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NATIONAL
RESEARCH COUNCIL

The Policy Partnership with the U.S. Government

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The National Academy of Sciences and its associated organizations—the National Academy of Engineering, the Institute of Medicine, and the National Research Council—together constitute the most important advisory mechanism for science and technology policy in the United States, and perhaps in the world. No other government has created a private scientific organization with such a relationship to itself. For over a century the federal government has turned to the Academy for advice concerning some of the most compelling issues of the day. In recent decades, advice rendered by the Academies, largely through the National Research Council, and by the Institute of Medicine has also exerted increasing influence on universities, businesses, other nongovernmental entities, and consumers.

The organizations that make up the National Academy of Sciences complex have evolved to meet the changing needs of government and society. Today, issues of science and technology are crucial throughout a greatly expanded federal government. The National Academy of Sciences and its sister organizations have also greatly expanded, with the National Research Council and the Institute of Medicine conducting studies across the broad spectrum of science and technology. This essay discusses the history and structure of the Academy complex, describes its activities in functional terms, explores the political dynamics of the relationship between the institution and the government, and speculates about some elements of the science and technology policy agenda that are likely to assume increasing prominence in the future.

ORIGINS, EVOLUTION, AND CURRENT STRUCTURE

The National Academy of Sciences was created by an act of the U.S. Congress in 1863 as a national institution of no more than 50 eminent scientists and engineers who could be requested by the government to serve the country voluntarily. Its charter provides that "the Academy shall, whenever called upon by any department of the government, investigate, examine, experiment, and report upon any subject of science or art, the actual expense of such investigations, examinations, experiments, and reports to be paid from appropriations which may be made for the purpose, but the Academy shall receive no compensation whatever for any services to the government of the United States."

Thus from its inception in legislation signed by Abraham Lincoln the National Academy of Sciences has had a dual role: it is both an honorific scientific society and an adviser and independent ally of the U.S. government. With the passage of time the institution has grown in both size and scope. Today the Academy complex consists of four closely related organizations: the National Academy of Sciences, the National Academy of Engineering, the Institute of Medicine, and the National Research Council, which has become the main operating arm of the Academies in conducting policy and technical studies for the federal government.

The National Academy of Sciences

From its original 50 members, the National Academy of Sciences (NAS) has grown to include about 1,500 distinguished scientists and engineers. The membership is divided into 25 disciplinary sections in six classes: the physical and mathematical sciences, the biological sciences, engineering and applied sciences, the medical sciences, the behavioral and social sciences, and applied biological and agricultural sciences.

As a scientific organization, the National Academy of Sciences publishes a scholarly journal, *The Proceedings of the National Academy of Sciences*, and organizes symposia and meetings on issues of particular importance to its membership. The Academy bestows a number of highly regarded prizes and scientific awards—some that have existed for decades—recognizing outstanding contributions of individual scientists. The Academy also maintains a strong network of contacts with scientific academies in other nations and serves as the convener of national committees adhering to the International Council of Scientific Unions.

In recent years the Academy has initiated a number of new activities for its members. The president and officers of the Academy meet with members in regional meetings held each winter in cities throughout the United States. The Academy's annual meetings, held each April, have been enlarged to include policy discussions on such issues as arms control, national security and the freedom of scientific communication, the status of scientific and mathematics education at the precollege level, science and technology and the future of the U.S. economy, the health threat posed by acquired immune deficiency syndrome (AIDS), and other topics of national concern. The president of the Academy also communicates with Academy members through a newsletter issued on a quarterly basis.

The National Academy of Engineering

The National Academy of Engineering (NAE) was created by the National Academy of Sciences in 1964 to recognize the fundamental role of engineering and technology in modern society. Since then, the National Academy of Engineering has elected over 1,300 members for their distinguished contributions to the science and practice of engineering. A principal role of the Academy has come to be the joint management, with the National Academy of Sciences, of the National Research Council.

The National Academy of Engineering is an autonomous organization that, like the National Academy of Sciences, conducts symposia, publishes special reports, participates in international activities, and awards medals and honors for engineering and public service achievement. Among its activities have been a series of symposia on technology and society, many of which have identified issues for in-depth study by the National Research Council.

In recent years the National Academy of Engineering has begun to examine ways in which it can increase its visibility among engineering professionals and the public and the visibility of engineering as a profession. It publishes *The Bridge* bimonthly as a means of communication with its members and with others in the engineering professions.

The Institute of Medicine

The Institute of Medicine (IOM) was created by the National Academy of Sciences in 1970 to work on matters affecting the status of medicine and the medical professions and the adequacy of health services for all sectors of society. The Institute now has 500 members, individuals, according to its charter, "of distinction and achievement, committed to the advancement of health science and education and to the improvement of health care." Unlike the National Academy of Engineering, the Institute of Medicine is a part of the National Academy of Sciences. It helps govern the National Research Council, its committees and panels are approved by the Research Council chairman, and it follows Research Council procedures in its studies.

Like its sister institutions, the Institute of Medicine cooperates with major scientific and professional societies. It also brings together organizations and individuals in national forums on major health policy issues.

The National Research Council

The National Research Council (NRC) was formed by the National Academy of Sciences in response to a request by President Wilson in 1916, as the United States was on the verge of entering World War I. It provided an institutional framework whereby large numbers of American scientists and engineers, both Academy members and nonmembers, could voluntarily serve the government through participation in NRC activities. The wartime effort was so successful that President Wilson perpetuated the National Research Council by Executive Order in 1918, and the arrangement was reaffirmed in a second Executive Order signed by President Dwight Eisenhower in 1956.

Today the National Research Council has about 950 committees, panels, boards, working groups, and so on (hereafter referred to collectively as committees) on which over 9,000 highly qualified scientists, engineers, physicians, and other professionals serve without compensation. This voluntary service, along with the procedures adopted by the Research Council to ensure the balance and objectivity of its studies, are the hallmarks of its service to the country.

The National Research Council is governed by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The presidents of the National Academy of Sciences and the National Academy of Engineering serve as the chairman and vice chairman, respectively, of the NRC Governing Board, which meets every two months to oversee the work of the organization. The Governing Board also includes 11 other members drawn from the governing councils of the two Academies and the Institute of Medicine. A six-member Executive Committee of the Governing Board meets monthly to review new NRC and IOM projects.

The National Research Council is organized into eight major units: the Commission on Behavioral and Social Sciences and Education; the Commission on Engineering and Technical Systems; the Commission on Physical Sciences, Mathematics, and Resources; the Commission on Life Sciences; the Office of International Affairs; the Office of Scientific and Engineering Personnel; the Transportation Research Board; and the Board on Agriculture. The Mathematical Sciences Education Board and the Strategic Highway Research Program are two special units within the National Research Council.

The National Research Council undertakes studies on questions of science and technology presented for consideration by federal agencies or by the Congress. With a few exceptions, all of the individual study committees work under the oversight of the major units of the National Research Council. In some cases, the Research Council or its sister organizations undertake studies on their own initiative, with funding from private sources such as industries, foundations, and philanthropists.

To maintain the quality and integrity of NRC studies, committee members are carefully selected to ensure adequate balance, and the final reports of committees are thoroughly reviewed. All reports are fully available to government agencies, the Congress, the private sector, the press, and the general public, with the exception of a few classified reports, for which unclassified summaries are made publicly available. A staff of several hundred professionals serves the Research Council's committees.

Any study to be done by a committee must first be approved by the NRC Governing Board or its Executive Committee. Governing Board review determines whether the issues are amenable to scientific and engineering analysis, whether the proposed study plans are sound, whether projected funding is sufficient for the stipulated task, and whether the required expertise is represented in the study plan. The chairman, vice chairman, and executive officer of the Research Council then review the contracts for the specific studies to ensure adherence to both the projected scope of the study and to NRC procedures, and they approve the appointments of all members on NRC committees.

There are a few committees that report directly to the National Academy of Sciences, the National Academy of Engineering, or the Institute of Medicine, rather than to the National Research Council. For instance, the Committee on Science, Engineering, and Public Policy (COSEPUP) reports directly to the councils of these groups and consists entirely of NAS, NAE, and IOM members. COSEPUP addresses policy issues affecting the status of science and the conduct of research and development by universities, industry, and the government.

A FUNCTIONAL ANALYSIS OF NRC ACTIVITIES

The units of the Academies, the Institute of Medicine, and the National Research Council tend to be viewed along organizational lines, with each unit conducting a wide range of activities. A more revealing way to view these activities is to divide them according to function into several broad categories: policy studies on technical matters, policy studies on the status and future directions of scientific disciplines, studies and programs concerned with scientific and engineering manpower, evaluation and monitoring of human health and the performance of systems or products, recommendations useful to government in its role as a promulgator of standards, the development and dissemination of technical information useful to state and local governments, and international programs.

The following functional survey by no means descriptively exhausts the activities carried out by the institution. But it may shed light on common themes irrespective of a given activity's institutional location.

Policy Studies on Technical Matters

Much of the work of the National Research Council and Institute of Medicine centers on policy studies of technical matters, with approximately 300 such studies being completed each year. These studies cover an exceedingly broad range of subjects, from public and private sector policies concerning alcohol abuse to the prospective disposal of military chemical munitions, from the hazards of low-altitude wind shear in aviation to the quality of care in nursing homes, from the impact of technology on employment to the safety of the Department of Energy's nuclear reactors. In recent years, important reports from the Academy complex have focused on acid rain, U.S. national security export controls, the AIDS epidemic, the use of nitrites and nitrates in foods, the biological effects of ionizing radiation, comparable worth in the workplace, depletion of stratospheric ozone, and science and creationism, to name a few. Descriptions of several of these policy studies provide the best means of illustrating the range of these projects, their origins, and the ways in which they are carried out.

The National Research Council has been involved in studying the climate-altering potential of carbon dioxide in the atmosphere since the landmark 1977 study *Energy and Climate.* In 1979 the White House Office of Science and Technology Policy asked the NRC's Climate Research Board to convene a small group of experts for a quick-response update of *Energy and Climate* and an analysis of possible mechanisms that might negate the warming phenomenon identified in that report. The board convened a summer study that deemed the analysis in *Energy and Climate* to be valid, although the study identified a mechanism that might delay the effects. Upon completion of the study, the presidential science adviser conveyed the potential seriousness of the problem to the President. In 1983 a committee of the board completed a thorough review of the carbon dioxide issue, published in the report *Changing Climate,* and in 1986 an NRC-sponsored workshop concluded that an increase in the amount of greenhouse gases in the atmosphere "will prove to be one of the major problems faced by human society in the decades to come."

The National Research Council has also been at the forefront of the continuing debate over the state of the earth's ozone layer and health and environmental effects that changes in it could cause. The 1975 report *Environmental Impact of Stratospheric Flight* and the 1976 reports *Halocarbons: Effects on Stratospheric Ozone* and *Halocarbons: Environmental Effects of Chlorofluoromethane Release* lent credence to early projections of ozone loss and brought the issue to national attention. The 1979 report *Protection Against Depletion of Stratospheric Ozone by Chlorofluorocarbons,* which discussed the effects of ozone depletion, ways to reduce that depletion, and options for implementing controls, suggested international controls on chlorofluorocarbons, paving the way for the controls that have since been adopted. Other reports have calculated rates of ozone depletion and have estimated the relationship between that depletion and certain types of skin cancer. While some of these reports have resulted from congressional charges, several have been self-initiated—that is, the National Research Council recognized the problem internally and supported the projects with private monies.

Following the 1982 crash of an airliner in New Orleans during an extreme thunderstorm, Congress asked the National Research Council to examine the effects of near-surface windshear and severe storm turbulence on aircraft safety. Two panels were formed, one to identify what is known about near surface windshear and turbulence and the methods of forecasting these effects, the other to examine the technical and aeronautic issues associated with aircraft operation. Their combined report, *Low-Altitude Wind Shear and Its Hazard to Aviation*, concluded that wind shear is an "infrequent but highly significant hazard" and called on the Federal Aviation Administration to sponsor "an urgent information and education campaign aimed at all aircraft pilots, including general aviation," about the potential hazards of wind shear. In response to the committee's recommendations, the Federal Aviation Administration greatly stepped up its education programs and undertook improvements and expansions of the Low-Level Wind Shear Alert System.

Also in 1982 the Committee on Diet, Nutrition, and Cancer released its report on the relationship between diet and the incidence of various kinds of cancer. It found that some types of diets or dietary components, such as high-fat diets or smoked foods, tend to increase the risk of cancer, while other foods, including certain fruits and vegetables, tend to lower the risk of cancer. The report's dietary recommendations led to the formation and widespread dissemination of similar guidelines by the National Cancer Institute and the National Cancer Society.

In response to the large increase in the number of pregnancies among teenage American girls since the early 1970s, the Panel on Adolescent Pregnancy and Childbearing was formed in 1985 to investigate the social and personal costs of teenage pregnancy and to suggest approaches to reduce the number of unintended pregnancies among teenagers. While calling for programs that can help teens decide to postpone sexual activity until they are older, the panel noted in its report *Risking the Future: Adolescent Sexuality, Pregnancy, and Childbearing* that "the major strategy for reducing early unintended pregnancy must be the encouragement of diligent contraceptive use by all sexually active teenagers." Although ready access to contraceptives has been claimed to cause more sexual activity among youths, the panel pointed out that there is no documented evidence for these claims. The panel also dealt with such contentious issues as parental consent for abortions, adoption procedures, and support for teenage parents.

In 1986 the National Academy of Sciences and Institute of Medicine formed a joint committee to examine the medical, scientific, and social issues surrounding the AIDS epidemic. Because of the urgency of the situation, the committee was asked to produce its findings within six months, and in October 1986 the committee released its report, *Confronting AIDS: Directions for Public Health, Health Care, and Research*. The report's principal recommendation for greatly increased funding for both research and public education has been reflected in budgetary increases in these areas, and its other recommendations have helped shape the national response to the epidemic.

Also in 1986 the nuclear reactor accident at Chernobyl led the Department of Energy to ask the National Research Council to form a committee to assess the safety of the department's major production and research reactors. In its report *Safety Issues at the Defense Production Reactors*, the committee focused on the N reactor at the Hanford Reservation in Washington and the K, L, and P reactors at the Savannah River Plant in South Carolina, which are the reactors in the United States used to produce tritium and plutonium for nuclear weapons. The committee concluded that the "level of uncertainty about how long the production reactors can be safely operated is high" and that the reactors may have to be shut down before new facilities can be established to produce tritium and plutonium. Since then, the N reactor has been closed and new safety issues have been addressed at the Savannah River reactors.

In 1987 the security, budget, and science advisers to President Reagan and the administrator of the National Aeronautics and Space Administration (NASA) asked the National Research Council to investigate the uses, costs, and overall feasibility of the permanently manned space station first called for by the President in 1984. In its *Report of the Committee on the Space Station*, the committee endorsed the phase one configuration of the facility, calling it "a good compromise among the needs of early users." But it questioned NASA's cost estimates for the space station and called planning for the second phase of the station premature until the nation's longer-range goals in space have been identified.

Finally, in the area of military affairs, the Naval Studies Board conducted a study in 1987-88 to investigate how future trends in technology may affect the Navy in the twenty-first century. Rather than forming a separate committee, the board constituted itself as a study committee, establishing a number of subgroups to examine specific areas of technology and issues related to the application of that technology. The result was a vision of a greatly transformed Navy in which information will be the dominant military factor and stealth and counterstealth measures will be critical to achieving advantage in maritime combat.

Policy Studies on the Status and Future Directions of Scientific Disciplines

A major function of the National Research Council is a continuing inquiry into the status and future directions of the scientific disciplines. Especially since the government assumed larger responsibility for funding of basic research in the 1950s, the in-depth examination of fields of science has been a valuable contribution of the institution. Reports on astronomy, the behavioral and social sciences, chemistry, materials science and engineering, and physics prepared in the 1960s and early 1970s helped guide the science in those disciplines and its financial support by the government. In particular, this work has guided the appropriation of funds for new facilities important to these disciplines. A large degree of scientific consensus on priorities has been achieved in these assessments, making possible more informed appropriation decisions by public officials in the Executive Branch and Congress.

In the 1980s the National Research Council has undertaken new disciplinary studies in the fields mentioned above, as well as in the areas of chemical engineering, the hydrologic sciences, mathematics, and the solid earth sciences. Several of these new studies have already had a major impact on their fields. For instance, the 1982 report *Astronomy and Astrophysics for the 1980s*, known as the Field report after its chairman George Field, was responsible in large measure for the federal commitment to build the Very Long Baseline Array, a new and exciting tool in radioastronomy.

The Committee on Science, Engineering, and Public Policy has also been involved in assessments of developments within scientific disciplines. The *Research Briefings* prepared by COSEPUP originated in a 1982 request that the academies undertake a series of surveys designed to inform presidential budget reviews. The briefings had to be done quickly and had to be ready to feed into the proper stage of the annual budget cycle. Six such briefings were presented in late 1982, and COSEPUP has continued to prepare research briefings annually for the Office of Science and Technology Policy and for the leaders of federal agencies since then. The briefings, which are compact, focused assessments of the status of particular scientific fields and opportunities within those fields, have become an important new policy instrument within the federal decision-making process. They are also widely read in the university and industrial research communities, as well as by scientists and policy officials in other nations.

From time to time the National Academy of Sciences and the National Research Council have created new institutions under the Academy's 1863 charter to foster scientific and technical communication and professional activities in the sciences and engineering. The establishment of the National Academy of Engineering and the Institute of Medicine are, of course, the best-known examples. Less well known was the role of the Academy complex in establishing the American Geophysical Union in 1919 and the Industrial Research Institute in 1938, both of which began under Academy auspices but are now totally independent of the institution.

In this vein the Government-University-Industry Research Roundtable was founded in 1982 under the councils of the two Academies and the Institute of Medicine. The Roundtable's membership includes university scientists and administrators, heads of the major federal agencies supporting research, and industrial executives. The Roundtable brings together individuals and organizations to discuss the nation's research enterprise and issues affecting the strength of that enterprise.

Science and Engineering Personnel

The health of the scientific disciplines is derived in large measure from the continuing supply and excellence of the human resources available to those disciplines. The Academy complex is very active in this area, both in examining policy issues associated with the supply and demand of scientific and engineering personnel and in managing associateship and fellowship programs involving individual scientists and engineers.

One effort in this area that has received a great deal of public attention has been an assessment of excellence in research doctorate-granting programs sponsored by a consortium of organizations including the National Research Council. The resultant five-volume report, *An Assessment of Research-Doctorate Programs in the United States*, focused on 32 disciplines within the mathematical and physical sciences, engineering, the biological sciences, the social sciences, and the arts and humanities. It carefully avoided comparing institutions; that is, it did not attempt a ten-best or ten-worst list. Instead it provided assessments by scholars of various measures relevant to appraising a particular department, with the relative importance of each measure left to the user.

The NRC's Office of Scientific and Engineering Personnel manages several programs for graduate study in the sciences and engineering and a broad program of research associateships at government facilities. It reviews applications submitted to the National Science Foundation for a graduate research fellowship program and a minority graduate research fellowship program. It performs a similar function for minority doctoral and postdoctoral fellowship programs funded by the Ford Foundation and for a fellowship program sponsored by the International Atomic Energy Agency. Most recently, it has begun overseeing a program of doctoral fellowships in the biological sciences sponsored by the Howard Hughes Medical Institute.

The National Research Council also operates an associateship program for a number of governmental agencies that provides opportunities for industrial and university scientists to work in government research laboratories. There are about 800 scientists and engineers involved in the program working in the facilities of some 28 federal agencies and laboratories.

In addition to the above activities, the Office of Scientific and Engineering Personnel is responsible for conducting two federally sponsored surveys of doctoral recipients and maintains a large data base on doctoral degree holders in the United States. These data are now quite valuable, as they span most of the post-World War II period.

The Office of Scientific and Engineering Personnel has been expanding the scope and volume of its analytic activities, which involve the formulation and evaluation of critical human resource issues.

The office has produced a number of studies and background papers, both for units within the Academy complex and for outside organizations, and is forging closer links between its analytic activities and more extensive operational activities.

Evaluating and Monitoring Human Health and the Performance of Systems or Products

In addition to the policy-oriented activities of the Academy complex, the National Research Council has been charged with monitoring and evaluating technical problems, which often requires reassessments of those problems over time. In some cases, these assignments have an operational nature requiring staff to conduct research. Some contend that these activities are not appropriate for the National Research Council, but others believe that few organizations provide the balance, objectivity, and capacity to monitor technical issues well over years or often decades.

The work of the Radiation Effects Research Foundation is illustrative. The foundation was born in 1946 as the Atomic Bomb Casualty Commission under a presidential directive from Harry Truman recommending that the National Academy of Sciences "undertake a long-range, continuing study of the biological and medical effects of the atomic bomb on man." Today the foundation is funded by the Department of Energy and the Government of Japan. Through policy and scientific boards jointly nominated by Japan and the United States, the foundation continues to study the survivors of the atomic bomb blasts and their descendants, adding concrete detail to the effects of nuclear radiation on humans.

The Medical Follow-up Agency is a unique creation for epidemiological studies that draws on the medical and personnel records of the military services and Veterans Administration. Its work includes studies of veterans who participated in tests of nuclear weapons in Nevada or the Pacific. Its studies of twins—from its unique twin registry of individuals who served in World War II or in Vietnam—have focused on such issues as schizophrenia, genetic predispositions to alcoholic psychosis and cirrhosis, and familial factors in early death.

From time to time the Executive Branch or Congress proposes new projects in which the National Research Council is charged with establishing protocols or procedures for evaluation and monitoring and, in some cases, conducting testing itself. For instance, the Centers for Disease Control (CDC) frequently requests that IOM and NRC committees review protocols for CDC studies. In this capacity the impaneled NRC and IOM teams are somewhat like "visiting committees" that evaluate the scientific integrity of CDC protocols.

The evaluation and monitoring role is not confined to the health area. In 1983 Congress directed the National Highway Traffic Safety Administration to request an NRC study on the costs and benefits of the 55-mph speed limit on interstate highways. The committee, which was established under the Transportation Research Board, concluded that the reduced speeds resulting from the speed limit save 2,000 to 4,000 lives per year, reduce serious highway injuries by 2 to 3 percent, and save about $2 billion per year in fuel consumption. The chief cost of the limit is a total of about 1 billion extra driving hours per year, which is an average of about 7 hours per driver per year. Given these costs and benefits the committee concluded that the 55-mph speed limit should be retained "on almost all of the nation's highways." However, the committee noted that the costs and benefits of the 55-mph speed limit are different for different parts of the highway system, leaving the door open for the later relaxation of the limit on interstate highways in certain rural areas.

Following the space shuttle Challenger disaster in 1986, NASA asked the National Research Council to form a panel of experts to oversee the design and construction of an improved solid rocket booster system for the shuttle. The panel conducted detailed technical evaluations of key steps in the redesign process and commented on the technical adequacy of scheduled NASA reviews of the redesign. Simultaneously, another NRC committee reviewed NASA's assessment of its policies and procedures for certifying the safety of critical shuttle components and recommended ways in which NASA can improve its risk assessment and risk management.

Recommendations Concerning Standards

In most industrial nations, performance standards that are widely used by the private sector arise from a combination of governmental and private sector actions. Thus in the United States a host of professional and engineering organizations, trade associations, private sector testing groups, and others are involved in making recommendations concerning standards that involve the physical sciences, engineering, health, medicine, and agriculture. Agencies of the federal government, such as the National Bureau of Standards, the Food and Drug Administration, and the Department of Agriculture, also set standards and often perform tests and measurements. Almost all standards, including the wide-ranging standards adopted by the government for the protection of the environment and worker safety, involve issues of scientific and technical judgment for which expert advice must be obtained.

In this context the government has turned to the National Research Council in many different areas for advice. Approximately every six years the NRC's Food and Nutrition Board has reviewed the recommended minimum dietary allowances for the major vitamins, minerals, and other nutrients. These studies have in turn been used by government departments to set the recommended dietary allowances (the RDAs). The Board on Agriculture has performed a similar service for the government in the area of animal nutrition, periodically assessing the changing scientific and technical bases for recommending dietary standards for domesticated livestock and pets.

Other units perform similar technical assessments for federal agencies responsible for setting standards. The Transportation Research Board has assessed the application of design standards developed to improve highway safety. The Safe Drinking Water Committee has produced a number of volumes that assess the risks to the public posed by exposure to drinking water contaminants.

In all of these cases, care must be taken to ensure that federal agencies understand that NRC recommendations are advisory. The responsibility for promulgating standards must be carried by the public officials in whom that responsibility is vested.

Technical Advice Fostering Intergovernmental and Interinstitutional Relations and Communication

In addition to the above roles, the Academy complex engages in activities that further the flow of technical and scientific information among federal, state, and local levels of government and between all levels of government and the private sector. The Transportation Research Board (TRB) is the longest established and most illustrative example. Established in 1920, TRB was initially designed to stimulate and correlate highway research and to make the findings of that research known widely among the states and private organizations. Today, TRB embraces all modes of transportation. It studies the planning, design, construction, operation, and maintenance of transportation facilities and their components; the economics, financing, and administration of transportation facilities and services; and the interaction of transportation systems with the physical, economic, and social environment. Funding for these activities is contributed by the 50 states, by transportation agencies of the federal government, and by private sector transportation agencies. The board produces technical reports and monographs that address questions of critical importance to all of these sponsors and to all users of the nation's transportation systems. It also conducts seminars, the results of which are widely disseminated to professionals in the transportation industries.

Part of the NRC's activities in fostering information exchange are designed to further coordination among the actions of the various institutions involved in a given area of science or technology. For instance, the Mathematical Sciences Education Board, which was established in 1985, brings together representatives of the many different groups concerned with the improvement of precollege mathematical education, including teachers, administrators, school board members, state school officers, parents, business leaders, and researchers. In addition to conducting research studies, the board organizes national and regional symposia, roundtable discussions, communication networks, and teacher assistance programs.

As states and localities assume greater visibility in the use and furtherance of science and technology, the National Research Council and the Institute of Medicine will have many opportunities to extend toward the states its network of advisory services and to disseminate the results of its studies broadly throughout the nation. One example of intergovernmental cooperation fostered by the National Research Council is a committee sponsored by the U.S. Department of the Interior and the State of California to study how irrigation affects water quality in the San Joaquin Valley, where deaths and deformities among ducks and fish in the Kesterson National Wildlife Refuge have been linked to high levels of selenium carried by farm drainage waters. Other elements of the National Research Council are also experimenting with increased contact at the state level.

Interinstitutional and intergovernmental activities within the National Research Council are subject to limitations, because an organization dependent on the contributed services of scientists, engineers, physicians, and other professionals has a finite capacity. The National Research Council therefore has to choose its projects with states and other organizations carefully. In some cases, the Research Council chooses to accept a project because specific regional or state knowledge will help a committee deal more effectively with broader questions of national policy. Projects are also sometimes undertaken to help states develop their own analysis or peer review systems.

International Affairs

The international activities of the Academy complex fall into four principal categories: interinstitutional communication among the science and engineering academies of different countries; participation in international scientific, engineering, and health organizations; exchange programs with the Soviet Union, other Eastern bloc nations, and the People's Republic of China; and programs supporting developing countries.

The National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine all maintain formal and informal ties with counterpart academies in other countries. For instance, the National Academy of Engineering is actively fostering an international dialogue of counterpart academies through the Council of Academies of Engineering and Technological Sciences, which has held international convocations roughly every two years since its founding in 1978.

Interinstitutional communication among scientists in the United States and abroad also takes place through the International Council of Scientific Unions (ICSU), which encompasses 20 disciplinary scientific unions and 70 academies of science around the world. The National Academy of Sciences is the national member of ICSU, housing the U.S. national committees that adhere to the organization. It arranges for financing, for meetings, and for cross-communication between disciplines in the United States and abroad through the national committees for those disciplines.

International scientific programs, both under the auspices of ICSU and through other mechanisms, further encourage international scientific cooperation. In 1984, for instance, NAS President Frank Press proposed before the International Association of Earthquake Engineering that an International Decade for Natural Hazard Reduction be established to reduce the massive losses that occur worldwide from natural hazards. The proposal received wide support, and an NRC committee was appointed to examine the feasibility of such a program. Prompted by the committee's report, the United Nations General Assembly adopted a resolution designating the 1990s as the International Decade for Natural Disaster Reduction in which the international community under the auspices of the United Nations will pay special attention to fostering international cooperation in the field of natural disaster reduction.

Collaborative relations between the National Academy of Sciences and the Academy of Sciences of the USSR have waxed and waned over the years. In the 1960s, Academy contacts were one of the only means of scientific contact. During the détente years of the 1970s, more than a dozen formal exchanges were arranged between governmental agencies of the two countries. However, levels of scientific participation and questions of human rights put a strain on the programs, culminating in a severing of relations upon the Soviet invasion of Afghanistan. In 1986, with a lessening of U.S.-Soviet tensions, Academy exchanges were resumed, and several new types of cooperative activities are being pursued. These include the organization of workshops, the promotion of invitational visits, and the initiation of cooperative research programs.

The National Research Council is also home for the Committee on Scholarly Communications with the People's Republic of China, which is jointly administered by the National Academy of Sciences, the Social Science Research Council, and the American Council of Learned Societies. The committee fosters exchanges between the two countries, arranges for scholars of the two countries to spend time at each other's institutions, provides a venue for discussion of science policy concerns, and offers a public outreach service for science and educational relations with the People's Republic of China.

The importance of the relationship between the United States and Japan led in 1985 to a series of high-level discussions sponsored by the Office of International Affairs, under the auspices of the Academies of Sciences and Engineering, between a group of American and a group of Japanese scientists, engineers, and industrialists. The recognition emerging from these meetings of the need to monitor and more fully understand science and technology policy issues affecting the U.S.-Japanese relationship led to the establishment of an Office of Japanese Affairs within the Office of International Affairs. The objectives of the office are to act as a focal point within the Academy complex and the larger science and engineering communities for information about areas of excellence in Japanese science and technology, to promote better working relationships between the technical communities of the two countries, and to examine various science and technology policy issues arising from U.S.-Japanese interactions.

Program activities with developing countries are centered in the Board on Science and Technology for International Development (BOSTID). BOSTID conducts an integrated program of overseas activities, research grants, policy and technical studies, conferences, seminars, and outreach activities aimed at finding ways of applying science and technology to problems of economic and social development.

THE NATIONAL RESEARCH COUNCIL AS A MIRROR OF CHANGING GOVERNMENTAL POLICY CONCERNS

Because the charter of the National Academy of Sciences and the Executive Order establishing the National Research Council link these institutions to the federal government, the agenda of the National Research Council and Institute of Medicine can be seen as an indicator of priorities in national policy and its underlying science and technology policy. These priorities may not be apparent at any given moment, but on a decadal scale some of the changes in this agenda become more apparent.

To the extent that sources of support serve as a broad indicator of the focus of policy within the federal government, one can observe significant shifts in priorities from the mid-1970s into the 1980s. The table below shows the percentages of federal funding from federal agencies in fiscal years 1976, 1983, and 1986. The federal government currently accounts for about five-sixths of the total operating funds of the Academy complex, so these percentages are fairly representative of the overall division of effort within the institution. Several of the shifts between these years—for example, the increases in funding from the Department of Defense and the Department of Energy—reflect changing national emphases in both policy and research and development priorities. Areas of civil domestic activity—represented, for example, by funding from the Department of Health and Human Services and the Environmental Protection Agency—show declines, reflecting the agenda of the Reagan administration. The increase in funding from the Agency for International Development comes from the BOSTID grant program, which began in 1981.

Support for the program budget from foundations, endowment income, and other private sources rose from 7 percent of the total in the early 1980s to 15 percent in the late 1980s. This funding has allowed several critical studies to be initiated that would not have been supported by government agencies.

Distribution of Academy Operating Funds from Federal Agencies

Agency	Percentage of Funding		
	1976	1983	1986
National Science Foundation	17.0	10.9	11.5
Department of Energy	12.5	19.3	17.6
National Aeronautics and Space Administration	12.0	13.6	11.6
Department of Transportation	11.5	11.1	12.8
Department of Health and Human Services	11.0	7.3	6.7
Veterans' Administration	10.0	0.3	1.1
Department of Defense	8.5	17.2	12.9
Environmental Protection Agency	6.0	2.3	3.3
Department of Commerce	3.0	3.5	2.7
Department of State	3.0	1.4	1.2
Agency for International Development	1.5	7.1	8.7
Department of the Interior	1.5	2.3	3.3
Other federal agencies	2.5	3.7	6.6

DYNAMICS OF THE RELATIONSHIP BETWEEN THE ACADEMY COMPLEX AND THE FEDERAL GOVERNMENT

As with any long-standing relationship between institutions, a variety of factors influence the initiation and execution of studies by the Academy complex and the ways in which the results of those studies enter into the decision-making processes of the federal government. The officers of the Academies, the National Research Council, and the Institute of Medicine must take these factors into account as they guide the work of their organizations. The factors discussed below are illustrative of the many forces, direct and indirect, that influence the relationship between the Academy complex and the federal government.

The Continuing Spread of Scientific and Technical Decision Making Throughout the Government

With the increased size of government since World War II and the growing influence of scientific and technical factors in governmental decisions, a large number of technical judgments must now be made at all levels of government. The President, leaders of Congress, and Cabinet officials all request studies of the National Research Council. Public officials who direct major governmental bureaus also turn to the Academy complex for assistance. Requests from throughout the federal government have continued to increase, even though there are other organizations, including official advisory units on science in both the executive and legislative branches, to which similar requests could be made. In fact, the constrained budget and staffing patterns associated with recent administrations may have heightened interest in using the advisory capabilities of the Academy complex.

This proliferation of requests presents a challenge: How can the Academy complex ensure that it continues to give priority to the most significant work in the face of myriad requests? The National Research Council generally responds affirmatively to requests from the executive branch or Congress. However, some governmental requests that seem important can, upon more objective evaluation, be seen to be somewhat parochial. Also, NRC staff and committee members sometimes present themselves as too ready to respond, a natural tendency of staff who are not tenured and committee members who are eager to serve in the time-honored NRC tradition. NRC leaders must weigh and balance these factors as they monitor the work of the organization.

Imperfect Statement of Requests or Charges

On occasion, requests from an executive agency or congressional committee are well intended but imperfectly stated. For instance, the initial request to the National Research Council or the Institute of Medicine might not have benefited from sufficient discussions by a scientific group, resulting in a charge that is overly ambitious in that it expects results that are not verifiable on the basis of available evidence. In other instances, government officials may attempt to predetermine or prejudice the outcome of a study through the statement of the charge.

In many of these cases, the statement of the charge becomes the subject of careful negotiations. Frequently there is a period of some sensitivity in which the empaneled committee must renegotiate the original request to the National Research Council or the Institute of Medicine.

Rapid Turnover of Officials in Congress and the Executive Branch

Historically, a continuity of tenure in political office existed within the legislative branch; many elected officials served in key committee and subcommittee assignments through a succession of Congresses. That continuity has been dramatically altered by judicial decisions requiring more frequent realignment of political districts to reflect population distributions within the United States. At the same time, the turnover of public officials within the executive branch has accelerated considerably, with many fewer professional civil servants and policy officials remaining at their posts over long periods.

In short, the Washington public policy scene has become a constantly changing panorama. The constant flux requires a continuing process of education, reeducation, discovery, and appreciation of the role of science and technology in public policy decision making. New public officials are often unaware of the capability of the Academy complex for technical assistance. Academy officers must make concerted efforts to contact elected and appointed officials to acquaint them with science and technology policy issues and to provide them with an understanding of the ways in which the institution can meet their needs for professional, objective advice.

Initiation of Studies in One Administration or Congress and Submission of Results to a Successor Administration or Congress

Because NRC and IOM studies typically take one to two years to complete, a certain number of them are inevitably commissioned by one administration or Congress with their results being presented to a successor administration or Congress. Rapid succession of presidencies over the last 20 years has exacerbated this phenomenon.

The implications are several. Whatever the merits of a study, there may be no reception for its findings since new officials in government may have no "ownership" of the commissioned project. If there has been a change of political party from one administration to the next, the study may be viewed suspiciously. Congressional committees often have similar propriety instincts. Academy committees and staff that have devoted their considerable talents and energy to a complex technical study can become discouraged if they receive indications that their product will not be read and taken seriously.

Conversely, it should be noted that occasionally an astute public official will seek the assistance of the National Research Council in studying an intractable technical or public policy issue before or at the height of the political process, thereby removing or at least dampening the political debate surrounding the problem by pointing to the ongoing study as a responsible process. To the extent that an NRC analysis can sharpen the areas of technical consensus associated with such an issue, it can be helpful in reaching policy resolution. But NRC officials must avoid becoming "used" in such a process. Matching science and technology policy analysis with political schedules is another of the tasks of the organization's leadership.

Policy and Program Tensions Between the Executive Branch and Congress

In recent years, a growing number of studies undertaken by the National Research Council have been mandated by congressional legislation. In many cases, these requests are seen as desirable by both the Congress and the executive branch and they proceed with the effectiveness of dual sponsorship. In some of these cases, however, a situation can arise in which the Research Council is in effect serving as a referee on issues where Congress is dissatisfied with a policy, program, or budgetary direction being proposed by the President through the departments and agencies of the executive branch. For example, after the Reagan administration took office it dramatically altered the appropriation requests for the National Aeronautics and Space Administration. The appropriation committees of the House of Representatives and the Senate, acting through NASA's appropriation, directed that Congress would call from time to time on the National Research Council to undertake reviews of administration proposals where it wanted independent program advice. A number of such studies have been requested.

Occasionally, the prospect of a legislative directive to an executive agency will prompt that agency to initiate a request, which can give it greater latitude in constructing the terms of reference of a study than if those terms were mandated by legislation. Such was the case with the Institute of Medicine's review of the organizational structure of the National Institutes of Health, which was published in the report *Responding to Health*

Needs and Scientific Opportunities: The Organizational Structure of the National Institutes of Health. The Department of Health and Human Services did not wish to have the study, but faced with the prospect of legislation it entered into a contract with the Institute. Sometimes, a difference of view between branches of government about commissioning an Academy study can also lead to a delay in funding, placing the institution "between" the congressional sponsor wanting the results by a specified time and an agency that may neither desire the study nor have an appropriation provided by Congress for the required contract.

Issues Addressed or Not Addressed Because of the Political Agenda of an Administration

Each administration has an agenda reflecting the mandate given to it by the electorate. In some instances, this agenda influences the administration's perception of science and technology policy and, in turn, its desire to use the National Research Council. In the Reagan administration's early years, for instance, the Environmental Protection Agency was reluctant to call on the Research Council to continue the examination of the scientific and technical issues associated with major environmental problems such as acid precipitation. The Research Council then decided, because of the importance of the issue, to proceed with a study of acid rain using its own funds. Ironically, the resulting study later became the basis for a revised governmental policy when international considerations, continued pressure from Congress, and a change of leadership at the Environmental Protection Agency led the administration to take action in this area.

Similarly, some public officials in the Carter administration with a consumer or public safety orientation were skeptical about using the National Research Council to consider scientific issues in public policy. Their concern was that the technical evidence would not support their administrative or regulatory goals.

Officials in both the executive branch and Congress occasionally approach the National Research Council with an unrealistic hope of additional advocacy, believing that advice from the institution will strengthen their case. NRC officials must keep these expectations in mind, deciding when the organization should use its own funds to initiate studies and how to respond objectively when an advocacy position is desired.

Sole-Source Contracting Procedures

The Academy complex enjoys a special relationship with the U.S. government because of its congressional charter and its long history of support to the government as a quasi-independent ally. The institution is nevertheless a contractor in the sense that it receives funds from the government for work that it undertakes. Over the last two decades, revisions of government procurement policies have increasingly strained a previously unchallenged sole-source relationship between government departments and agencies and the Academy complex. Today considerable pressure is being applied through legislation, executive order, and administrative practice to require competitive bidding for all procured governmental services and products, including policy studies. Thus departments of government that want to draw on the Academy complex are being forced to undergo complicated administrative procedures, often by way of a request for proposals in which the Academy, among others, could be a bidder.

For its part, the National Research Council and the Institute of Medicine have eschewed putting themselves into the position of being respondents to competitive procurement procedures. In most instances, they will not respond to requests for proposals unless there is a specific indication that an organization such as the National Research Council or the Institute of Medicine would be selected for the study.

Several policies ameliorate this problem. The Office of Management and Budget recognizes the National Research Council's unique role and has advised agencies that it considers the Research

Council suitable for sole-source procurement because of its unique status. For over two decades the National Science Foundation has had in force with the National Research Council several key master contracts or basic ordering agreements to which additional tasks can be added as new requests for policy studies arise. The Department of Defense has a similar master agreement. Nonetheless, procurement procedures complicate the relationship between the Academy complex and the government, often adding undesired weeks or months into the initiation of a project.

Attempts to Alter NRC Procedures Through Government Contracts

Although public officials seek objectivity and independence when they approach the National Research Council for assistance, many remain uncomfortable with the process because the recommendations of a study cannot be predicted. NRC procedures that ensure objectivity include the sole right by the Research Council to appoint committees, no release of findings and recommendations until the work has undergone internal NRC review, conduct of deliberative work in executive session, and so on. These procedures reduce the day-to-day oversight of NRC studies by the government.

Sometimes, contracting officials seek to modify NRC procedures through a government contract in such a way as to increase an agency's input and monitoring of an activity. Changes in procedure requested by government contracting officials can appear subtle or innocuous. Moreover, negotiation of a contract generally follows agreement on the substantive elements of a study by NRC and agency staff, which often creates a momentum or pressure to push forward with a project. NRC officials must guard against the erosion of internal procedures through alterations proposed in contract negotiations. At the same time, they must seek to understand an agency's unease about the independence and objectivity of NRC studies and seek to accommodate such concern through discussions and arrangements consistent with internal NRC procedures.

Policy Impedance Created by the Organizational Structure of Government

Some science and technology policy issues may not come into clear focus within the executive branch because of the organization of government itself. As government has grown, similar functions have often been assigned to a number of widely scattered agencies, with no single agency having a clear leadership role. The result is policy fragmentation. In the area of water science and technology policy, for instance, at least a dozen federal agencies have responsibility for various aspects of the policy. Major responsibility is centered on the Environmental Protection Agency, the U.S. Army Corps of Engineers, the Department of the Interior, research agencies such as the Geological Survey and National Science Foundation, authorities such as the Tennessee Valley Authority, and regulatory entities such as the Federal Energy Regulatory Commission (which allocates sites for hydropower). Major issues of water supply and demand, water distribution, and water quality, which according to many people will be critically important in future decades, are not always tractable within the diffuse organizational structure of the government. Many similar examples could be cited.

In such instances of policy fragmentation, National Research Council committees and staff sometimes have difficulty gaining consensus among government agencies on an agenda of technical or policy studies. Occasionally, the Research Council succeeds in facilitating communication among the agencies to initiate policy work that is in their collective interest. Such situations can also require National Research Council committees to obtain core funds through many small contracts. Either outcome can present problems for NRC committees, staff, and management; the desire to provide technical or policy assistance must be tempered by pragmatism concerning the actual role being served.

Conflicts Between Quality and Timeliness

Most matters of science and technology policy require the study and formulation of conclusions over periods of time that are inconsistent with political schedules, which tend to be driven by annual appropriations, elections in the legislative bodies, the presidential term of office, and so on. Thus a principal challenge for the Academy complex is to find ways to deliver its advice in a timely fashion.

Within the framework of scholarship, Academy projects are driven by adherence to scientific and technical completeness; committees want to respond in a comprehensive and scientifically accurate way. There is a strong desire for quality even if it means devoting additional time and human and financial resources to the analysis. Many government policy issues involving science or technology, on the other hand, require decisions mandated by legislative or administrative cycles, even if the available evidence and analyses are incomplete. Some of these deadlines are established by statute. Therefore, many requests to the National Research Council or the Institute of Medicine will be effective only if the resulting studies are completed by the date at which a decision must be made by a public official. If a report arrives late, even if it is a more comprehensive or technically accurate document, it will have no usefulness in that decision. Academy officials must therefore balance the relationship between timeliness and completeness to ensure that quality is not compromised while meeting the deadlines of decision makers.

Changing Priorities of Financial or Political Support

With the passage of time, federal financial support for some activities undertaken by the National Research Council has waned even though that activity continues to have many supporters within government and the scientific community. These changes may be ascribed to altered political conditions or to changing financial priorities. International scientific exchanges and other international programs are an example. As appropriations tightened during the late 1970s and 1980s, funding for international exchange operations and international policy studies was frequently questioned. The Academy's exchange programs and activities in the International Council of Scientific Unions are among the efforts that have been affected by these pressures.

Analysts contend that these problems are due in part to the character of the programs, in that they no longer attract the best scientists. Nonetheless, waning governmental support and annual uncertainty as to the level of that support create tension between sponsoring agencies and the NRC's international offices. NRC officials must be alert to fluctuations in governmental interest, and they must devise ways to reshape and sometimes curtail efforts or seek independent funding if they are to be continued.

Conflicting Interests in Longer-Range Forecasts of Science and Technology

Many officials within the executive branch and Congress have recognized a need for longer-range technical and scientific forecasting. They point out that science should be better able to describe or give warning about impending crises and that national leaders should be better prepared to exploit scientific advances. Congress has taken a number of steps to encourage such longer-range forecasting. For example, it has required agencies such as the National Science Foundation and the National Aeronautics and Space Administration to prepare scientific outlooks or perspectives periodically on emerging opportunities and problems. Many of these longer-range forecasts entail contributions by the Academy complex, as in COSEPUP's preparation of the research briefings.

Most public officials and legislators agree that these longer-range forecasts are commendable. However, day-to-day crises within government, tensions between the political leadership in the executive branch and Congress, the political cycles of government, and other operational problems tend to cause this longer-range advice to lie fallow and go unused.

Because of the disparity between shorter-term and longer-term governmental objectives and their policy needs, the National Research Council is often in a dilemma as to the appropriate level of institutional commitment to request for long-term forecasts. The problem centers on the organization's system of voluntary service by scientists and engineers. Policy assessments, either longer-term reviews or focused shorter-term studies, demand the diversion of time and energy from other pursuits, including the research of individual committee members. NRC officials are reluctant to call committees together for studies that go unread and unused. Nonetheless, few organizations are so well equipped to provide perspective on emerging issues and scientific and engineering opportunities.

THE U.S. SCIENCE AND TECHNOLOGY POLICY AGENDA IN THE 1990s

Looking ahead to the 1990s, one can anticipate that the agenda of the National Research Council will continue to mirror national concerns. Emerging themes are already apparent. To remain effective, the Academy complex will have to restructure its agenda regularly to remain at the forefront in the analysis of emerging opportunities in science and engineering and the scientific and technical elements of national policy. Some of the areas in which the institution can be expected to invest considerable attention are discussed below.

Industrial Productivity and International Competitiveness

As the world's economies have lagged, all industrialized nations have been concerned with national industrial policies, directing and redirecting them toward the enhancement of productivity. The rising industrial capacity of Japan and other Pacific-rim nations has been an object of special attention in the United States.

The Academy complex has already made major contributions to this discussion and has laid the groundwork for additional activity. The National Academy of Engineering has analyzed the current domestic and international posture of a number of basic manufacturing sectors, including the machine tool, automotive, textile, electronics, pharmaceutical, and steel industries. Other studies have examined the changing technological elements of the workplace and the implications of these changes for the current and future work force. The 1983 NRC report *International Competition in Advanced Technology: Decisions for America* outlined a possible strategy for meeting foreign competition in high-technology industries. In addition, the National Research Council has several standing committees, such as the Manufacturing Studies Board and the National Materials Advisory Board, engaged in studying problems of international competitiveness.

AIDS and Other Health Policy Concerns

By the early 1990s, the AIDS epidemic will have worsened considerably, with several hundred thousand cases in the United States and health care costs in the billions. The already strained health care industry will be strapped, particularly in high-impact areas. Sustained attention to the scientific, clinical, and societal aspects of AIDS will be critical in the 1990s. Within the Academy complex, this effort will involve not only the Institute of Medicine but increasingly other units, such as the Commission on Behavioral and Social Sciences and Education and the Office of International Affairs.

The organization, financing, and delivery of health care in the United States will continue to be important issues in the 1990s, as will the allocation of research resources. For instance, consideration of catastrophic health insurance and mandated employer health insurance are recent indicators of an extensive and ongoing rethinking of questions of health benefits and their financing.

The Consequences of an Aging Population

The U.S. health care system, the social policies of federal, state, and local governments, and public and private employers will all be dramatically influenced by the demographic changes that will take place in the United States in the years ahead. The Academy complex, through the coordinating leadership of the Institute of Medicine, has responded by undertaking a series of projects on the issues associated with an aging population. Some of these activities have been initiated with the institution's own funds. Examining the consequences of these demographic changes will contribute to public policy in medicine, health care, housing, transportation, and other public and private sector areas.

Regulation of Environmental Standards, Health, and Human Safety

In the late 1960s and early 1970s, public policy within the United States dramatically shifted to include a heightened awareness and concern for the environment, for potential risks to human health, and for the safety of workers and consumers. Major legislation was enacted to improve air quality, water quality, the safety and health of employees in the workplace, the safety of consumer products, and so on.

Two decades of experience with these regulatory regimes have now accumulated. There is a growing national consensus that "mid-course corrections" are needed, but there is less consensus on exactly what should be done. Some have advocated a major overhaul of current legislation. Polarizing approaches to regulatory policy in presidential administrations have impeded rational public debate. The 1983 NRC report *Risk Assessment in the Federal Government: Managing the Process* was an important contribution to the ongoing discussion about the rationalization of regulatory programs. Building on that study, the NRC's Committee on Risk Perception and Communication has examined how best to convey assessments of risk to nonspecialists. Other NRC activities can be expected in this area in the years ahead.

Global Change and Other Environmental Issues

Environmental issues have not been at the center of recent national policy discussion, but they have never been far below the surface. A new chapter in environmental policy will open with increasing scientific understanding of global change caused by greenhouse gases or ozone depletion. The rapidly increasing capabilities of biotechnology will generate dramatic new environmental opportunities as well as challenges. Regulation of the products of biotechnology, including genetically engineered organisms to be released in the environment, would benefit greatly from the development of a comprehensive scientific framework.

Energy

Like the environment, energy has not been a focus of policy attention during the 1980s, but it is likely to reemerge as one during the 1990s. Research and development on alternative energy supplies has progressed slowly, due in part to governmental and industrial policies and in part to the lack of a solid science base for some energy alternatives. As knowledge of global environmental change increases, questions of nuclear power and alternative sources of energy may again become pressing.

Reinvigorating Public Education and Precollege Science and Mathematics Teaching

As it has become apparent that the technical literacy of the next generation of Americans will be critically important for effective participation in the workplace and that public policy decisions involving science and technology must have the support of the public, education in science and mathematics has become a matter of national concern. The Academy complex has initiated a number of activities in this area. In 1982 the NAS and NAE held a convocation on the status of precollege science and mathematics instruction, with the report from this meeting being widely circulated. Among others, the chief school officers of the 16,000 school districts in the United States received copies. As previously noted, the National Research Council established the Mathematical Sciences Education Board in 1985 to serve as a resource to localities interested in strengthening their mathematical sciences curricula. The National Academy of Sciences and the Smithsonian Institution have joined to create a National Science Resources Center to improve the teaching of science and mathematics in the nation's schools. The report *High Schools and the Changing Workplace: The Employer's View*, which was released by COSEPUP in 1984, has had an important effect on the debate over educational standards.

Defense and the National Security

Since the late 1970s, appropriations for research and development related to national security have increased, reversing a trend that saw military research and development decline from the late 1960s to the late 1970s. The Department of Defense, through the Army, Navy, and Air Force, can be expected to continue to call on the National

Research Council for technical and policy studies. The Army, for example, has asked the National Research Council to create a standing committee, the Board on Army Science and Technology, to provide various assessments that would improve the Army's internal program of research and development. The Army has also called on the National Research Council to assist in the technical review of other issues. For example, *Disposal of Chemical Munitions and Agents* assessed the current technical and human safety status of stored chemical munitions and ways in which obsolete chemical munitions might be safely disposed. The study by the Naval Studies Board on the Navy of the next century is another example of the NRC's service to branches of the military. NRC initiatives in technical areas related to defense research and development policy will remain an important component of the organization's activities in the 1990s.

Export of sophisticated technological products to the Soviet Union directly or indirectly through third-country sales and transfer received much attention during the early years of the Reagan administration. The advocates of increased export controls contend that part of a growing Soviet capacity to deploy technologically advanced weapons is due to the flow of equipment, products, and knowledge from the West, a flow that offsets a lagging domestic economy and lack of internal capacity to translate basic scientific discoveries into advanced technological products.

The U.S. government has several conflicting policy objectives in this area: national defense, legitimate restrictions on the trade of militarily significant technology, international trade, the promotion of industrial development including overseas markets, and broad support for basic research and its publication. Conflicts among these objectives have resulted in proposed policies that would greatly restrict the free flow of basic scientific knowledge.

COSEPUP has issued two major studies of this issue. The 1982 report *Scientific Communication and National Security* concluded that policies restricting the flow of knowledge through the scientific literature would make a limited contribution to national security while greatly affecting the use of basic research by American universities and industries. In 1987 the report *Balancing the National Interest: U.S. National Security Export Controls and Global Economic Competition* found that while export controls are a necessary and appropriate mechanism to keep sensitive high-technology equipment from Warsaw Pact countries, current export controls in some cases hinder trade and create mistrust between the United States and its allies.

Arms Control

Finding effective mechanisms for reducing the threat of nuclear war and encouraging limitations on the development of destabilizing weaponry without reducing the essential national security of the United States is a central issue in foreign policy. Since 1980 the National Academy of Sciences has taken a novel approach to this question through its Committee on International Security and Arms Control (CISAC), which consists of about 18 scientists and individuals who have been deeply involved in many aspects of military technology and arms control. Committee members meet periodically with their Soviet counterparts to discuss international security issues. From the outset these meetings have been unofficial and private and thus have made it possible to explore questions not currently on the official negotiating agenda. Many of the topics explored in the early 1980s, including the possibility of deep cuts in the numbers of international continental ballistic missiles, have since entered official discussions.

Federal Allocations for Research and Development in an Era of Constrained National Budgets

For over a decade the nation has been awakening to the realization that there are finite limits to public expenditures and to the responsibilities of government. The era of constraint on public expenditures will extend into the foreseeable future, forcing priorities to be established among various potential expenditures of public funds, including those allocated to research and development. While support for research and development has continued and increased, there is an increased need to establish clear priorities and directions and to gain consensus among scientists, engineers, and public officials about these priorities. The balance between civil and defense research expenditures and the relative emphases given research, development, and procurement in the defense sector must also be addressed.

Increased activities by the Research Council can be expected as priorities for research and development are contrasted with priorities for other public programs. For instance, the presidential science adviser has requested that the NRC review research facility requirements for materials science and earthquake engineering. The National Science Foundation has turned to the National Academy of Engineering for advice on establishing engineering research centers and to the National Academy of Sciences for advice on establishing science and technology centers. These requests continue a tradition of advice from the Academy complex concerning resource allocation, but the new intensity of discussion adds a dimension to the work that was absent a decade or more ago.

Emerging Frontiers in the Scientific and Engineering Disciplines

New developments in the scientific and engineering disciplines, such as the increasing power of computational tools, will continue to reshape those disciplines in exciting ways. For example, the effort to sequence the entire human genome, discussed in the 1988 NRC report *Mapping and Sequencing the Human Genome*, would be the largest project ever undertaken in biology and would yield a wealth of biological and medical advances. The Academy complex will remain in the forefront of such issues through its examinations of policy and technical issues and its assessments of scientific and engineering disciplines.

Conclusion

The examples given above illustrate the directions in which national debate, discussion, and decision making can be expected to take the National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and National Research Council in the future. As in the past, the challenge lies not only in the scientific and technical issues themselves but also in maintaining a keen appreciation of the sometimes turbulent forces that drive national and international discussions of science and technology policy.