Bush Administration proposal to charge users of Federal facilities, such as Brookhaven National Laboratory's synchrotrons light source, a fee to cover operating costs. See Mark Crawford, ''Researchers Protest User Fees at National Labs," Science, vol. 251, Mar. 1, 1991, p. 1016.

49 In response t. outside panel recommendations, three agencies with substantial inhouse research—the Department of Agriculture, the National Oceanic and Atmospheric Administration, and the Environmental Protection Agency—me seeking to expand their extramural programs, if Congress approves. See Elizabeth Pennisi, ''New Policies at Three Federal Agencies Lend More Support to Outside Research,'' *The Scientist,* vol. 5, No. 2, Jan. 21, 1991, pp. 3,5.

50 See Bette Hileman, ''Facts and Figures for chemical R&D,' *Chemical & Engineering News,* vol. 68, No. 34, Aug. 20, 1990, pp. 28-30.

### Risk-Taking and Conservatism

Agency cultures promote differences in the kinds of projects selected for funding. In particular, agencies differ to a large extent in the amount of risk-taking in research that they encourage in scientific programs and by research managers. Risk-taking can be defined in a number of ways. Perhaps most important is that risky research is not considered in the mainstream, no specific outcome of the project is assured, and a large chance of failure exists (i.e., of not reaching the objectives set out in the proposal). However, the definition of risky research changes depending on the agency and field of inquiry, and to some extent, every research project is inherently ''risky. '

Within agency cultures some programs can assume more risks, because in the pursuit of a specific objective it is often wise to try some conservative, yet slower means, along with more experimental, less certain paths that might yield large payoffs. DOD claims to take the most risks in the course of its research program. DOD ***expects*** that most basic research will not attain the results that it originally proposed. Within the 6.1 category, DOD research managers assume that less than 30 percent of the projects will succeed; within 6.2, roughly 30 to 60 percent; and, within 6.3A, roughly 60 to 90 percent. Supporting unsuccessful projects is viewed as part of the business of finding projects that do pay off.[51]

in contrast, when there is no defined goal, how is risk defined-proposals that earn diverse ratings from peer reviewers? that are submitted by researchers with no track record? or that appear to be of marginal interest to the particular program weighing its merits? Attributes of risk are not clear cut. Further, the pace and impact of results emerging from federally funded research projects are no guide to their ''riskiness,'' judged retrospectively.

Yet NSF and NIH managers claim that 90 percent or more of the projects that the agencies support are "successful.' Success in the NSF and NIH context may mean that refereed publications were produced from the project. This satisfies the criterion of adding to the archive of knowledge, without measuring how that research was received by the community.[52] NSF has recognized a need to support more "high-risk" projects, instituting the Small Grants for Exploratory Research program to engender more risk-taking (see box 4-D).

Since it is obvious that not all scientific advances are made through slowly evolving research (epitomized by DOE's fusion energy program), but often with new and exciting projects, it is important for each Federal agency (and probably most research programs within it) to support both kinds of projects. This point is recognized by the scientific community when it simultaneously urges funds for new avenues of science as well as for the "science base, " by which is meant the protection of evolutionary (and usually individual investigator, small team) research. While DOD addresses risk-taking through expectations for project outcomes and NSF has created a separate program, most agencies rely on program manager discretion to incorporate risk-taking. As priorities are set in new areas, it is very important to continue, and even augment, risk-taking in individual investigator research, and agencies should be encouraged to increase their efforts to fund risky projects.

### Flexibility

When new priorities are introduced at a research agency, it must be flexible enough to reorient and develop relevant programs. Flexibility can be defined in a number of ways. But the most critical aspect of flexibility for funding scenarios in the Federal Government is the ability to make tradeoffs among scientific programs and to pursue growth by substitution-to start and stop programs, and to encourage new ideas without allowing fiscal constraints to hinder (or undermine altogether) their pursuit.

At the program level, flexibility is already provided in several ways. First, many agencies budget discretionary monies for managers to pursue new ideas. For example, some agencies (e.g., the Office of Naval Research) divide their pools of money into ''core' and 'accelerated' research initiatives. Core programs maintain expertise in certain areas and rely on principal investigators to propose goals for their research. Accelerated initiatives allow significant amounts of money to be quickly infused into a specific project area. Second, programs that disburse

[51] These figures are a consensus among the Department of Defense managers whom OTA interviewed.

[52] For example, see Malcolm Gladwell, "Are Nobel Prizes for U.S. Vestiges of 'Golden Age'?" *The Washington Post, Nov. 16, 1990,* p. A6.

### Box 4-D—Small Grants for Exploratory Research

Risk-taking is an important part of scientific research. In particular, the rate of scientific advancement witnessed this century could not have been achieved had the Nation not invested in some high-risk research along the way. However, the National Science Foundation (NSF) has been criticized that its funding decisions, based on a system of external peer review system, has become too conservative.[1] In response, NSF instituted in 1989 the Small Grants for Exploratory Research (SGER) program, which funds only small, high-risk research projects. In the words of a former NSF assistant director, who spearheaded the pilot program that led to SGER: ''With the small amount of money, relatively, that NSF can give out, we cannot take care of all research needs. On the other hand, we have sufficient amounts of money to stimulate more creative and innovative research by playing a catalytic role.

SGER grants are funded differently from ordinary NSF grants in several important ways. ‘he definitive difference is that SGER grants go exclusively to researchers who are exploring "novel ideas" or "emerging research areas. In addition, NSF eliminated formal, external peer review. Final recommendations on funding are left entirely up to the program manager, although the manager may certainly seek as much advice as he or she desires. More than in other NSF programs, grant applicants are encouraged to discuss their proposals with the pro@ manager before submitting them in order to ascertain the proposal's chance for success. This reduces the number of unsuccessful proposals submitted, thus increasing the efficiency of the process and saving time. Also, this practice helps to foster a favorable working relationship between the researcher and the program manager. However, critics fear that this interaction might ''. . . work against faculty who are not comfortable with selling themselves to others.

Processing speed is another important aspect of the SGER program, as high-risk research often implies fast-paced. SGER grants are limited to $50,000, and the duration is no more than 2 years, usually only 1. Keeping grants on this smaller scale can make them easier to process.

In 1990, NSF funded 244 SGER proposals (while declining 210) at an average award of $34,254.[5] Also encouraging is the amount of activity in divisions, such as the biological sciences and Earth sciences, where the SGER prograrn is being instituted for the first time.[6] The SGER program appears to provide an outlet for NSF to fund cutting-edge, high-risk research that the traditional NSF peer review system might not be equipped or inclined to support. The genre most served seems to be "cross-disciplinary' research, such as studies of natural disasters.[7] In addition, an Expedited Awards for Novel Research program (forerunner of SGER) survey of recipients found that 90 percent of SGER-funded researchers go on to apply for a regular NSF grant.[8]

SGER program spending is limited to 5 percent of each program. However, it appears to provide access to NSF funding for new researchers and, as one researcher put it, SGER support might result in ". . . fewer publications per dollar, but more chances for quantum leaps in advancing science. "[9]

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1The National Science Foundations own survey of 14,000 applicants who had been awarded or declined fund@ during fiscal year 1985 found that two out of three agreed with this statement: "NSF is not likely to fund high-risk exploratory research because the like W of obtaining favorable reviews is slim," See National Science Foundation, Program Evaluation Staff, *Proposal Review at NSF: Perceptions@ Principal Investigators*, NSF 88-4 (Washington, DC: February 1988), p. 18.

2Nam Suh quoted in David Bjerklie, "Fast-Track Grants," *Technology Review.* vol. 93, No. 6, August/September 1990, p. 19.

3What follows, unless otherwisindicated, is based on National Science Foundation, Small Grants for Exploratory Research brochure, 1989.

4James M. McCullough, tire, Program Evaluation Staff, National Science Foundation, "Responses to Bulletin Board Message About Quick-Response, Non-Reviewed Gin@" Mar. 10, 1989, p. 5.

5Preliminary statistics on the Small Grants for Exploratory Research program provided by James McCullough, director, Program Evaluation Staff, National Science Foundation, personal communication, Jan. 23, 1990.

6National Science Foundation, unpublished data, Aug. 8, 1990.

7The fate of such proposals at the National Science Foundation, at least before the scope of the Engineering Directorate was enlarged, was problematic. See Alan L. Porter and Frederick A. Rossini, ''Peer Review of Interdisciplinary Research Proposals,'' Science, *Technology, & Human Values*, vol. 10, No. 3, summer 198S, pp. 33-38.

8Investigators without prior National Science Foundation support are encouraged to apply to the Small Grants for Exploratory Research program, and the program indeed seems to attract many fret-time applicants. See Bjerklie, op. cit., footnote 2, p. 19.

9Responses to McCullough, op. cit., footnote 4, p. 7.

money by manager discretion have inherent flexibility. Specifically, program managers have the ability to continue or disband a research project, whereas in competitive peer reviewed grant programs many more persons—the ad hoc or standing peer review panel and the program manager-are asked to concur on a specific decision. Finally, in some programs, such as the Office of Space Science and Applications at NASA, managers are allowed some portion of their budget as discretionary. Discretionary money is important to foster new ideas within a ''zero-sum' climate where money spent on one research project detracts from another.

Agencywide tradeoffs in budgeting and resource allocation are very important, but once a program has been initiated it is hard to end. This happens for a number of reasons. First, many people have become invested in working and supporting the program. Second, the program's political constituency may wish to see it pursued, and may lobby both Congress and the agency. Finally and most likely, given funding constraints, it maybe very difficult to start a new program. It tends to be easier to redefine an old program to meet new goals, though it may not be immediately as effective as a completely new program.

OTA finds that agencies and managers throughout the Federal research system could be provided with the means, and perhaps incentives, to be more flexible. Ending one program and starting another could be made easier. More discretionary money could be provided, incentives for managers could be increased, and manager discretion accompanied by accountability and attention to success could be encouraged. Flexibility to adapt to research developments within a changing budget envelope is imperative. The production of excellence in research and the reduction of stress if funding does not keep pace with demand by the research community must go hand-in-hand.

## Strategic Planning

Strategic plans have recently been employed by many of the research agencies as an important component of the research portfolio.[53] These agencies include the three services in DOD, CSRS in USDA, the NSF research programs (through NSB), and the Office of Space Science and Applications in NASA. While these agencies have always planned their near-term activities, many agencies have begun to codify the plans and publicly distribute them for comment.[54]

Strategic plans are very useful because they communicate within the organization, the Federal Government, and the research community the intentions of the research program over the next 5 to 20 years. They articulate the mission of the research investment and outline the steps necessary to attain intermediate and long-term goals. The mission may be as general as supporting research in abroad area, or as specific as solving a particular problem or developing the foundation for a specific technology. For instance, in the strategic plan for OSSA, NASA states that it will attempt to launch a combination of small and big satellite missions every year, thus showing a commitment to small science missions in space. If a program already has a clear idea of its mission and the means of attaining its goals, then the construction of a strategic plan is relatively easy. If that understanding does not exist, then the creation of a plan can be very useful in defining and pursuing those objectives.

Often the formation of a strategic plan is resisted within a program for fear of perpetuating relative funding differences and forcing decisions prematurely to pursue specific objectives. Judicious and regular revision of plans has led to a more realistic allocation of funds and allowed oversight by the executive branch and Congress to proceed smoothly. Rather than arbitrarily freezing the program, its potential can be highlighted and new options entertained within and without the current program structure.

While strategic plans are not the solution to all of the problems presented by the changing research economy, and can be used to justify decisions rather than to improve on them, OTA finds that strategic and contingency plans (especially when accompanied by ex post evaluation—see chapter 8) are elements that can be employed by the research

[53] There is a school of thought (to which OTA substantially subscribes) that strategic plans are primarily useful for communication and have two negative potentials: 1) they may be put on the shelf and ignored, and 2) they may be implemented blindly. Strategic plarming needs to be an institutionalized ongoing process, and plans need to be working documents that are constantly revised so theplarming horizon rolls forward.

[54] Programs and agencies within the Department of Defense, the National Aeronautics and Space Administration, the National Science Foundation, and the U.S. Department of Agriculture have recently produced strategiplans. The National Institutes of Health is in the process of developing one.

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agencies to plan for the future, increase communication, and accommodate new and continuing developments within the Federal system.

### Redirecting the Agencies and Addressing New Problems

What happens when the current mission of the agencies is no longer well formulated or appropriate? Many agencies have been chastised that their mission is either out of date or lost amid a multitude of programs. Observers further claim that the agencies are calcifying, pursuing programs and setting priorities because of tradition rather than national need.[55]

For example, DOE has been challenged that it does not support research that primarily seeks to solve the Nation's energy problems, but instead supports a broad array of research programs from high-energy colliders to radiation exposure in humans. Some claim that these problems would be better pursued in an agency like NSF and that DOE should concentrate on energy research. In a contrasting example, USDA has been repeatedly criticized for supporting a narrow research agenda. Biotechnology and other fields related to agriculture do not easily gain support within the USDA system. Critics point out that the USDA system does not coordinate well and many research opportunities fall through the cracks between ARS, CSRS, the Forest Service, and other programs.[56] In a third example, after a series of large programs had not lived up to expectations (e.g., the Space Shuttle and the Hubble Space Telescope), a Presidential commission was created to conduct a comprehensive review of NASA priorities and procedures.[57]

Many agency problems result from Federal attempts to cope with tighter budgets and setting of priorities. OTA finds that the Federal agencies are responsive to changing national needs, but are limited by the program structure and budget. Agency missions were defined many decades ago, often when budgets were expanding, and these mission statements were ambitious. Agencies always seek growth as an overall objective. But decisionmaking structures do not serve as well when tradeoffs between agency programs must be made and managers have little incentive to terminate programs.[58] For the research system to thrive in the 1990s, the termination of some programs in favor of others may be required.

Some also question whether the scope of many agencies' programs should be reduced so that whatever they decide to do they can do well. Perhaps lessons learned at DARPA are instructive. DARPA rarely pursues a problem without the required funds, and attempts not to start programs at low levels (which implies that the budget must free up to accommodate the program sometime in the future). DARPA personnel regard this philosophy as crucial to their success.

In summary, crafting goals and missions for the Federal agencies as the research economy changes is not just a matter of the scientific objectives, but also of management. The agencies were created at different times over the last half century and carry with them cultural traditions and organizational structures. As new goals are assigned to the research system, Congress and the executive branch must pay special attention to the capabilities and decision-making mechanisms of each agency. his includes the methods by which priorities are implemented in the selection of researchers and projects for support. OTA considers these methods next.

## Funding Allocation in the Federal Agencies

When applying for Federal research funds, researchers submit a proposal. In general, a proposal requests support for an individual, a specific project, or a center,[59] and is submitted to a particular program in an agency for review. The process of review can be thought of as a continuum of methods ranging

[55] Remarks at "OTA Workshop on Costs of Research and Federal Decisionmaking," July 9, 1990.

[56] Office of Technology Assessment, op. cit., footnote *34;* U.S. Congress, Office of Technology Assessment, *U.S. Investment in Biotechnology*, OTA-BA-360 (Washington, DC: U.S. Government Printing Office, 1988); and U.S. General Accounting Office, *Biotechnology : Analysis of Federally Funded Research* (Washington, *DC:* U.S. Government Printing Office, 1986).

[57] Advisory Committee on the Future of the U.S. Space Program, op. cit., footnote 18.

[58] Indeed they are encouraged t. keep programs in operation. See Harvey Averch, "Policy Uses of 'Evaluation of Research' Literate," OTA contractor report, July 1990. Available through the National Technical Information Service, see app. F.

[59] For a case study analysis of Federal mechanisms used to fund university research, see U.S. General Accounting Office, *University Funding: Assessing Federal Funding Mechanisms for University Research,* GAO/RCED-86-75 (Washington, DC: February 1986).

from soliciting advice from experts outside the agency, or *peer review,* to relying solely on the judgment of the research officer who must defend decisions to award or decline funding; this might be called *manager discretion. In* practice, a mix of these methods, even within the same agency, is common.

### Peer Review

"Peer review" describes a family of methods used to make funding decisions about research projects. It usually comprises a multistage process, where reviews of the proposal are solicited from experts in the scientific subdiscipline of the proposal. Reviewers are most often asked about the technical excellence of the proposal, the competence of the researchers, and the potential impact of the proposed project results on a scientific discipline or interdisciplinary research area. Peers may also be asked about the project's relevance to the objectives of the funding program. The proposals and reviews may then be considered by a panel of experts, and competing proposals compared. The panel eventually ranks the proposals in the order in which they think the proposed projects should be funded.

There are distinct advantages to this form of proposal review: the participants are acknowledged experts who make absolute and relative judgments of proposal quality, or ''scientific merit, ' and who offer their time on a largely volunteer basis. The process is expected to operate according to values of fairness and expediency. However, at the two agencies that depend most on external peers, NSF and NIH, problems with and suspicions about systematic biases in proposal review have produced a series of studies and self-studies.[60] Such studies raised questions about the composition of review panels and the fate of proposals submitted by investigators at research universities.[61]

Probably the most predominant criticism of peer review, and the one that has troubled Congress the most, has been the allegation that it is controlled by an "old boys network," which informally favors those like themselves, and that decisions are made behind closed doors where aspersions can be cast against a researcher without providing a forum for refuting them. Attempts have been made at both NSF and NIH to correct faults found in peer review, but neither agency would suggest that all of the problems have been freed. Rather, given the strength of peer review in soliciting expert opinion, they ask ''what method is *better?' '*[62]

### Manager Discretion

Manager discretion as a project selection method refers to agency investment in the expert judgment of a single decisionmaker or administrator-the program manager.[63] This is not only the *technical* judgment of the manager, but also his or her ability to put together the best portfolio of research to achieve the goals of the program. Manager success is therefore seldom evaluated on the basis of one project or before a series of projects are complete. Rather, it is based on the success of an entire research program. In agencies that rely heavily on manager discretion, there is strict accountability of managers for program decisions. But managers do not work in isolation; there is oversight from superiors, and inhouse advice is readily available. In

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[60] These are reviewed in D.E. Chubin and E.J. Hackett, *Peerless Science: Peer Review and U.S. Science Policy* (Albany, NY: SUNY Press, 1990), chs. 2 and 3; U.S. General Accounting Office, *University Funding: Information on the Role of Peer Review at NSF and NIH, GAO/RCED-87-87FS (Washington DC:* March 1987); and NIH Peer Review Committee, "Sustaining the Quality of Peer Review: A Report of the Ad Hoc Panel,'' unpublished report, December 1989. Early studies of note include: NIH Grants Peer Review Study Team, *Grants Peer Review: Report to the Director, NZH Phase Z (Washington DC:* December 1976); Grace M. Carter, *What We Know and Do Not* Know *About the Peer Review System,* report N-1878-RC/NIH (Santa Monica, CA: RAND Corp., June 1982); Stephen Cole et al., *PeerReview in the National Science Foundation: Phase I of a Study* (Washington, DC: National Academy of Sciences, 1978); and Jonathan R. Cole and Stephen Cole, *Peer Review in the National Science Foundation: Phase II of a* Study (Washington, DC: National Academy of Sciences, 1981).

[61] For a recent example of such analysis at the National Science Foundation, see James McCullough, ' 'First Comprehensive Survey of NSF Applicants Focuses on Their Concerns About Proposal Review,' *Science, Technology, & Human Values,* vol. 14, No. 1, winter 1989, pp. 78-88, and associated commentaries that follow the article.

[62] See Jon Turney, ' 'End of the Peer Show," New *Scientist,* vol. 127, Sept. 22, 1990; and Jeremy Cherfas, ''PeerReview: Software for Hard Choices," *Science,* vol. 250, Oct. 19, 1990, pp. 367-368.

[63] What OTA is calling "manager discretion" is discussed in the organizations literature as a management tool or approach that springs, for example in the case of the National Aeronautics and Space Administration space program, from ". . . the complex conceptual, planning, administrative, and evaluative tasks facing the agency and its contractors. ' See Karl G. Harr, Jr. and Virginia C. Lopez, "The National Aeronautics and Space Administration: Its Social Genesis, Development and Impact,'' *Managing Innovation: The Social Dimensions of Creativity, Innovation and Technology,* S.B. Lundstedt and E.W. Colglazier (eds.) (New York, NY: Pergamon Press, 1982), p. 181.

particular, technical judgments of inhouse staff are commonly solicited, and additional reviewers can be tapped from outside the agency.

Manager discretion has many advantages as a funding allocation mechanism. First, because program managers are intricately involved in the development of a program, they can best gauge the relevance of projects selected for funding to program objectives. Second, manager discretion allows an agency to implement new goals quickly, since it is easier to instruct managers to alter selection criteria or allocation methods (and hold them accountable for doing so) than to convince external peer reviewers to weigh factors others than technical merit in the rating of proposals. Finally, the ethos of manager discretion can result in the funding of proposals that do not reflect the collective wisdom in vogue. As put by one manager at the Office of Naval Research, where manager discretion is the rule: ''We don't take votes in the science Community. "[64]

However, manager discretion can also suffer from isolation—soliciting too little opinion from outside of the agency, as well as relying foremost, and sometime solely, on the technical judgment of the program manager. Manager decisions can also be seen as capricious, since they are not based on a consensus among peers, Also, wherever manager discretion is used as a decisionmaking device, it assumes an organizational structure that recognizes managerial responsibility for activities and objectives within time and cost limits.

Although on the surface peer review and manager discretion seem very different, many agencies use a combination of the two in their decisionmaking. What follows is a brief description of the funding allocation methods in the major research agencies. For a more detailed discussion, see appendix C.

## Agency Overview

NIH *can* be considered the original **site** of peer review in the Federal Government, beginning with the National Advisory Cancer Council in 1937.[65] Today, NIH has an elaborate "study section" system for soliciting and reviewing proposals from extramural researchers. Section "secretaries' are pivotal in proposal processing. Study section recommendations are directed to 1 of 13 institutes and must ultimately be approved as funded projects by the appropriate advisory council. NIH intramural researchers located in NIH laboratories around the country compete for separate support. NIH uses almost 100 chartered panels to recommend decisions about the relative merits of proposals.[66]

DOD research agencies rely primarily on inhouse review and manager discretion. DARPA in particular is known for its strong program managers. DARPA solicits proposals tailored to a field of interest and specific research objectives. Funding is awarded (and withdrawn) almost exclusively at the discretion of the project manager. The Office of Naval Research controls most of the 6.1 funding for the Navy and is also noted for the independence of its program managers who are often referred to as ' 'czars.'' The Air Force Office of Scientific Research disburses all of the Air Force's 6.1 budget, both to its own laboratories and to universities, with inhouse review and manager discretion decisive in project selection. Army research programs are decentralized, and inhouse review is used to allocate monies to universities and numerous DOD laboratories. The University Research Initiative in the Office of the Secretary of Defense supports additional research at universities. The funding, however, is allocated through the services and DARPA.

Research proposals at NASA are processed differently by the Office of Space Science and Applications and by the Office of Aeronautics, Exploration, and Technology. At OSSA, proposals relating to future flight missions are solicited through Announcements of Opportunity (AOs). Research Announcements are more modest in scope than AOs, and can solicit ''guest' observers (who will participate in a mission after the original investigators) and support theoretical work. Unsolicited proposals are also considered. Funding is based primarily on technical merit reviewed by an expert panel selected by the program manager, an inhouse group, or an outside contractor. NASA staff provide further

[64] OTA interviews at the Office of Naval Research, spring 1990.

[65] The National Institutes of Health epitomizes how much project selection can be influenced, in the longrun, by the very scientists who receive the funds. See Nicholas C. Mullins, "The Structure of an Elite: The Advising Structure of the U.S. Public Health Service,'' *Science Studies*, vol. 2, 1972, pp. 3-29.

[66] The National Institutes of Health is the largest part of the Department of Health and Human Services; only one other Component of this department, the Alcohol, Drug Abuse, and Mental Health Administration, supports extramural research.

review to determine feasibility and mission relevance. Proposals are ranked and the program manager selects from the top 20 to 40 percent. Division managers must approve these selections.[67] At OAET, proposals are solicited through Requests for Proposals. All responses are reviewed inhouse, and most grants and contracts are administered by NASA laboratories. In all, one-half of OAET's total R&D funds is disbursed to the laboratories (chiefly Ames, Langley, and Lewis), while 30 percent goes to industry, and 20 percent to universities.

DOE's civilian science programs use many of the same proposal review techniques as NASA, with peer review of scientific merit and final judgment by the program manager. All proposals are solicited through Broad Agency Announcements. The majority of research funds are awarded to the laboratories, and these expenditures are estimated in the budget request for DOE. Almost all of the agency's defense research is done at the laboratories; funding is competed among them and distributed on the basis of inhouse reviews.

NSF funds only extramural research.[68] It uses program announcements and, through its system of ''rotating' program managers, routinely circulates members of the research community into the agency's decisionmaking apparatus. Although peer review is the guiding principle of NSF proposal review, its form varies greatly within and across agency directorates, divisions, and programs.

USDA is a multilimbed agency. The funding procedures of the Agricultural Research Service are highly centralized and totally inhouse. Proposals are received in response to an annually revised 5-year National Program. They are sent for external review only *after* the decision to fund has been made and only to approve the dollar amount of support. The Agriculture Grants Program of the Cooperative State Research Service is a separate arm of USDA. Outside panels rank proposals and, along with program managers, determine funding levels. CSRS also has "nationally targeted programs" and "special programs, ' the latter being congressionally earmarked funds. Both categories are supervised inhouse. The Forest Service is another arm of USDA, with stations scattered around the United States competing for funds nom the National Program. Research work unit descriptions are solicited from all of the laboratories and are competed at the national level; outside review is rarely solicited.

## Blurring of Peer Review and Manager Discretion

This overview illustrates the various combinations of peer advice and manager discretion used in the research agencies. Some research agencies have always used a particular method-DOD has consistently relied on manager discretion augmented by informal reviews. Some agencies have recently altered their methods.

For instance, NSF renamed its proposal review process ''merit review' in 1986 to reiterate that ''merit consists of more than peer judgments, especially relevance to agency missions.[69] Likewise, NIH stresses the role of institute advisory councils in weighing priority scores against program relevance[70] (for an example see box 4-E). While it has always been the case that technical merit is a necessary but not sufficient condition for research funding at agencies other than NSF and NIH, the exercise of manager discretion in the selection processes of these peer review-based agencies has become more explicit.

The issue is not which method, peer review or manager discretion, is better, but that either one, or a combination, can be used effectively to address

[67] Other discretionary money (representing about 10 percent of the budget) is available to the division director and the program manager. It is disbursed for projects of higher risk, or for specific needs not addressed through the procedures described above, using a less formal procedure (sometimes only with internal review).

[68] For example, in fiscal year 1989, the National Science Foundation (NSF) received 44,300 proposals and made 16,700 awards. The agency supports the research of 18,900 scientists (including salary for an average of 2 months each year), 3,600 postdoctoral researchers, and 15,600 graduate students. The average award amount to individual investigators ranges across directorates from $50,000 to $150,000. Comparable information in all of these categories, over the last decade, is lacking for the other agencies except the National Institutes of Health and the Department of Veterans Affairs. See U.S. Congress, Office of Technology Assessment, "Proposal Pressure in the 1980s: An Indicator of Stress on the Federal Research System," staff paper of the Science, Education, and Transportation Program, April 1990, pp. 4-7, and table 1. Since publication of OTA staff paper, NSF has developed revised numbers for competitively *reviewed* proposals: 27,300 received and 8,400 awarded with a median annual award of $55,000. Linda Parker, National Science Foundation personal communication, Jan. 23, 1990.

[69] National Science Foundation, Advisory Committee on Merit Review, *Final Report*, NSF 86-93 (Washington, DC: 1986).

[70] For a historical perspective, *see* Stephen P. Strickland, *The Story of the NIH Grants Programs* (Lanham, *MD:* University Press of America, 1989).

## BOX 4-E-Fine-Tuning Project **Selection at NIGMS**

The mission of the National Institute of General Medical Sciences (NIGMS), one of the 13 National Institutes of Health, is the support of basic research in the life sciences. Early in 1990, the National Advisory General Medical SCience (NAGMS) Council issued new guidelines that expand the factors taken into consideration by the scientific staff in making project funding decisions.[1] "In times of extremely constrained funding," the NAGMS Council stated that ". . . the Institute [must] promote the broadest possible diversity of ideas and approaches,.. ." and ". . . encourage the ideas and talents of established investigators and of the young or new investigators who will provide the next generation of research accomplishments." The NAGMS Council recommended a policy authorizing that special consideration be given to a highly rated application from an investigator". . . who has no other significant source of research support . . ." as opposed to such applications from investigator ". . l whose total research support from all sources, including the pending award exceeds $500,000 (direct costs)."

Under this policy, the advisory council chose to free up funds by: 1) reducing the amount of funding received by some investigators in the $500,000 plus category, 2) not approving two awards for projects that were within the "theoretical" NIGMS payline, and 3) cutting 30 percent of the competing continuation grants (60 out of 200) beyond the 12 percent across-the-board reduction. As a result of this shift of funds, 6 percent of institute awards (n=21) were made to "' . . . grantees who had no other significant source of research support and who also had percentilesw that were beyond the theoretical Institute payline,... " i.e., who would not have been funded under the traditional NAGMS guidelines.

What are the lessons derived from this advisory council action?There are at least two appraisals. The positive one is that an NIH advisory council is searching for ways to support investigators without compromising the integrity of either the peer review system or the research to be funded. Priority scores were intended as the chief input to, but not the sole determinant of, award decisions. The NAGMS Council recognizcs the imprecision of priority scores at the margin, and does not embrace their use as the sole criterion for funding,

An appraisal that is more negative is most clearly stated in a letter sent in June 1990 to Acting NIH Director William F. Raub.[2] Citing "... little comfort in the idea that the change is only temporary,..." the author notes that ".... there will always be a case to be made for redistributionist policies, because there are always more losers than winners and many of the losers are quite meritorious." He protests that peer judgements about the quality of science will be secondary to consideration of the financial condition of the applicants.

Another criticism is that the new NAGMS policy is merely another in a series of ad hoc responses to the problem Caused by the' insufficient number of new and competiting.grants,"... rather than looking broadly at NIH's total research and training portfolio and the adequacy of its budget to support it...NIH has other programs to achieve other purposes: for example, the special program for young investigators. We support those programs and want them to be adequately funded. But the core NIH research grant programs should not be used to solve problems extraneous to their proper goals."[3]

Expanding the pool of supported investigators, especially the "next generation," and diversifying the approaches to research that fail within the NIGMS mandane is part of the NIH mission. On the other hand, the NAGMS policy is seen by some as tampering l with the traditional NIH review system. This use of discretionary action by program" officers and advisors should be applauded, but continues to be a source of debate in government and the scientific community.

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[1]The following is paraphrased or quoted from National Advisory General Medical Sciences Council, January 1990 "Motion and Guidelines Regarding Funding Decisions," unpublished manuscript, Feb. 8,1990.

[2]Excerpts from the letter are used below to illustrate generic points probably held by others. The anonymity of the author is preserved.

[3]Ibid.

programmatic goals (and the choice of which method depends on the goal) .71 In general, OTA has found that the agencies will often adapt funding allocation strategies to new goals.

### Set-Asides and Formula Funding

**In** addition to the mainstream disbursal of funds, agencies often allocate funds using other types of programs. The two prominent categories of such programs are *set-asides* and *formula funding. While their origins* differ, each method of funding clearly allows the Federal research agencies the discretion to pursue certain national needs by applying a different or reordered set of criteria to the selection of research performers.

*Set-aside* programs are agencywide discretionary actions. They select one characteristic that captures a need not served by mainstream proposal review and restricts competition for research funding to a pool of eligibles who qualify by virtue of that characteristic. Thus, there are set-asides for women, ethnic minorities, young investigators, investigators located at traditionally nonresearch institutions, and investigators residing in States that have been underrepresented in the amount of Federal research funds they receive relative to their share of the general population or the number of undergraduates they enroll. (There are set-asides in other agencies as well. See box 4-F.)

The assumption underlying set-aside programs is that there are capable researchers everywhere who-for lack of opportunity or obvious disparities in experience-are disadvantaged in the ordinary competitive proposal process. The solution is a separate competition, still organized around the criterion of technical merit, that pits like against like. (For a model of an NSF set-aside that attempts simultaneously to strengthen institutional research capability and geographic diversity, see box 4-G.) For some researchers, set-asides are the only way into the Federal grants system; for others it is a springboard to continued competition in regular agency programs.

*Photo credit: U.S. Department of Energy*

**Scientists study the results of a nuclear magnetic resonance experiment. Several agency set-aside programs address the recruitment and retention of women in scientific fields.**

*Formula funding can* be traced to the Hatch Act (1887), which authorized the allocation of Federal funds to land-grant universities for the conduct of research.[72] These funds are a kind of categorical or block grant disbursed to the States, which enjoy considerable discretion in their use. Typically, the subject areas to be addressed by formula-supported research are selected by directors, deans, department heads, and faculty in the land-g-rant institutions, within the broad guidelines of the enabling legislative acts. Peer review methods may be employed at this decentralized level.[73] In agriculture, competitive grant funding is used to augment formula funding that expands the science base, e.g., new research in agricultural biotechnology.

71 ''It is much harder t. rely on managerial discretion in an agency that has responsibility for the health and progress of science. There is also probably value in a variety of blends between managerial discretion and peer review in different agencies and in different programs of a single agency. ' Brooks, op. cit., footnote 39.

72The roots of formula funding are perhaps the strongest in agriculture, where Hatch and the Smith-Lever Act (1914) formulas (the latter directed to agricultural extension services) prescribed allocations to each State proportional to the magnitude of its agricultural enterprise. These proportions are indexed roughly to annual cash sales of agricultural products in the States and the investment of State funds in the State Agricultural Experiment Stations. For details, see Don Holt, Illinois Agricultural Experiment Station, "Recapturing the Vision: The Case for Formula Funds," proceedings of the 1989 Annual Meetings of the Agricultural Research Institute, Bethesda, MD, May 1990.

73For example, the criteria for project selection in agriculture include: potential economic and social importance of the research activity to the State, region, and Nation; potential for the activity to generate other research support; need to fill gaps in agricultural knowledge; and need to provide continuity in long-term research programs. See Don Holt, Illinois Agricultural Experiment Station, ''Mechanisms for Federal Funding of Agricultural Research and Development" mimeo, August 1988, p. 4.

**Box 4-F—Small Business Innovation Research Program (SBIR)**

The Small Business Development Act of 1986 (Public Law 99-443) requires Federal agencies that spend more than $100 million annually on extramural research or research and development (R&D) to set aside 1.25 percent (when fully operational) of those funds for a Small Business Innovation Research (SBIR) program.[1] These programs are intended to encourage innovation by allocating grants or contracts specifically to small businesses conducting research on relevant topics. Minority firms are also encouraged to compete.

The notion of a set-aside program for small businesses, initiated by the National Science Foundation in 1977, was initially disparaged by the academic research community, who viewed the program as a drain on available funds. It was instituted governmentwide in 1982, and now provides substantial funds for science and technology-intensive firms conducting research on agency objectives considered too risky to interest financial investors. The seed money supplied by the Federal Government for the initial phases of research is leveraged in later phases by private capital. The receipt of SBIR funds is considered an asset by some investors, who feel that it reflects a measure of endorsement by Federal granting agencies.

The program has three phases. In phase I, projects are tested for scientific merit and feasibility. In phase II, the principal research effort, successful phase-I projects are supported for up to 2 years. Products or services that reach phase III are developed for private or government use. Before a project can enter phase III, it must secure additional sources of support because SBIR finding ceases after phase II.

In fiscal year 1990, the U.S. Department of Agriculture funded 32 phase-I and 13 phase-II projects at a total of $14.1 million. The award rate was 10 percent. In the same year, the U.S. Environmental Protection Agency funded over 15 phase-I and nearly 20 phase-II projects at no more than $25,000 each. The Department of Commerce spent $1 million on 9 phase-I and 2 phase-II grants in fiscal year 1990. One of the largest contributors, by virtue of the size of its budget, is the National Institutes of Health, which spent $73 *million* on SBIR in fiscal year 1990. Biotechnology companies have fared well under the NIH SBIR program and praise the program for giving them the boost needed to conduct high-risk research.[2]

SBIR was reauthorized in 1987 for an additional 5 years-until 1993. It continues to be one of the few sources of direct Federal support for applied R&D conducted by small companies.

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1 This act is based on a 1982 act (Public Law 97-219) and a successful experimental program of the National Science Foundation (NSF). The sources for what appears below are program solicitations of the Small Business Admitration's and NSF'S Small Business innovation Research Programs, *Washington FAX*, Sept. **24**, 1990, and National Science Foundation staff, personal communications, December 1990.

2 B see Jeffrey Mervis, "Scientific Conflict of Interest Regulations Offer Loophole to Small Business Program," *The Scientist, vol.* 5, No. **6, Mar.** 18, 1991, pp. 1, 8-9.

Advocates of formula funding state that:

> Formula funds created the public institutional structure of U.S. agriculture and remain essential to preserving the unique strengths of key institutions. Formula funds leverage much State and private support for agricultural research. They distribute costs in proportion to producer, consumer, and spillover benefits. Formula funds provide much needed continuity to programs that are otherwise fragmented by the short-term, unpredictable nature of gifts, grants, and contracts. They are needed to offset unrecoverable indirect costs of projects, including . . . depreciation on buildings and equipment. . . . By decentralizing scientific priority setting and operational management, they avoid capricious top-down decisions and overcome the deleterious averaging effect of consensus-based management. Critics of formula funds focus on the need for peer review, incorrectly implying that formula funds are not allocated competitively. The peer review issue clouds other important issues, including. . . the inability of typical peer review panels to apply site- and situation-specific criteria.[74]

Yet many still question the review received for formula funded projects, and favor funds awarded through openly competitive programs as "better spent.

Both set-asides and formula finding represent a form of legislated and/or within-agency recognition that certain research goals cannot be achieved via conventional proposal review. Thus, agency programs are created to direct funding that satisfies

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74 Holt, op. cit., footnote 72, p. 1.

## Box 4-G—The NSF EPSCoR Program: Geography and Research Capability

Nowhere has the concern for regional distribution of Federal research funds been better institutionalized than in the National Science Foundation's (NSF) Experimental program to Stimulate Competitive Research (EPSCoR).[1] Established in 1978, EPSCoR awards ". . . small amounts of money to 16 have-not States and Puerto Rico to use as a magnet to help their universities and local industries excel in one or more areas of science and engineering. The States are Alabama, Arkansas, Idaho, Kentucky, Louisiana, Maine, Mississippi, Montana Nevada, North Dakota, Oklahoma, South Carolina, South Dakota, Vermont, West Virginia, Wyoming, and the Commonwealth of Puerto Rico.

The EPSCoR States have formed a nonprofit organization, the Coalition of EPSCoR States, that argues for greater Federal investment in the development of science and engineering capability nationwide. Relative to the Nation as a whole, the Coalition points out, EPSCoR States". . . have low per-capita incomes, high unemployment, poor schools, retarded **economic** development, and low levels of science education attainment and scientific manpower production. The EPSCoR States received 5.4 percent of Federal R&D funds in 1980, and 5,6 percent in 1987. By improving the competitive position of States with underdeveloped science and engineering fundamental research infrastructures, EPSCoR hopes to contribute to the health of all research and development (R&D) within the United States.[4]

### EPSCoR as Antidote

Selection as an EPSCoR-eligible State allows the State to compete for a research enhancement award of between $3 and $5 million over 3 to 5 years. The money is awarded to a lead institution within a State to implement the proposed State R&D plan, to stimulate academic research activity, and to enhance the competitive stature of institutions in select research areas.[5] The size of a State's EPSCoR award is determined by the quality, number, and type of projects; the current status of its research environment; the scope and magnitude of the proposed improvements; and the potential to demonstrate significant change as judged by merit reviews

The objectives of EPSCoR are to increase the competitiveness of participant scientists and engineers-working as individual investigators, in research groups, or in a research center—to obtain other R&D funds; to effect permanent improvements in the quality of science and engineering research and education programs; and to ensure that improvements achieved through EPSCoR-initiated activities continue beyond the end of the EPSCoR grant period?

EPSCoR can also leverage investment from other sources; and, for every Federal dollar, three local dollars are being invested in support of EPSCoR from industry and other sectors.[8] In Montana, for example, about 220 researchers have received aid and about one-half of them have gone on to win Federal grants through NSF's regular merit review system. Another 20 percent have won support from non-Federal sources. South Carolina has enjoyed similar success: the mathematics departments at both Clemson University and the University of South Carolina ranked 47th and 62d, respectively, in outside support after participating in EPSCoR. Previously, neither had been among the top 100.[9]

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1Nationa Science Foundation Division of Research Initiation anc Improvement ''Experimenta Program To Stimulate Competitive Research Program Plan FY 1989- 1995,' unpublished report n.d

'Jeffrey Mervis ''When There's No Enough Money To Go Around,' *The Scientist,* vol. **4, No. 8,** Apr. 16, 1990, pp. 1, 8.

3Coalitior of EPSCoR States, 'EPSCoR A State-Based Approach to Expanding American Research Capacity, ' a congressional briefing paper, Feb. 20, 1990.

4Josepł G Danek ''A Mode Program for Expanding the Nation's Science and Engineering Infrastructure, " summary for the annua meeting of the Americar Associatior for the Advancement of Science, New Orleans, LA, Feb. 20 1990

5Josepł G Danek Nationa Science Foundation personal communication Decembe1 1990 By its descriptive ianguage the National Science Foundation apparently does not like to emphasize thatEPSCORisan''equity' program; rather it refers to EPSCoR as a capacity building program.

6Nationa Science Foundation, op cit., footnote 1 p 2.

7Ibid. p. 1

8Danek op. cit., footnote 4

9Colleer Cordes ' 'Troy NSF Program Hailed as Model for Broader Distribution of U.S. Funds, ' *The Chronicle of Higher Education* vol *36,* No 45, July 25, 1990, p. A17.

*Continued on* next page

### Box 4-G—The NSF EPSCoR Program: Geography and Research Capability--Continued

**Prospects for Emulation**

Several statewide EPSCoR initiatives have created ongoing organizations dedicated to the long-term support of science and engineering research. Included are the following: Montanans on a New Track for Science; Louisiana Stimulus for Excellence in Research; Oklahoma Center for the Advancement of Science and Technology; and Arkansas Science and Technology Authority.[10] Through participation in the EPSCoR program, these and other States have been able to target their weaknesses and make significant strides in meeting the needs and improving the quality of their research communities in select areas.[11]

EPSCoR was funded at roughly $11 million in fiscal year 1991. The EPSCoR Coalition is seeking additional funds from NSF and for the establishment of similar programs in other agencies. The National Aeronautics and Space Administration (NASA), for example, is embarking on a program to help academic researchers compete for NASA funds and to improve overall scientific literacy in underfunded States. The U.S. Department of Agriculture is considering the provision of seed grants to scientists who have not received competitive grants from them in 5 or more years.[12]

The prospect of redistribution worries critics of EPSCoR who fear a dilution of research capability. They claim that EPSCoR undercuts peer review. But because the program aims to make States **more competitive at a national** level, it pits them against one another for limited funds.[13] Acting Director of the National Institutes of Health, William Raub, also suggests that an EPSCoR-type program may not be transferable to the health care arena. Many poorly funded colleges simply do not possess an adequate research infrastructure; there is no clinical program or animal facility in which such research might be supported. 14

Thus, if expanding the EPSCoR model across Federal agencies is to be seen as a serious intervention, then several questions remain. In the face of a tight Federal budget, how much money should be devoted to assisting scientists and engineers in some States to become more competitive? (Would doubling or tripling the amount of the annual EPSCoR award multiply or hasten returns?) At what level has a State made enough progress to graduate from EPSCoR, or fallen behind enough to be added to the list?[15]

Quantitative measures of success must also be developed. Areas that might be examined include: the extent of increased competitiveness for Federal R&D funding among individual investigators and research groups, the scope and effectiveness of departmental and institutional enhancements of the research environment, and the demonstration of long-term State financial support of EPSCoR to advance the cause of education and human resources for science and engineering.[16] If broader geographic distribution of Federal research funding is sought, the EPSCoR model could be emulated.

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10Dane op. cit., footnote 4.

11National Science Foundation, op. cit., footnote [illegible].

12Mervis, op. cit., footnote 2, p. 12. The Department of Energy, the Department of Defense, and the Environmental Protection Agency were directed by the 101st Congress to introduce EPSCoR programs. See Audrey T. Leath, "Congress Heaps Funds on EPSCoR for Research 'Have-Not' States," *Physics Today*, February 1991, pp. 77-7

13Cordes, op. cit., footnote 9, p. A1

14Ibid, p. 12.

15Ibid, p. A17.

16Given the concentration of ethnic minorities in many EPSCoR States, the human resources potential of the program to increase participation in scientific careers has yet to be emphasized, except in Puerto Rico. Established in 1980 with EPSCoR and University of Puerto Rico support (and Subsequent.Iy from the National Science Foundation's Research Centers of Excellence Program in 1988), the Resource Center for Science and Engineering offers programs at every stage of the educational pipeline. The university has awarded 91 Ph.D.s in the sciences in the last decade, making it the leading grantor of doctoral degrees to minority scientists. See Manuel Gomez, "A Comprehensive Regional Center to Develop Human Resources in Science and mathematics in Puerto Rico," presented at the Fifth EPSCoR Conference, Au 15, 199

longstanding or emerging needs in novel ways. Such departures are almost always seen as diluting quality, i.e., trading off excellence in research for the fulfillment of "subsidiary" agency objectives. But at what point do these objectives become central to the agency mission, or address multiple deficiencies in the distribution of research funds and the execution of research?

This question cuts to the core of this study: What does the Federal Government expect research funding to accomplish? Entering the 1990s, OTA foresees agency funding criteria and methods, on the one hand, and researcher expectations, on the other, changing to accommodate a wider range of demands imposed on the Federal research system.

## Summary

In this chapter, OTA has introduced the Federal research agencies, and outlined their priority setting and funding allocation mechanisms. In general, the Federal agencies are characterized by diversity, pluralism, decentralization, and a division of labor, but together they form a comprehensive research system.

Each agency follows its research mission, but there is much disagreement, both within the agencies and in various research communities, over what constitutes that mission. Agency programs and research foci change in response to shifting priorities, but as with all large organizations, this change occurs slowly. The pace of change is especially hampered in research by the long-term nature of the work and by the inability to reorient programs quickly. Risk-taking, flexibility, strategic planning, and redirecting agencies are longstanding challenges.

Agencies use a combination of peer review and manager discretion to allocate funds. In addition to the mainstream programs, agencies also create set-aside programs to foster the development of underprivileged parts of the research community. In another type of funding, some agencies (especially USDA) disburse funds by formula, which are allocated as block grants to specific institutions.

Agencies have a good sense of their research constituencies and attempt to cultivate both their development and long-term responsiveness. Nevertheless, much of the brunt of the pressure on the scientific community is reflected in agency programs. Program managers must make tough decisions about where to allocate funds and how to support personnel, facilities, and equipment.

In summary, agencies have the resources to adapt to changing internal and external priorities. However, Congress may wish to increase agencies' ability to set and coordinate goals and to address other issues. These issues—priority setting at several levels of decisionmaking, costs of research, human resources for the research work force, and data collection and analysis on the Federal research system—are discussed in the following chapters.