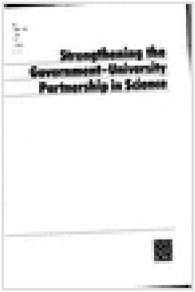

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Strengthening the Government-University Partnership in Science

Report of the Ad Hoc Committee on Government-University Relationships in Support of Science
Committee on Science, Engineering, and Public Policy

National Academy of Sciences
National Academy of Engineering
Institute of Medicine

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*Photocopies of the background papers of the Committee on Government-University Relationships in Support of Science are available from the National Academy Press, 2101 Constitution Avenue, NW, Washington, DC 20418.

Preface

Over the past decade the relationship between the federal government and the universities with regard to federally funded scientific research has become increasingly strained. Mounting concern over the deterioration of this relationship and its impact on research led the late Philip Handler, then President of the National Academy of Sciences (NAS), to appoint this Ad Hoc Committee on Government-University Relationships in Support of Science.

In a letter dated January 12, 1981, Dr. Handler briefly described the growth of the academic/scientific enterprise, with the support of the federal government, since World War II. The letter states:

> The marriage of the universities and the federal government was hurriedly made during World War II when the emergency situation did not permit time for debate or discussion. There was no debate concerning a philosophy that would frame the terms of the arrangement.

Dr. Handler's letter then referred to some of the problems involved in the government-university relationship. He went on to outline the Committee's broad charge:

> The Council of this Academy and I have agreed that the time is propitious to bring into being a group of individuals of mixed backgrounds who, after review of this history, would not design yet more patches but rather consider what the form of an ideal relationship might really be, what should be the terms by which the universities and the federal government acknowledge their partnership in this enterprise and how they could go forward together

with a minimum of tension, conflict, [and] controversy.

The Committee includes 25 leaders of universities, industry, and public life. In spring 1981 it was placed under the recently reorganized Committee on Science, Engineering, and Public Policy of the National Academy complex. The study was initiated in summer 1981 with the assistance of planning grants from the Lounsbery Foundation and the White House Office of Science and Technology Policy. Support for the principal work of the Committee, which was undertaken in 1982, was provided by the Sloan Foundation and a consortium of private foundations that provides funds to the Academy complex. The consortium includes the Carnegie Corporation of New York, the Charles E. Culpeper Foundation, the William and Flora Hewlett Foundation, the John D. and Catherine T. MacArthur Foundation, the Andrew W. Mellon Foundation, and the Rockefeller Foundation.

From the beginning, the Committee was faced with the question of how to address effectively a set of problems that had been the subject of intense scrutiny by many groups in many places. In particular, we had to confront the fact that two groups--the National Commission on Research and the Sloan Commission on Government and Higher Education--had recently completed lengthy reports on the very matters that were the subject of the Committee's attention. Such reports exert immediate impact but have not restored the quality of the partnership. The Committee was determined to find a new and more lasting approach, not simply repeat work already performed.

This report takes its shape from that determination. We decided early, after meeting with members of the National Commission on Research and the Sloan Commission, that we would do the groundwork necessary to bring into being a continuing forum to facilitate understanding between the government and university communities and to promote resolution of their disagreements over major issues of policy. The concept of such a forum had originated in the National Commission on Research.

As background for its deliberations, the Committee commissioned papers on federal support for graduate education in the sciences and engineering, the grant and contract policies of industry and foundations compared with those of the federal government, and national science policy and research priorities. In preparing this report, the Committee has drawn from the data and analyses in these papers. Parts of Chapter 1 are based on the paper by Albert Teich. The data on trends in graduate education in Chapter 3 come from the paper by Susan Fallows. The paper by Cedric Chernick on the grant and contract policies of the government and other supporters of research contributed to the discussion of accountability in Chapter 7.

The views of many people outside the Committee have influenced this report. At five of its meetings, the Committee talked with people in universities, federal agencies, and Congress. The acknowledgments lists them. In addition, the Committee sent letters to about 750 individuals in government, universities, and the private sector and published an open letter in Science asking for comments on 10 major issues. The Committee received 169 responses, many of them representing the views of several individuals or groups. The letters came from all sectors surveyed and gave the Committee valuable insights into the distinct, sometimes conflicting perspectives of the parties involved. Taken together they provide a wealth of documentation of the intensity of feeling and wide range of opinion about these issues. The text of the outreach letter, excerpts from selected letters, and the list of respondents appear in Appendix A.

It is against this background of the thoughtful expression of opinion of many researchers, university administrators, government officials, and industry leaders that the Committee reached its principal conclusion: There is an overwhelming need for better mutual understanding among the partners. To that end the Committee devoted its major efforts toward establishing the Forum as a device for improving communication on important issues of policy. John Gardner chaired a subcommittee appointed to pursue this objective. He is responsible in large part for the Committee's principal achievement--the Forum on Government-University Relationships--which is described in Part I of this report.

As the Committee's work progressed, all members contributed to the analyses of specific problems that form Part II of this report. The Committee is grateful for the individual work done in the preparation of working drafts and sections of the report by many of its members. We particularly wish to acknowledge the contributions of Donald Fredrickson, John Gardner, and Linda Wilson.

The Committee is deeply grateful for the splendid and invaluable work of its Staff Director, Patricia Warren, not only in managing the project and the production of the report but also in her substantive and research contributions to its content. The fine editorial work of Kenneth Reese and the historical insights of Hunter Dupree are gratefully acknowledged as well. We also thank Patricia Ducy, Maryann Kowalczyk, and Frances Shaw for their assistance in arranging our meetings and typing successive drafts of the report.

Three main elements are the focus of our report--the federal government, the universities, and the community of scientists and engineers in these institutions, most of whom are also members of teaching faculties. The same three elements were dealt with in a report of the NAS Committee on Science and Public Policy, Federal Support of Basic Research in Institutions of Higher Learning (1964). That report gave a rationale for federal support of basic research in universities and reasons why support of basic research and support of graduate education must be merged.* The Committee accepts that rationale as its basic premise and moves on to consider how the supporters and the recipients of federal support can go forward together with a minimum of tension and controversy.

We find much in both government and the academic community that needs improvement, but we have made no attempt to prescribe detailed policies for either party. Instead our treatment of the issues is illustrative, a prototypical agenda for the Forum. On some aspects of the issues, however, we offer informed opinions that amount to recommendations.

Some of our descriptions of the issues go further than others. Accountability, for example, is a long-time source of tensions in the partnership and is treated at some length. The three-way relationship among government, academe, and industry is discussed less extensively. That relationship has been developing rapidly, and a set of general principles is not yet obvious; our interest, moreover, was focused narrowly on the interaction between government-university and industry-university relations.

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*For an earlier statement of this rationale see the report of the President's Science Advisory Committee, Scientific Progress, the Universities, and the Federal Government, issued in November 1960.

The Committee did not examine one important issue: scientific freedom. We did not do so because the question of imposing controls on a major element of this essential principle--freedom of communication--was being studied concurrently by a panel of the Committee on Science, Engineering, and Public Policy. The panel's excellent report has since appeared.*

The Committee also did not examine the question of national science policy per se. We are aware that some believe that a more explicit federal science policy than now exists is needed to set priorities for the distribution of resources in support of science, especially when those resources are limited. The issue certainly has implications for the government-university relationship; we elected not to study it because it transcends that relationship.

The past 40 years have seen remarkable growth in support of many kinds for basic research and graduate education, and the role of the federal government has on balance been highly constructive. On the whole our universities are much stronger in the sciences and engineering today than they were a generation ago. We have great confidence that energetic leadership and constant effort can find solutions to the problems of the partnership.

BURKE MARSHALL, Chairman
Ad Hoc Committee on Government-University Relationships in Support of Science

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*Committee on Science, Engineering, and Public Policy, Scientific Communication and National Security (Washington, D.C.: National Academy Press, 1982).

Acknowledgments

The Committee is indebted to the many individuals and groups who provided information and advice used in preparing this report. The following people, who were invited to attend the Committee's meetings, provided valuable insights into the government-university relationship. They are listed in the capacity in which they spoke to the Committee.

RAYMOND BEAUDET, former Associate Director of Audit Agency, U.S. Department of Health and Human Services
EDWARD BRANDT, Assistant Secretary for Health, U.S. Department of Health and Human Services
WILLIAM CAREY, Executive Officer, American Association for the Advancement of Science
JOHN CROWLEY, Director of Federal Relations for Science Research, Association of American Universities
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CARL KAYSEN, Director of Science, Technology and Society, Massachusetts Institute of Technology

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WILLIAM SEWELL, Professor Emeritus, University of Wisconsin
JOHN SLAUGHTER, Director, National Science Foundation
ALVIN TRIVELPIECE, Director, Office of Energy Research, Department of Energy
LEO YOUNG, Director, Research and Laboratory Management, Deputy Undersecretary of Defense for Research and Engineering, U.S. Department of Defense

In addition, the following people have offered assistance by providing materials and other information for the Committee's consideration:

WILLIAM BLANPIED, Head, Office of Special Projects, Office of Planning and Resources Management, National Science Foundation
ROBERT CASSMAN, Staff, Committee on Science and Technology, U.S. House of Representatives
NEWTON CATTELL, Executive Director for Federal Relations, Association of American Universities
JOHN COOPER, President, Association of American Medical Colleges
J. MERTON ENGLAND, Historian, National Science Foundation
PENNY FOSTER, Study Director, University and Non-Profit Institutions Studies Group, National Science Foundation

Summary

The federal government and the nation's universities have enjoyed for more than a generation an immensely important and successful partnership in research and education in the sciences and engineering. The broad terms of the collaboration are straightforward: The government supplies major support for education and research, especially basic research, in the universities; the universities educate scientists and engineers and produce knowledge deemed essential to the well-being of the nation and of mankind. The partners have agreed on these terms since the beginning of the enterprise. Certain tensions have always been inherent in the relationship, however, and during the past decade or so they have intensified to a potentially damaging level. Concern that these conflicts are now serious enough to threaten the productivity of scientific research and education in the United States led to the appointment of this Ad Hoc Committee on Government-University Relationships in Support of Science.

The Committee's broad charge was to "address the basic relationship between universities and the federal government with respect to the scientific endeavor." In doing so, we have examined the evolution of the partnership, its condition today, and the problems it faces. The Committee has concluded that resolution of these problems requires more than anything else sustained effort to achieve greater mutual comprehension and consensus on the principles essential to the partnership and on the application of those principles. To that end, we describe in Part I of this report a new and independent body--the Forum on Government-University Relationships. The Forum is concerned with science and technology and is designed to improve communication between the partners and to facilitate resolution of the problems they share and will share in the future. The establishment of the Forum, first suggested in 1980 by the National Commission on Research, is the primary result of the Committee's work.

We have also considered the origin and substance of specific issues in government-university relations. On some of these issues we have reached judgments and offer opinions that we hope will facilitate solutions; on others we state only our understanding of where the discussion stands. All of these issues, we believe, are worthy candidates for the agenda of the Forum. They are discussed in Part II of this report.

BASES FOR JUDGMENT

The Committee has examined many of the previous assessments of the partnership. Its views have been shaped by the following premises:

- Scientific knowledge and the consequent technological strength are indispensable to the United States. Continuous growth and application of our knowledge of the laws of nature are essential if we are to maintain and improve our health, economic productivity and well-being, social stability, national security, and our contributions to world peace and the well-being of mankind.
- We live in an era of extraordinary achievement in basic and applied research and development. The new knowledge and the powerful new tools and techniques that continue to become available could presage a burst of progress that would easily surpass the astonishing scientific and technological gains of the past 40 years.
- A steady and adequate supply of new scientists and engineers educated in modern research facilities is required to preserve the nation's strength in science, to turn new scientific knowledge to practical use, and to manage and administer scientific and technological enterprises.
- The nation's universities contribute to scientific progress and its application to human needs in two vital and tightly linked ways. They educate our scientists and engineers, and they perform about half the basic research conducted today in the United States.
- All concerned with the partnership since its beginning have recognized that the great strength of

education and research in this country is founded on certain characteristics: freedom of inquiry; respect for excellence; and diversity of support, participants, and objectives.

- The nation depends on the federal government for the major proportion of support for basic research in the universities. Private foundations, industry, and state governments supply a degree of support, but only the federal government can provide the resources needed to fund basic research at the level appropriate to the nation's continued economic and social well-being.
- Both universities and government are responsible for ensuring that public money provided for their joint enterprise is properly accounted for and effectively spent.

PART I
THE FORUM ON GOVERNMENT-UNIVERSITY RELATIONSHIPS

Previous assessments of the government-university relationship have come from diverse sources, but through them all run the same issues, problems, and differences in perspective. The studies have had little lasting impact on the operation of the partnership; the misunderstandings have persisted and the problems have worsened. The Committee concluded early in its deliberations that an entirely new tack must be pursued to break this chain. After thorough discussion within the Committee and with key people outside, we elected to devote our primary effort to the establishment of the Forum on Government-University Relationships.

The Forum will be a permanent mechanism sponsored by the National Academy of Sciences (NAS). Its charter was drafted by the Committee and approved with minor modifications by the NAS Council, the governing body of the Academy, in November 1982. Organizations and agencies inside and outside government that have participatory interests in the government-university partnership will be asked to serve as endorsers of the Forum. The effectiveness of this new instrument will also depend critically on the confidence of Congress.

The National Academy of Sciences did not seek a key role in the enterprise. Extensive consultation with scientists, university administrators, and federal officials convinced the Committee that the NAS was by far the most acceptable sponsor for the Forum. On this basis, the President and NAS Council agreed to cooperate.

The Forum is designed to improve communication on key issues among participants whose goals differ. It will not make final decisions with respect to a conflict. It is a device for seeking understanding and common ground. It will seek to move the parties toward consensus and so enhance the likelihood of resolving whatever conflict may be at hand.

The Forum will allow controversial issues to be considered exhaustively. It will allow participants the time needed to reach mutual understanding; it will avoid one-shot debates that give time only for attack and rebuttal. The existence of the Forum, of course, will not preclude academic and federal officials from negotiating specific issues on their own.

The Forum will be administered by a core group of seven people of breadth, distinction, and credibility, assisted by an executive director and staff. The members of the core group are not the Forum--they are its conveners. Their sole interests are the integrity of the government-university relationship, the health of academic science and engineering, and achievement of the national purpose in the federal involvement in science and technology.

The core group will select the issues to be placed on the Forum's agenda, giving due weight to the concerns of the constituent groups and the public. The core group will assign priority to the issues that seem most destructive of a healthy relationship between the government and the universities in science and technology.

The participants in the Forum will vary with the issues at hand. The core group will bring into the Forum individuals on all sides of any given issue who are directly concerned with the problems and who are in a position to influence the relevant policies.

When the Forum has duly considered an issue, it will, as a rule, report back to its various constituencies--groups that have a legitimate interest in the government-university partnership in science and engineering. These constituencies include working scientists and engineers, laboratory directors, university administrators, those concerned with industrial research, scientific and engineering associations, university associations, government agencies dealing directly with the universities, and government agencies concerned with patterns of funding and accountability.

The Forum's reports to its constituencies will state all sides of the issue; describe the differing assumptions, definitions, objectives, and values that make the issue difficult; and indicate the extent to which accommodation has been achieved. Neither the Forum nor the core group will make binding decisions.

The Forum will operate largely independently of the NAS, but will report periodically to the NAS and to its endorsers. The core group will function as a kind of governing board of the enterprise, responsible through the President of the NAS to its Council.

PART II
PROBLEMS FACING THE PARTNERSHIP

The Committee's treatment of issues in government-university relations, as noted earlier, did not extend to proposals of definitive solutions to specific problems. Rather, our findings constitute informed opinion and discussion for the Forum's consideration.

Graduate Education in the Sciences and Engineering

1. People are the indispensable resource in the pursuit of scientific knowledge and its application to practical problems. Thus our system of graduate education in the sciences and engineering is critical to the future vitality of U.S. science and technology. Through graduate education the scientific community continuously renews itself and its ability to educate new generations of technical manpower at all degree levels. The federal government has contributed extensively to the growth of the system by funding academic research and by supporting graduate students with fellowships, training grants, and other means. The government's commitment to support of graduate education, however, has been aimed primarily at specific manpower shortages; it has been much less explicit than the federal commitment to academic research, despite the linkage of research and education in U.S. universities. Federal support of graduate students, moreover, has been declining for a decade.

Support of graduate education in the sciences and engineering requires federal participation, explicitly provided for in allocations for research and development.

2. Our system of graduate education is pluralistic and decentralized. It is a flexible system, adjusting to shifting scientific priorities and opportunities, allocations of resources, and personal choices by students. The interdependence of the variables that affect the system, however, is poorly understood. The decline in federal support of graduate students, for example, is one of several trends in scientific and engineering education. Doctorates awarded annually in all sciences and engineering peaked in 1973 and declined about 7 percent, to 18,200, by 1980. Doctorates awarded annually in the physical sciences and engineering fell one-third, to about 5,000, from 1971 to 1980. The ratio of doctorates awarded annually to baccalaureates awarded six years earlier fell from about 12 per 1,000 in 1970 to 6 per 1,000 in 1980. The proportion of foreign graduate students rose from about 15 percent of full-time graduate enrollments in 1974 to 25 percent in 1980. Despite the apparent correlation of these trends with declining federal support of graduate students in the sciences and engineering, federal support has not been shown to be the controlling factor.

Continuing government-university study is needed of the dynamics of the U.S. system of graduate education in the sciences and engineering, particularly the incentives that affect students' choices of field of study, level of degree, and career. Such studies are difficult and costly, but they would enhance the design of more effective policies for graduate education than exist today.

3. The employment outlook for scientists and engineers affects career choices by graduate students, current and prospective. The disparity in salaries offered by industry and universities, for example, is leading engineers and computer scientists to bypass academe for careers in industry. This is one reason universities are expected to continue to have difficulty attracting doctoral-level faculty in these fields during the 1980s. In other sciences, new doctorate recipients are expected to have difficulty obtaining tenure-track or other permanent positions at universities during the coming decade, although the severity of the problem will vary by field of science.

Such forecasts are imprecise; the universities, government, and industry alike have proved unable to predict supply and demand for technical manpower accurately.

Between 4 and 10 years are required to educate a baccalaureate scientist or engineer through the doctoral level. The time factor severely limits the extent to which the numbers of graduate students can be adjusted to respond to shifts in demand for specialists in narrowly defined fields. A broad education for scientists and engineers is generally desirable, but becomes imperative to create the flexibility to respond to national needs and enhance the stability of the employment market for technical manpower. The long-range requirements for technical manpower require continuing attention.

Federal support of graduate education in the sciences and engineering would best be geared to long-term manpower considerations rather than the short-term behavior of the labor market.

4. Most graduate students have modest means at best, and the costs of graduate education are high. Financial support for graduate students must be considered important in planning for scientific manpower. Long experience indicates that such support is best made available in different forms from different sources. This pluralistic approach has helped to offset the threat to our system of graduate education and research presented by deep cuts in federal fellowships during the past decade.

Federal and other financial support for graduate students in the sciences and engineering is most effective when provided by many sources in a variety of forms, including research assistantships, portable fellowships, training grants, work-study funds, and loans.

The need is great for more productive dialogue between government and the universities on issues in graduate education in the sciences and engineering, a subject critical to the future of U.S. science and technology.

Research Capacity

The federal investment in academic science during the 20 years following World War II spurred rapid growth in research capacity--the human, physical, and financial resources needed to respond promptly to scientific opportunities and emergencies. Although the project grant has always been the backbone of the system, it was not itself designed to build research capacity and cannot sustain it alone. To ensure stability in research capacity, universities need some discretionary research funding. Such funds, however, have been shrinking for more than a decade. A specific and serious problem with academic research capacity is deterioration and obsolescence of equipment and facilities.

1. Research support provided to universities by federal project grants does not cover a variety of persistent scientific needs. Among them are equipment that cannot be justified for any single project, support for preliminary exploration of new ideas, funds needed by beginning scientists to establish a record of performance, and temporary support for experienced scientists who are changing the field of their research. The present array of external funding mechanisms does not provide enough general research support to sustain these elements of the research infrastructure.

The Committee finds merit in the concept of grants designed to sustain academic research capacity, even at the cost of shifting 1 to 3 percent of federal funding from project grants to institutional grants. The long-established Biomedical Research Support Grant of the National Institutes of Health is a successful example. This grant is proportional to the total project funding awarded on the basis of peer review and so meets the goal of using the available funds to support the best research most effectively. The Committee recognizes that general research support raises federal concerns that include quality assurance, accountability, and competition with the need to fund specific, mission-oriented research projects. The concerns of both the government and the universities about general research support warrant consideration of the issue by the Forum.

The quality of university research would be improved by extending to all federal funding agencies and departments the concept of the Biomedical Research Support Grant of the National Institutes of Health as a means of providing a small amount of general research support. Such support would be allocated most effectively by each university within a general framework established by the government in consultation with the universities and the scientific community.

2. The deterioration and obsolescence of scientific equipment and facilities in the nation's universities are widely recognized. The problem cannot be measured precisely in dollars, and it is more serious in some fields of science and in some universities than in others. Nevertheless, scientists in government and industry as well as in academe consider the gap in equipment and facilities a serious threat to the quality of education and research in this country.

The situation has several origins, a major one being lack of planning. The government has invested substantially in academic research equipment and facilities, especially during 1950-1965. Neither the government nor the universities, however, made adequate commitments for replacing equipment and facilities when they wore out or for regularly acquiring advanced equipment as it became available.

Worn and obsolete equipment has several effects. Some scientific problems cannot be solved without specific types of equipment; others cannot be solved efficiently. Equipment can wear until it is too costly and sometimes even too dangerous to operate. Fully as important, students cannot be educated properly with outdated scientific equipment. Such effects are cumulative. U.S. academic science on the whole remains strong, but it faces gradual erosion if the decline in equipment and facilities is not checked.

The problem cannot be solved solely by diverting some fraction of federal research funds to equipment and facilities. Nor is it realistic to expect to solve it solely by massive new federal investment, although long-term federal funding certainly is necessary. The Economic Recovery Tax Act of 1981 contains incentives for contributions of equipment by industry to academic institutions, and the Department of Defense and other federal agencies have established instrumentation programs. Nevertheless, additional approaches are needed to close the gap and forestall its recurrence. Government, industry, and the universities all have a stake in the problem, and the Committee has suggested options for each in Chapter 4. Each sector will have hard choices to make.

The deterioration of scientific equipment and facilities in the nation's universities calls for a joint, corrective effort by government, industry, and the universities. This effort would entail, in the short term, replacement of worn and obsolete equipment by state-of-the-art equipment and, in the long term, a sustained, comprehensive program providing for construction of facilities and development, acquisition, maintenance, and operation of modern equipment.

Industry-University Relations and the Federal Interest

Relations between industry and the universities have been developing rapidly. In many fields of science and engineering, industrial support of research, faculty, and graduate students is the most rapidly growing segment of funding, although it remains a small fraction of the total. At the same time, industry-university relationships interact significantly with government-university relationships in research and education.

1. More extensive and closer relations between industry and academe are potentially beneficial to all parties. For universities they offer exposure to marketplace needs, diversification of funding sources, and availability of modern instrumentation, each of which can improve the soundness and broaden the scope of research. Industry benefits when its relations with academe help to sustain and augment the flow of graduates and the scientific base supporting commercial technology. These results contribute to the economy and security of the United States.

2. Industrial and federal support of academic research usually have different goals and are not interchangeable. Industrial support generally is focused on different modes of research from federal support and fluctuates with economic conditions and with the fortunes of individual companies. Companies tend to support academic research in subjects relevant to their missions. Industry feels that it supports broader scientific activities through its taxes.

The federal government and industry share objectives--well-educated manpower and a scientific and engineering knowledge base for technology--that are best attained through universities, but industrial funding of academic research and education cannot be expected to substitute for federal funding, particularly in support of basic research across all scientific disciplines.

3. Industry-university relations properly can take many different forms. The needs and requirements of the

partners should take precedence, so long as the public interest is served. Definition of the full range of possible cooperative activities and initiatives for exploring specific activities must come from the academic and industrial sectors themselves. Regulatory barriers to development of industrial-academic relations should be avoided unless serious abuses become evident.

Further encouragement by federal, state, and local governments of industrial support of academic research is warranted. Particularly critical is the clarification of proprietary rights when industrial and federal funds are commingled; a clear statement of de minimus conditions for government quitting of claims, including march-in rights, against inventions would help to encourage some forms of private support without jeopardizing public interests. Other steps could include:

- Federal matching funds or tax incentives beyond those now available for industrial support of academic research.
- Federal, state, and local tax incentives, in addition to those now provided, for industrial donations of laboratory space and equipment.

4. The Committee recognizes the concern that the handling of trade secrets and proprietary data entailed by some industrial-academic agreements could hamper freedom of scientific communication and so impede the progress of science and the ability of universities to perform research on behalf of the government. Many government-university and industry-university agreements permit a short delay for patent and publication reviews before manuscripts are submitted. If the delay is short compared to the time required for publication, if the material to be published is complete in that it includes all relevant information about methods and techniques, and if the university's ultimate right to publish is absolute, then scientific communication should not be impaired seriously by such agreements. However, the potential for inhibiting scientific communication is of real concern, is difficult to determine, and needs to be examined further as experience is gained. Agreements that permit parallel submission of manuscripts to sponsor and journal, as recommended by the Panel on Scientific Communication and National Security, could avoid some of these difficulties.

The Committee believes that it is possible to fashion industry-university collaboration without damaging freedom of scientific communication and scientific progress, providing contractual arrangements do not result in extended periods of secrecy, do not limit discussion of experimental methods and techniques, and do not infringe upon the university's ultimate right to publish. However, careful attention by the participants in such arrangements is required to ensure against adverse effects.

5. Commercial interests in academe potentially could divert faculty loyalties and disrupt cohesiveness, compromise the pursuit of knowledge, and affect the choice of research topics and the course of scientific investigations. It is the responsibility of the parties involved to be aware of these dangers and to build in safeguards against them. Perhaps the soundest safeguard is the integrity of the scientists buttressed by codes of ethics and standards of behavior advocated by faculties and institutions. Similarly, industry should recognize the legitimate bounds on its influence and not exceed them. Full and open discussion and agreement on these matters is an essential prerequisite to industry-university arrangements.

6. Issues of propriety in industry-university relations will be handled differently among institutions because of the differences in their missions and the extent to which they are supported by public funds. Even so, several states have found acceptable ways to allow and even encourage commercial interests to use state-financed university facilities, intellectual property, and human resources. These activities may provide models for federal activities involving industry-university relations.

Cost Sharing and Indirect Costs

Cost sharing and indirect costs have been debated repeatedly by the government and the universities. The basic problem is lack of agreement on the real costs of research, who should pay them, and why. This lack of consensus has detracted from the quality of the government-university partnership and has generated antagonism within the universities.

The costs of federally sponsored research are shared by the government and the universities. Cost sharing by a university covers the difference between the total actual cost of a project and the amount provided by its sponsor. Federal statutes require cost sharing on all research grants to educational institutions, usually on a project-by-project basis.

The costs of research are classified as direct or indirect. Direct costs are those that can be identified specifically with a particular project. Indirect costs are those that are incurred for purposes in common, such as the heating of buildings, and that cannot readily and specifically be identified with a particular project.

Both direct and indirect costs are real costs of research. Because indirect costs cannot be attributed readily to specific activities, however, they must be apportioned among university activities, including research projects, in some equitable way. The apportionment necessarily involves judgments and compromises; no single method is right, and none will be optimal for every project.

1. Universities voluntarily contribute substantially to the support of research. The Committee believes that they would continue to share the costs of research if not required by statute to do so and without the documentation now required. The documentation of cost sharing itself imposes costs and complicates the reporting of faculty effort and the calculation of indirect costs. We concur with the earlier recommendations of the Government Procurement Commission, the Federal Paperwork Commission, and the National Commission on Research that mandatory cost sharing and documentation of cost sharing should be eliminated.

<u>The administrative costs of research and some of the friction in the government-university relationship would be reduced by eliminating from the appropriation acts the general cost-sharing requirement affecting all research grants and by revising Office of Management and Budget circulars and federal agencies' manuals to eliminate the administrative requirement for documentation of cost sharing, except for programs specifically designed for joint funding.</u>

2. Progress toward resolving the recurring struggles among academic administrators, investigators, and the

government over indirect costs requires separate treatment of two fundamental questions: What are the total direct and indirect costs of research? Who should bear what fraction of the costs of research and why?

Resolution of the conflict over indirect costs requires that representatives of all parties to the government-university relationship:

- Develop consensus on criteria for determining the actual costs of research, regardless of who pays.
- Examine current and alternative methods for apportioning costs among functions of the university and among individual projects.
- Agree on methods for determining and apportioning costs.
- Agree on the rationale for sharing of costs by government and the universities.

3. Universities differ in organization, work undertaken, services provided, and geographical location. These differences influence the magnitude of costs and whether they are classified as direct or indirect.

Imposition of a uniform indirect cost rate on all universities would be both unsound and inequitable.

Universities also differ substantially in the extent of their reliance on federal grants and contracts, which in turn affects the importance of recovery of indirect costs to the university and to the government.

A wider choice of mutually acceptable methods for treating indirect costs is needed. Such methods should include some that offer simplicity in accounting procedures in exchange for less than full recovery of costs.

4. The Committee recognizes the deep concern about the control of indirect costs in general and especially those associated with National Institutes of Health grants, for which the ratio of indirect costs to total costs has been rising faster than at some other agencies. Many people are convinced that the ratio of indirect to total costs must not continue to rise. Such concerns have led to recurring proposals to limit indirect cost rates by either a ceiling or a percentage limitation on the negotiated rate. These solutions, however, are not

appropriate for control of costs because they do not address the factors that cause indirect costs to rise. We identify in Chapter 6 a number of measures that would help control costs.

Development of better methods and incentives for cost control requires a joint government-university approach involving representatives of all parties concerned. The Forum on Government-University Relationships is a possible mechanism for addressing these issues.

Accountability

Accountability has become a major source of disagreement within the government-university relationship. Accountability for federally funded research has two aspects: financial and administrative accountability and accountability for scientific performance. The main disagreements arise in four areas: differences in the parties' relative confidence in the validity and necessity of the accountability requirements; differences in the interpretation of the requirements; differences about the cost-effectiveness of the requirements and their effects on the research process; and differences in the extent to which limited resources should be invested in accountability procedures.

1. Financial and administrative accountability and scientific accountability are fundamentally different. Both are essential, but stricter attention to one form of accountability cannot compensate for inherent uncertainties in the other. Methods of accountability that are poorly suited to the organization of research in U.S. universities can disrupt the academic environment and lower the quality and productivity of research.

Efforts to enhance accountability are best directed toward ensuring the validity and cost-effectiveness of the methods of accountability employed.

2. The friction over Office of Management and Budget Circular A-21 (cost principles for educational institutions) is a serious problem that has several causes: disagreement over certain premises of A-21; widespread unfamiliarity with its purpose and content; dissatisfaction with some of its provisions; and the manner in

which it has been interpreted and implemented. The 1982 revision of the effort-reporting requirements in A-21 will provide some relief. Lasting improvement, however, will require development of consensus on the validity and appropriateness of the policy guides, basic considerations, and specific provisions in A-21; it will also require a simpler, less costly, and more valid method of accountability for performance. The Committee endorses the salary documentation method proposed by the National Commission on Research and proposes associated refinements in Circular A-21.

The Committee agrees with the National Commission on Research on the need for thorough reexamination of OMB Circulars A-21 and A-110 (administrative requirements for grants and agreements with institutions of higher education). Representatives of all parties in the government-university relationship must accept responsibility for familiarizing themselves with OMB Circulars A-21 and A-110 and reaching consensus on the changes needed.

The Forum on Government-University Relationships could serve to develop the mutual understanding needed to reach consensus on revision of Office of Management and Budget Circulars A-21 and A-110.

3. The financial accountability problem arises in part because some federal requirements and controls are poorly suited to the grant relationship and because the administration of research support is fragmented into many individual projects. In particular, the Federal Grant and Cooperative Agreement Act of 1977 calls for the use of grants (as opposed to contracts and cooperative agreements) for assistance without major federal involvement in the conduct of the work supported by the grant. The point is to emphasize optimal research results rather than control of cost inputs.

The accountability requirements for grants need to be redrawn to give the institution and the principal investigator the authority and the responsibility for performing the work with the minimal federal involvement called for by the Federal Grant and Cooperative Agreement Act.

4. For many federal research grants of modest size, payment by cost reimbursement and the associated accounting and administrative procedures are unnecessary and not cost-effective.

The use of fixed-amount awards, instead of cost-reimbursement awards, would be advantageous for grants of modest size, where they would simplify handling and provide flexibility with negligible risk of inadequate accountability.

5. The Committee is encouraged by the efforts under way to improve the audit process. We believe that further savings could be made if the frequency of both the revision of the indirect cost rate and the audit of direct and indirect costs were changed from annually to every two to three years, with optional interim revision or audit in unusual circumstances.

6. The Committee believes that the judgment of scientific peers is the best way to select research for support and to ensure accountability and quality in scientific performance. The peer review system nevertheless should be subject to regular reexamination to ensure that its quality and fairness are maintained, a task to which the Forum might contribute.

The system for ensuring scientific accountability could be strengthened by making past performance a more explicit factor in reviews of proposals and making such assessments a matter of record.

7. Cases of scientific fraud come to light from time to time, despite the strong protection against it provided by the scientific method. The Committee has not studied the problem, but we know of no evidence that it is growing. Nevertheless, widely publicized instances of fraud are damaging to science. Because of growing public concern, the Forum should consider the issue and universities should redouble their efforts to maintain the highest ethical standards.

The primary responsibility for preventing scientific fraud rests with scientists and their institutions. Universities and investigators should make extremely clear their expectations of high ethical standards, should instill in students and new investigators the most stringent scientific ethics, and should ensure effective supervision in all research they undertake.

Introduction

Since World War II the federal government and the nation's universities have pursued a vigorous collaboration in research and education in the sciences and engineering. The government provides major support for education and research, especially basic research, in the universities; the universities educate scientists and engineers and produce knowledge deemed essential to the well-being of the nation and of mankind. This enterprise has grown and succeeded to such an extent that the participants have become mutually dependent. The dependence has evolved because of the importance of the academic contribution to U.S. science and technology on one hand, and the importance of federal funds to the stability of universities, the work of academic scientists and engineers, and the strength of graduate education and research on the other.

Although the government and the universities have benefited from their mutual dependence, significant differences mark their goals, responsibilities, and methods of operation. Some tensions are inevitable--and probably beneficial--in such a relationship. Nevertheless, conflicts among the government, the universities, and academic scientists and engineers have intensified to the point that they threaten the productivity of our system of scientific research and education.

The Committee has considered the government-university partnership in the broad context of the scientific process, governmental decision making and oversight, and the requirements of the academic setting. We have also considered current economic constraints and long-term national needs.

Our report has two parts. In Part I we describe the evolution of the government-university partnership (Chapter 1), the origins of the problems that trouble it today (Chapter 1), and a new means of dealing with them--the Forum on Government-University Relationships (Chapter 2). This idea was first suggested in 1980 by the National Commission on Research. The commission proposed the creation of a new and independent body--a forum--designed to improve communication between the partners and facilitate solutions to the problems they share and will share in the future. The Committee has extended this proposal and has completed plans for the Forum. We view this as our major accomplishment.

In Part II of this report we examine some major issues facing the partnership:

- Graduate education in the sciences and engineering
- General research support
- Equipment and facilities for research
- The three-way relationship among government, industry, and the universities
- The handling of cost sharing and indirect costs related to federally funded research
- Accountability for public funds provided to support research

We have described in some detail the form these issues and the related problems take at present (Chapters 3 through 7). We have developed suggestions of routes to solutions, but have, for the most part, avoided making recommendations. Instead, our treatment of the issues is illustrative, a prototypical agenda for the Forum.

BASES OF JUDGMENT

The Committee has benefited substantially from the many analyses of the government-university partnership that have appeared in recent years. These analyses have come from governmental, academic, and other sources.[1-4] Noteworthy among the most recent are the reports of the National Commission on Research and the Sloan Commission on Government and Higher Education.[5,6] In addition to many previous assessments, a major contribution to our study was made by the 169 people throughout the U.S. research community whose thoughtful letters provided much material for this report. Their names and excerpts from selected letters are in Appendix A.

The Committee's views have been shaped by the following premises:

- Scientific knowledge and the consequent technological strength are indispensable to the United States. Continuous growth and application of our knowledge of the laws of nature are essential if we are to maintain and improve our health, economic productivity and well-being, social stability, national security, and our contributions to world peace and the well-being of mankind.
- We live in an era of extraordinary achievement in basic and applied research and development. The new knowledge and the powerful new tools and techniques that continue to become available could presage a burst of progress that would easily surpass the astonishing scientific and technological gains of the past 40 years.
- A steady and adequate supply of new scientists and engineers educated in modern research facilities is required to preserve the nation's strength in science, to turn new scientific knowledge to practical use, and to manage and administer scientific and technological enterprises.
- The nation's universities contribute to scientific progress and its application to human needs in two vital and tightly linked ways. They educate our scientists and engineers, and they perform about half the basic research conducted today in the United States.
- The nation depends on the federal government for the major proportion of support for basic research in the universities. Private foundations, industry, and state governments supply a degree of support, but only the federal government can provide the resources needed to fund basic research at the level appropriate to the nation's continued economic and social well-being.
- Both universities and government are responsible for ensuring that public money provided for their joint enterprise is properly accounted for and effectively spent.

In addition to these premises, the Committee recognizes that the great strength of education and research in this country is founded on certain characteristics. These characteristics have been recognized by all concerned with the partnership since its beginning and must be preserved if the partnership is to continue to be productive:

- Freedom of inquiry--freedom to pursue new knowledge wherever the path of discovery may lead and freedom to communicate what is learned.
- Respect for excellence--the award of support for basic research primarily because of its scientific merit and regardless of the age and rank of the investigator.
- Diversity--channeling of support for research through diverse agencies to diverse individuals and institutions, with the initiative for identifying research topics resting primarily with the scientists.

These characteristics follow naturally from the nation's political and cultural traditions; adherence to them is fundamental to the strength of the enterprise.

LINKAGE OF EDUCATION AND RESEARCH

The intertwining of education and research in our universities must be kept to the fore in addressing the problems of the partnership. The universities do about half the nation's basic research; the concentration of so much research in educational institutions is a hallmark of the U.S. system and a major source of its strength.

Graduate students clearly benefit from the enthusiasm and scientific insights of instructors who are themselves doing research. Instructors benefit in turn from the stimulation and clarification of their ideas derived from guiding their students and answering their questions. Graduate students and postdoctoral fellows make up a significant proportion of the research staff in academic laboratories. In addition, they bring to research fresh insights as well as energy and freedom from conventional attitudes--qualities that are needed for the intellectual leap involved in developing new ideas. Concepts that bring revolutionary change to science often are conceived and developed by very young people.

Without a steady flow of young scientists, research institutions become more conservative and hierarchical, less flexible and less daring. The U.S. research structure, with its strong emphasis on university-based fundamental research and support for individual investigators, is designed to ensure first-rate education of scientists and engineers. That contribution is essential to the nation's scientific and technological productivity.

ACHIEVEMENTS OF THE PARTNERSHIP

The government-university partnership was formed initially to harness science in the national interest as our involvement in World War II drew near. It was subsequently developed to nurture and expand research and education in the sciences and engineering. The goal of the partners was to ensure the nation's long-range economic and social well-being and security in a world that would grow ever more dependent on scientific knowledge. In pursuit of this aim, the government has made large and continuing financial commitments. Has this investment paid off? Has it been in the national interest and contributed to the national welfare? The answers clearly are yes.

The past four decades have seen striking advances in our comprehension of matter, life, the universe, and ourselves. The genetic code has been cracked, genes selectively exchanged, and bacteria conditioned to make human proteins. A unified understanding of the fundamental forces of nature appears to be within reach. The movements of the ocean floors and of the continents have been explained. Men have walked on the moon. The dramatically expanding power to compute, to store, and to integrate information is itself multiplying our capabilities for discovery. The laser has become an essential tool in science, industry, and medicine. World food production has increased fast enough to match a doubled world population. Polio and measles are now exceedingly rare in the United States. Smallpox has been eliminated worldwide.

Such achievements reflect an explosion of scientific knowledge unmatched in any other period of history. Scientists of many nations have contributed, and the United States can be justly proud of its place among them. More than half the recipients of Nobel prizes in the sciences from 1950 to 1981 have been citizens of this country.

The universal nature of science and its contributions to the well-being of mankind are complemented by further justification for its support--its critical and ever-growing importance to this country's economy and standard of living, to the health of our citizens, to our security, and--most of all, perhaps--to our continuous renewal as a society.

THE ORIGINS OF LEADERSHIP

A mix of forces propelled this country to leadership in science. We came out of World War II an affluent and powerful nation. Oppression abroad had driven to our shores many of the world's most creative scientists. Powerful industries had geared up to give U.S. armed forces equipment embodying the best technology available. And we had a number of excellent universities eager and well positioned to expand their efforts in scientific research.

These institutions of higher learning housed a tradition that was peculiarly American. On one hand they strove to emulate the disciplined organization of European universities, especially those of Germany in the nineteenth century; on the other they enjoyed a characteristic diversity and looseness of organization. Quality of ideas took precedence over age, academic rank, and other formal credentials. Some of these universities were private; others were state institutions. Some were very young; others dated from colonial times.

The government-university relationship grew from the nation's great success in applying science to national needs during World War II. The results of this effort suggested that federal support of postwar science on a much larger scale could yield extensive benefits for the nation. The prescription for the partnership was set down in 1945 by the late Vannevar Bush in Science, The Endless Frontier.[7] This classic statement of science policy argued in part that:

> The government should accept new responsibilities for promoting the flow of new scientific knowledge and the development of scientific talent in our youth. These responsibilities are the proper concern of the government, for they vitally affect our health, our jobs, and our national security. It is in keeping also with basic United States policy that the government should foster the opening of new frontiers and this is the modern way to do it.

GROWTH AND CONTRACTION

The government-university partnership envisioned by Bush grew rapidly and substantially after 1950. Federal funding of academic research (including federally funded research and development centers--FFRDCs) increased an average of 15 percent annually, in real terms,* from 1954 to 1964. In the mid-1960s, however, after 15 years of rapid and uninterrupted growth, the inflow of federal dollars began to slow. From 1964 to 1968 the average annual growth rate in federal funding of academic science fell to 7 percent.[8] Federal obligations for academic research and development (including FFRDCs) peaked in 1968, in constant dollars,* and fluctuated until 1975, when they moved above the 1968 peak. Obligations peaked most recently in 1979 and declined a total of about 9 percent through 1983, when inflation is taken into account.[9] Industrial spending on research and development, in-house and in universities, is beginning to grow, but industry can only supplement, not replace, the federal government in the funding of basic research. The uncertain outlook for federal support and the absence of comparable funding alternatives, combined with steadily growing maintenance costs, have put the heavily research-oriented universities in a state that many of them consider precarious.

CONFLICTS IN VIEWPOINT

A faltering economy reinforces the tensions inherent in the government-university relationship. The relationship is further complicated by its three-sided nature. The government, a large and diverse bureaucracy, has responsibilities that extend far beyond the federal-academic partnership. Academic scientists, an aggregate of largely autonomous individuals, are interested primarily in teaching and research. Universities are complex and diverse institutions required to maintain their scientific activities in balance with interrelated responsibilities for teaching and service. Three such different entities inherently view issues differently.

The differences in viewpoint are evident in several areas:

- Federal officials contend that universities are slow to improve their financial management practices and

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*The expressions "in real terms" and "in constant dollars" mean that dollar values have been adjusted to take account of inflation.

that they sometimes divert federal funds from one sponsored project to another or to unsponsored projects (cost transfers). Academic administrators and investigators believe that federal financial oversight is far more constraining and rigidly enforced than need be. The universities argue that standards of documentation have escalated to an impractical level and if followed rigorously would substantially reduce the productivity of research and increase its cost.

- Peer review is the most effective way scientists have found to select the best research for support and to ensure scientific accountability. Some people, however, criticize peer review on the grounds that emphasis on scientific merit may lead to concentration of the available resources or favoring of established scientists and more conventional research topics.
- The predominance of project grants among federal funding mechanisms neglects the universities' needs for funds that they can use flexibly to provide for new research initiatives, communal resources such as equipment and facilities, and institutional stability.
- Investigators' needs for long-term, continuous support of research are inconsistent with the government's annual appropriations cycles.
- Within the university, administrators' needs to pay for research administration, facilities, and services (indirect costs of research) compete with investigators' needs to pay for research staff and supplies (direct costs of research).
- In enjoying freedom of inquiry and communication, scientists also must accept responsibility for not encroaching on the public interest. Even so, federal responsibilities for public well-being may lead to actions, such as restrictions on potentially hazardous research or regulation of classified research, that scientists view as unduly compromising essential scientific freedoms.

THE NEED FOR COMMUNICATION

The roles and responsibilities of government, universities, and academic scientists in their mutual enterprise are marked by crucial differences. The responsibility of federal agencies is the prudent and productive use of appropriated funds to achieve the national purposes for which the funds were made available. The basic obligation of the universities is to advance and transmit knowledge, to educate each new generation, and to provide conditions in which scholars and scholarly activity can flourish. The scientists must maintain the integrity of scientific inquiry and the conditions essential to its pursuit.[10]

The problem is to fashion the relationship in a way that accommodates at once the independence and interdependence of the three parties, while not subordinating one to the others and not spurring mutual interference in the performance of roles. The challenge is great, and it is made more difficult by the tradition--on all sides--of pluralistic decision making. The pervasive risk is divergent interpretations, as seen in the fate of the many analyses of the partnership that have appeared in the past decade. Through them all run the same issues, problems, and differences of perspective. The studies come and go, but the misunderstandings persist and the problems worsen. The overwhelming need is sustained discussion leading to the mutual comprehension and consensus required to permit effective action to be taken.

All the partners face hard choices, and it is essential that the necessary adjustments be made in a manner that best serves the long-range interests of the nation. The Committee is confident, however, that the adjustments can be made, and in a way that will not disrupt those elements most essential to the continued vigor of the scientific enterprise. Helping to achieve the necessary communication and understanding is the goal of the Forum, described in Chapter 2 of this report.

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Part I
The Partnership and the Forum—Perspectives and Structure

1
The Government-University Partnership

Scientific research and development (R&D) involved total expenditures of about $77 billion in the United States in fiscal 1982.[1] The federal government provided about 47 percent of R&D funding and industry about 50 percent.* Although only 10 percent (an estimated $7 billion) of all U.S. R&D was carried out in universities in 1982, this included about 50 percent (about $4.6 billion) of the nation's basic research. The federal government is the major source of funds for academic science, supplying about 66 percent of the support for all university R&D and about 70 percent of the support for basic research.[3]

In this chapter we look at the evolution of the government-university partnership and its characteristics today. From the perspective of the 1980s, it is difficult to recall the attitude toward federal support of academic research that prevailed before World War II or to appreciate the great transformation of our universities that resulted from the massive postwar infusion of federal funds. The war, however, marked a turning point, not a beginning, in government-university relations. The origins of our system of academic science and of government's approach to meeting its needs in science and technology go back to the nation's first years.

*In 1940 the nation's research and development budget was $345 million. Of this total, $234 million or 68 percent came from industry, 19 percent from the federal government, 9 percent from colleges and universities, and 4 percent from other sources, including private foundations and endowments.[2]

HISTORICAL PERSPECTIVE

Federal Responsibility for Science

The Constitution does not require the federal government to support scientific research or graduate education in science and engineering in the nation's universities. Congress rejected the idea of a national university as long ago as 1796. An innate suspicion of fostering intellectual elitism or of encroaching on the rights of the states in educational matters was reflected in the long congressional hesitation over accepting James Smithson's bequest in 1836 to create a federal scientific institution. Its lack of specific mandates for science or education notwithstanding, however, the federal government needed many kinds of technicians and specialized knowledge. Initially these demands were met through mission-oriented laboratories and science agencies, the first of which was the Coast Survey, created in 1807. In 1862 the Morrill Act created support for the building of the land-grant colleges, and in 1887 the Hatch Act provided for an agricultural experiment station in every state, many of them at the land-grant schools. The U.S. Department of Agriculture (USDA), created in 1862, became a major provider of graduate training in science and engineering and a sponsor of research before university education in science in the United States was well established. In 1915 the National Advisory Committee for Aeronautics was established to conduct research into problems of flight. It was the first federal agency to award contracts for research projects at colleges and universities.[4]

Both the National Advisory Committee for Aeronautics and USDA emphasized applied rather than basic research.[5] This policy was articulated in 1903 by the Presidential Committee on Organization of Government Scientific Work and restated in 1909 by a committee of the National Academy of Sciences: ". . . science on the part of the Government should be limited nearly to utilitarian purposes evidently for the general welfare."[6]

Thus the first main thrust of federal science policy was the creation of an array of government laboratories, oriented primarily toward problems, not disciplines. The funding and oversight of the laboratories were controlled by the senators and representatives whose congressional committees had jurisdiction over the parent agencies or departments. As more and more departments sought to meet their scientific needs, increasingly diverse congressional committees became concerned with science--the origin of the pluralism in both Congress and the executive branch that is so characteristic of the federal government today. Congress occasionally deliberated about establishing a Department of Science to coordinate the ever-burgeoning federal scientific activities. It first did so in 1884 but rejected the idea then and on several subsequent occasions.[6]

The System Before 1940

Except for aeronautics and USDA's activities in the experiment stations at land-grant colleges, the government funded little science in institutions of higher learning before 1940. It was mainly the universities and their scientists who feared the political interference that was widely believed to be inevitable if public funds should support science, but many in government were of similar mind. Industry, foundations, and other private donors were supporting some research in university laboratories as the nation approached involvement in World War II. Academic budgets for science were relatively lean, however, and preeminence in most of the fundamental sciences resided abroad.

Great as had been the accomplishments of the government in building institutions and creating a federal capacity for science, the decade preceding World War II brought into sharp relief the shortcomings of the U.S. research structure. Each of the major supporters of science--the federal government, the universities, industry, and the foundations--had its own traditions and internal coherence, but a clear relationship and adequate communication among them were lacking.[7]

Government

By the 1930s the government's research establishment, with a few exceptions, had lost some of its luster relative to the other sectors of science support. The depression had led to severe budget cuts in the science agencies, which had trouble holding good scientists and maintaining adequate laboratories and equipment. The military departments were able to do research at only a very modest level through most of the 1930s. National security ranked well below agriculture and only a little above natural resources in terms of federal support of intramural R&D.[7]

Universities

Although their development came late in the nation's experience, U.S. universities had clearly emerged by the 1930s as the national home of basic research. Toward the close of the 1800s, the universities had adopted and very quickly begun to improve on the German model, especially in diversity and number of institutions. They began to compete intensively for faculty and eminence, and after 1900 strong and specialized university departments, laboratories, and research libraries began to emerge.[7-10]

The best scientists taught at a small number of universities, where they did research supported mainly by university funds from state or private sources. University research was also supported in part by the professors themselves, and they did not account to anyone for their time or for minor expenditures.

Industry

By the late 1930s industrial research had become the showpiece of U.S. applied science. After World War I, research laboratories began to appear in the corporations of the United States.[11] More and more businesses found science not only a useful tool in testing and production but also a source of innovation and diversification. In some cases, most notably the chemical and electrical manufacturing companies, research occupied a prominent position. In the battle for long-term support, however, industrial scientists became much more aware of the need to shape explicit arguments for basic research than did their counterparts in the universities. Even with the most enlightened management, an industrial research laboratory could devote little of its resources to basic research for the sake of science. Industrial scientists eventually had to adapt their research strategies to the mission of the company.

Occasionally, as with the National Research Fund in the 1920s, corporations had organized to give direct support to research in the universities. But the depression had defeated such efforts, and by 1940 recovery was still not sufficiently complete to permit significant industrial support of academic research.[7]*

Private Foundations

The private foundation, a significant institution for the support of science, had arisen by the first decade of the twentieth century.[12] Even before World War I, the major foundations controlled resources large enough to make a definite impact on science in the United States. The foundations pioneered in supporting science by both institutional grants, such as those of the Rockefeller Foundation's General Education Board, and grants to individual projects. Some established institutions for fundamental research with no pedagogical or applied objectives--for example, the Rockefeller Institute for Medical Research and the Carnegie Institution of Washington. The grant-giving foundations channeled resources into other sectors, especially the universities.

Between the wars, foundations supported efforts to coordinate the national research structure that were very close to the public purposes of the government itself. The Rockefeller Foundation's support of President Franklin Roosevelt's Science Advisory Board, within the structure of the National Research Council, is an example. The foundations also supported the highly effective National Research Council program of fellowships in science, thus pioneering in techniques for the support of education that would later serve as models for the government. By the late 1930s, however, the foundations' capital funds had been depleted by the depression, and little prospect existed for expansion of their resources.[7]

Thus in the late 1930s, the supporters of science existed side by side but independently. The balance among them had grown up over such a long period that a major shift of personnel and laboratories from one sector to another seemed almost inconceivable. That was changed by the outbreak of war in Europe in 1939.

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*One exception was the relationship between the aircraft industry in California and the Guggenheim Aeronautical Laboratory at the California Institute of Technology.

Creation of the Present System: 1940-1945

Before Pearl Harbor, a scientific link between the universities and the government was established in the interest of national security. As the United States prepared for possible participation in World War II, a group of scientists led by Vannevar Bush, president of the Carnegie Institution of Washington, sought to help President Roosevelt mobilize the nation's scientists for research on weaponry. In June 1940, the National Defense Research Committee was created by executive order with Bush as chairman. It could pursue research on weaponry on its own initiative with funds allocated directly by the Bureau of the Budget and the President. In July 1941, the structure was expanded to include a Committee on Medical Research and renamed the Office of Scientific Research and Development.[13] The office was never considered permanent; it was closed at the end of 1947.

The Office of Scientific Research and Development operated no laboratories of its own but used special research contracts to support work in industry and universities. The office adopted the principle that an institution should neither make a profit nor suffer a loss as a result of contract work. This principle led immediately to allowing a charge for overhead costs that were not easily specified in the contracts. Since by definition these costs were hard to determine, the Office of Scientific Research and Development used for universities a formula of 50 percent of the payroll for a project.[7]

The Opening of the Endless Frontier: 1945

The Office of Scientific Research and Development demonstrated what U.S. scientists--particularly the underutilized talent in the universities--could accomplish with adequate support. Emerging from the war with its industrial strength intact, its affluence unchallenged, and a fresh sense of its destiny, the United States was ready to continue a role for the federal government in many affairs that in the past had been concerns of the private sector.

In November 1944, Bush was asked by President Roosevelt to make recommendations for postwar federal involvement in science. He did so with the aid of advisory committees representing different sectors of science and delivered his recommendations to President Truman in July 1945 in a classic statement of science policy, Science, The Endless Frontier.[14] His major arguments were: that support of science is a proper concern of government because scientific progress is essential to national welfare; that support of science includes not only support of research but also support of scientific education; that scientific research requires freedom of inquiry, and the most natural home for basic research is the universities; and that a new federal agency, which does not conduct research of its own, should be responsible for the allocation of federal funds to all sectors of science.

Expansion of the System: 1945-1950

Within a few years, the recommendations of Bush and his advisory committees led to government support of university-based science that far exceeded any dimensions they had imagined. The evolution of the federal structure for science, however, departed from their original plan. Instead of a decrease in the pluralism of government support, the number of agencies expanded, and some of them grew faster and became more powerful than the new agency proposed by Bush.

During the protracted congressional debate before the National Science Foundation was finally born, other agencies emerged. The Office of Naval Research, founded in 1946,[15] took an early lead in sponsoring basic research in the universities. It had a civilian chief scientist, a Naval Research Advisory Committee, and many subsidiary committees that brought eminent scientists in from the universities on a part-time basis to advise the Navy on what projects to support. From the point of view of the government, using scientific merit as the major basis for spending money and consulting the most experienced university scientists in making the decisions were the best forms of quality control the taxpayer could have on public expenditures for science.

In 1946 the Atomic Energy Commission (AEC) was created to husband the military and peaceful uses of nuclear energy, whose awesome power had been revealed to the world the summer before in Japan. The personnel and resources of the Manhattan Project--begun by the Office of Scientific Research and Development and later transferred to the Army Corps of Engineers--were assigned to

AEC. From this beginning, supplemented later by other facilities, came the national laboratories and the federally funded research and development centers of the present-day U.S. Department of Energy (DOE), which was formed in 1977. These are not intramural laboratories in the original government model--they are contract facilities operated by a university (such as Los Alamos or Lawrence Berkeley National Laboratories operated by the University of California), by industrial corporations (such as Oak Ridge National Laboratory run by Union Carbide Corporation), or by a consortium of universities (such as Brookhaven National Laboratory).

In 1944 Congress had added the National Cancer Institute to the National Institute of Health, which in turn traced its lineage directly to the National Hygienic Laboratory, a federal intramural laboratory established in 1887. In 1948 several more institutes were created by Congress, becoming the collective National Institutes of Health (NIH). An agency within the Public Health Service, NIH in 1953 followed its parent into the U.S. Department of Health, Education, and Welfare (DHEW), changed in 1979 to the U.S. Department of Health and Human Services (DHHS). NIH assumed most of the wartime biomedical research projects when the Office of Scientific Research and Development went out of business in 1947. By 1950 the annual NIH budget was $50 million. Its project grant and peer review mechanisms were to become crucial aspects of the federal funding of university R&D in the United States.

Establishment of the National Science Foundation: 1950

By 1950 the government already had many centers for supporting research and graduate education. The comprehensive new science agency of the Bush report had lost many functions to existing agencies with secure sources of funding, especially in the new U.S. Department of Defense (DOD). Indeed, it could be argued that a new government agency for science was unnecessary. However, the realization that many gaps still existed in support of science and that overwhelming dependence of university science on DOD and AEC would lead to serious imbalances suggested that a National Science Foundation was needed in the long run, even if it did not achieve a comprehensive position in national science policy.

The act creating the National Science Foundation (NSF) became law in 1950.[16] It was created as an independent agency to be governed by a presidentially appointed National Science Board. NSF gradually assumed a distinctive role among its longer-established and mission-oriented counterparts. Its support of basic research was a guarantee that greater knowledge and research capability would be available to the nation in the future than could be secured by mechanisms geared to priorities of the moment. NSF also began early to support graduate education by means of fellowships. And almost as early it began to develop programs to assist science education at the undergraduate and precollege levels.

The Effects of Sputnik: 1957

The launching of Sputnik, the first earth-orbiting satellite, by the Soviet Union in 1957 led to several major changes in the federal science structure. One was the creation in 1958 of the National Aeronautics and Space Administration (NASA), which replaced the National Advisory Committee for Aeronautics and placed the nation's efforts at space exploration in a civilian agency. From the beginning, most of NASA's R&D was conducted in industrial firms and its own intramural facilities, but the agency also supported basic scientific research and graduate education in universities and at large FFRDCs.

Sputnik also raised the question of whether science advice to the chief executive--then President Dwight D. Eisenhower--was adequate. Up to that time, the government's diverse science activities had been coordinated loosely within the executive branch, largely by the Bureau of the Budget. In 1957 James R. Killian, Jr., was named the first full-time White House science adviser and chairman of a new President's Science Advisory Committee.[17]*

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*In April 1951, President Harry S. Truman established the Office of Defense Mobilization and, within it, a Science Advisory Committee under Oliver E. Buckley. The committee was designed to make high-level policy advisers available to the head of the Office of Defense Mobilization and the President for planning R&D for the military and other federal agencies. With Killian's appointment, this committee was transferred to the White House and became the President's Science Advisory Committee.

In the wake of Sputnik, the government's scientific priorities, particularly the whole range of U.S. education, were subjected to rigorous scrutiny. Sputnik provided the impetus needed to enact an aid-to-education program that had made no progress in Congress for years. The National Defense Education Act, among other things, authorized fellowships in specific fields of science and provided subsidies to educational institutions to create low-interest loans for needy students in all disciplines. The purpose of this financial assistance was to direct students into areas of national need in which shortages were anticipated.

An important shift in sources of federal support for university research occurred during the post-Sputnik decade. In 1954 DOD and AEC were underwriting about 70 percent of the federally supported R&D on campus and almost 99 percent of the federal research spending in universities and university-administered FFRDCs combined.[18] In 1964, DOD, AEC, and NASA, the three agencies most closely related to national security, still accounted for more than two-thirds of federal obligations for academic science, including FFRDCs. The sources of on-campus support excluding FFRDCs, however, had changed significantly by 1964, when DHEW (mainly NIH) and NSF accounted for more than half the total.[5,19]

Rapid Growth of the System: Early 1960s

The decade following Sputnik saw explosive growth in academic science. Federal funding of academic research (including FFRDCs) increased an average of 20 percent annually in real terms from 1958 to 1964.[20] Federal research expenditures at universities and university-administered FFRDCs rose from $547 million in 1958 to more than $1.5 billion in 1964.[21] Much of this growth was in research related to space and defense, but the effect of Sputnik on funding carried over to other agencies and projects.[5]

The universities were able to respond vigorously to the greater availability of research funds partly because at the same time enrollment and instructional needs were growing briskly.[22] Between 1950 and 1965, enrollments grew at an average annual rate of more than 9 percent: nearly 400,000 students were added each year.[23] The decade of the 1960s saw a net increase of 500 new institutions of higher learning.[24]* This growth was due to the increasing proportion of 18-year-olds in the population and the steadily increasing fraction of the college-age population that was enrolling in college.[23] Along with their general growth, the universities grew sharply in their capacity for research and for graduate training in the sciences and engineering. The universities that were the major receivers of federal funds in particular expanded their facilities, faculty, and enrollments. Other universities attempted to emulate the leaders, establishing Ph.D. programs and competing for research funds.

The End of Rapid Growth

By the mid-1960s, annual federal expenditures for all research and development exceeded $13 billion, and the portion for basic research approached $2 billion.[1] The size of the R&D bill began to attract the attention of the public. A slowdown in funding began after 15 years of rapid growth. Between 1964 and 1968, federal spending on academic research (including FFRDCs), in constant dollars, increased at an annual rate of 7 percent, compared with a real growth rate of 15 percent between 1954 and 1964.[5] Federal obligations for academic research and development (including FFRDCs) peaked in 1968, in constant dollars, fluctuated for the next six years, and moved above the 1968 peak in 1975. Estimated obligations for 1983 were about 13 percent above the 1968 peak, giving an average annual growth of less than 1 percent for the 15-year period, when inflation is taken into account. Obligations peaked most recently in 1979 and declined a total of about 9 percent through 1983.[25]

Effects of Growth on University Structure

Our pluralistic system of supporting science developed the flexibility and stability necessary for striking

*Institutions are those in the United States included in the annual directories of higher education issued by the U.S. Office of Education and the National Center for Education Statistics.

achievements during the 1960s. It is important to note, however, that this period of unprecedented growth had significant effects on the structure and operation of universities.

The system did embody safeguards against the possibility that the flow of federal funds would disturb the autonomy of the universities. The use of project funding allowed scientists to communicate their plans directly to the government agencies, which allocated money in accordance with the federal budgeting process. Final decisions on the choice of individual projects to be supported were made by agency program officers with advice from the scientists themselves. A grant was awarded to support a specific investigator, so the government was not in the position of certifying the university as a whole. The university received the money and paid for the research. In principle, the university structure, the authority of its administrators, and the freedom of the principal investigator should be left untouched by federal money. In practice, however, none of them was left unchanged.

Federal money made possible the creation of numerous new professorships subject to the appointment and promotion procedures of the universities. Principal investigators in their research proposals created many new places for postdoctoral fellows, graduate assistants, nonfaculty research personnel, and support staff. Positions opened and were filled, maintaining the steady tide of new hands and minds essential to vigorous research programs. In this way and without much overall strategy the education of people for new types of research and for independent careers was folded into the project system.[26] Steadily increasing funding would be needed, however, to support research by the successive waves of new scientists and engineers. Other consequences were the erosion of the institutional autonomy of the universities and a change in the relationship between the university and its faculty.

Although funding of specific projects remained the backbone of the system, another trend was established. This was the creation in the universities of organized research units, ranging from multidisciplinary task forces to fully developed institutions. These units usually combined basic research with targeted missions or applied research. Some of them were designed to provide demonstrations or service in addition to research.[27] While all these structures were encompassed by the formal organization of the university, they not infrequently conflicted with the traditional academic departmental and divisional structure.

The theoretical simplicity of the government's determination of the faculty members it wished to support on research project grants was doomed to give way in practice to complexities and restrictions for both investigators and institutions. The principal locus of faculty support was shifted from the university to external sponsors. This fact, combined with the traditional autonomy of the faculty, made university stewardship of funds a complex matter. In addition, the discreteness of project grants generally meant that principal investigators might need more than one grant to maintain their laboratories. The grants might come from more than one agency or relate to training on one hand and research on the other. They involved preparation of renewal requests and negotiations with different science administrators, raised questions of cost transfers, and entailed sacrifice of flexibility. As the university's control over its faculty scientists diminished, it found its accountability for their actions increasing.

The many investigators and their laboratories necessitated on certain campuses an unprecedented development of business offices whose sole task was to handle research grants and contracts. Better accounting procedures than many universities possessed had to be developed to keep track of the total costs of research. At first the universities attempted to absorb the growing administrative and other general costs associated with government grants. Before long, however, they could no longer ignore the costs of facilities shared with other functions of the university, and attempts were made to calculate indirect costs so that the government could reimburse its fair share of them. During the height of the expansion of the system, many institutions were incurring capital charges for facilities and equipment that could not be funded under any one project.

Academic science began to feel the effects of its own growth. While funds for fellowships, research, and facilities were still rising during the 1960s, the growing numbers of scientists reduced the support per capita. The fraction of Ph.D. academic staff in science receiving federal support and doing basic research (in all fields) declined from 69 percent in 1964 to 57 percent in 1970. In the same period, federal and other research funds per scientist and engineer in doctorate-granting universities fell from $13,138 to $11,826 (in constant 1961 dollars).[2]

THE PARTNERSHIP TODAY

To gain perspective on academic science in the United States today, it is useful to consider a somewhat larger universe of similar and related research activities. We might call these activities "universitylike" in that they are primarily research (not development), both basic and applied. More than 90 percent of the research of this sort is supported by the federal government in four different institutional settings: universities, the government's intramural laboratories, FFRDCs operated by universities, and other nonprofit laboratories.

Total federal obligations for such research were about $8.8 billion in fiscal 1982 (Table 1). Approximately 43 percent was conducted on campus; 38 percent in intramural laboratories by scientists who are government employees; 11 percent in FFRDCs, funded primarily by DOE; and 7 percent in other nonprofit laboratories. Table 1 shows only expenditures for FFRDCs operated under contracts awarded to universities; others are operated by industrial contractors. Many of the other nonprofit laboratories are affiliated with academic institutions and are important centers of graduate and postgraduate training in research. The classical examples are the large teaching hospitals or comprehensive cancer research centers, which are corporations independent of their affiliated universities. This category depends most heavily on support from DHHS (primarily NIH).

Federal Science Agencies

Federal funding of academic science is dominated by six departments or independent agencies--DHHS, NSF, DOD, DOE, NASA, and USDA. They account for about 95 percent of federal support of basic and applied research on campus. DHHS and NSF between them support about 70 percent of it.

To a certain extent, the maximum expression of pluralism in federal support of academic R&D lies in each agency's determination of its priorities and the selection of the scientists or institutions best suited to the work. Administrative practices for reimbursement of costs and fiscal accountability have become relatively standardized over the years. The auditing arms of DHHS and DOD, for example, oversee the accounts in most institutions supported by federal funds. The indirect cost rates for

TABLE 1 Obligations for Basic and Applied Research Supported by Selected Federal Agencies, Fiscal 1982 ($ millions)[a]

Agency	Academic On-Campus Research	FFRDCs Operated by Universities	Other Nonprofit Laboratories	Government Intramural Laboratories[b]	TOTAL
DHHS	2,049	14	452	821	3,336
DOD	409	81	73	1,117	1,680
DOE	241	770	30	76	1,117
NASA	158	50	42	735	985
NSF	697	72	40	113	922
USDA	263	--	1	493	757
TOTAL	3,817	987	638	3,355	8,797

[a]Obligations represent the amount for grants or contracts awarded and similar transactions during a given period, regardless of when the funds were appropriated and when payment is required. Obligations in a given year may be larger or smaller than expenditures in that year.
The goverment also supports research performed by industrial firms, FFRDCs administered by industry, FFRDCs administered by nonprofit institutions, state and local governments, and foreign organizations or governments, which are not listed in this table.
[b]Agency administrative costs are included under intramural, which are therefore exaggerated estimates of research obligations.

SOURCE: National Science Foundation, Federal Funds for Research and Development: Fiscal Years 1981, 1982, and 1983, Detailed Statistical Tables (Washington, D.C., 1983).

academic institutions are set by negotiations handled by one federal agency for all agencies supporting scientific work in that institution. The agencies retain their individuality, however, in a number of practices. NIH, for example, does not permit carryover of funds from year to year in most of its grants; NSF does. NIH adjusts indirect costs annually for any inflation during the year; NSF permits adjustments but may not provide additional funds. Peer reviewers at NIH do not consider indirect costs in their deliberations. NSF reviewers are given total costs in their considerations.

The diverse sources of federal funds for university R&D are a remarkable feature of the system and one of its greatest strengths. Occasionally, the differences among agencies' practices create administrative burdens or misunderstandings between scientists and administrators within institutions and between scientists and agencies. Nevertheless, the missions are so different that uniform policies and procedures often are neither desirable nor possible. For most purposes, the agencies seek and accomplish the essential communications with scientists and universities. Only when generic problems arise does the absence of a means of regular communication among agencies become a difficulty.

How the Government Supports Research

The federal government supports scientific research in diverse ways: through individual research projects and large research programs; in research centers and large facilities; in national laboratories; and by broad institutional support. The relative emphasis that the various agencies place on the different forms of support is a statement of federal science policy. In an agency that aims primarily to strengthen basic science and support individual scientists, for example, the project grant will be predominant. Agencies that emphasize specific technological goals and the application of science and technology will rely more on research contracts and support of large centers or facilities built around specific objectives.

The Project Grant

Although federal agencies use various funding mechanisms, the postwar surge of government funding in academic science was accomplished largely through the research project grant. Such grants are relatively modest--normally less than $150,000 per year--but in 1979 they accounted for 47 percent of total federal support of academic research and development.[28] Most of the work funded in this way is basic research.

The contemporary project grant is a direct descendant of the contract used by the Office of Scientific Research and Development during World War II, with some important modifications. First, today's grant is considered a form of assistance rather than procurement of services. Second, the body of regulations associated with research grants has grown considerably. Third, most agencies now use some form of peer review to decide which research to support. And finally, universities are required to share in the cost of research supported by federal grants by foregoing some portion of reimbursement for the costs of research projects--a practice commonly referred to as cost sharing.[5]

NIH and NSF use project grants extensively. They also use other kinds of grants, and sometimes contracts, to support specialized centers or organized research units, large-scale clinical trials, and other large projects. The bulk of their support of academic research, however, is for the work of individual scientists. The awards are made to the academic institutions, which are charged with their stewardship, but the award decisions are based principally on the ideas and qualifications of the principal investigator(s).

Research grants are made for a limited term, usually three years. The proposals are initiated by a principal investigator, who seeks funding for a specific project or experiment. Most projects support the activities of the senior investigator, who will be assisted by one or more graduate students, postdoctoral fellows, and laboratory assistants. NIH has nearly 14,000 project grants in effect in any one year; about a third of the grantees annually must compete for renewal. NSF supports about 12,000 grants.[29]

The principal advantage of the project grant is the emphasis on scientific merit in the selection process and the consequent decentralization of initiative. Another advantage is that, because the grants are relatively small, agencies can shift the emphasis of their funding without disrupting large programs.

There are disadvantages to the project grant as well. Current heavy reliance on project funding creates gaps in the research support system that universities are increasingly unable to fill. These include funds for shared equipment and facilities too large to be supported by a single project, start-up money for new research initiatives, funds needed by beginning scientists to establish a record of performance, and temporary support for experienced scientists who are changing the field of their research. Another disadvantage is that the thousands of grants involved impose a heavy administrative load on both the universities and the government and a heavy load of proposal writing and reviewing on thousands of investigators. Each proposal must be reviewed individually by peers, and each grant entails individual accounting and reporting, both scientific and financial. Three years is a relatively brief period in scientific research. Investigators who dedicate their careers to such endeavors are thus exposed to great uncertainty about their ability to maintain the continuity of their efforts.

Peer Review

Federal agencies use various types of peer review of proposals to select the research they wish to support. Some agencies use internal review exclusively, some use only external review, and others use both. Program officers in the agencies award funds on the basis of the quality and promise of the research and set priorities among the proposals judged as acceptable. Table 2 shows the various review processes used by the six federal agencies that fund the major share of academic research.

Federal agencies employ scientists to administer their research programs full-time. Those agencies that rely on their own scientists for technical review of research proposals are said to use internal review. While criteria for excellence are generally the same as in agencies using external review, agencies using internal review usually have a stronger mission orientation.

In agencies that use external review, proposals are reviewed by scientists employed outside the funding agency. The term peer review has come to have a widely accepted meaning that is essentially the same as external review: review by scientists who are actively engaged in research, who are not employed by a funding agency, and who have the research experience that will permit them to make discerning judgments on the scientific merits of proposals.[30]

NIH and NSF are the only agencies that rely exclusively on external review. DOD, NASA, and DOE use external review for a part of their awards. Recent legislation has established in USDA a small, competitive grants program that uses peer review, but most of the department's extramural research funds are allocated to state agricultural experiment stations on the basis of legislatively mandated formulas.[5,30]

At NIH each project is assigned to the appropriate institute or institutes, then forwarded to one of the standing review panels, called study sections. Each of these consists of 12-20 research scientists who read all proposals submitted to their sections, meet three or four times a year to discuss the proposals, and award each a numerical priority score on the basis of scientific merit. These rankings go to the assigned institutes, where they are reviewed for program relevance by the advisory councils, which have the statutory authority to approve awards. The ability of peer reviewers to distinguish differences among excellent proposals is limited and is a source of increasing tension as the number of approved grants that are not funded increases.[5] In recent years the number of approved grants has greatly exceeded the available funds; the various institutes were able to fund only an average of 35 percent (ranging from 29-48 percent) of approved grants in fiscal 1982.[31]

At NSF the Directorate of Biological, Behavioral, and Social Sciences regularly uses panels of reviewers. The other directorates do so less regularly. In these directorates program officers usually obtain opinions by mail from 3-10 reviewers knowledgeable in the field represented by the proposal and make the final judgment on the basis of these recommendations. Decisions of program officers are then reviewed within NSF before the award is made. NSF, too, receives far more meritorious proposals than it can fund.

Coordination of Budget and Policy

The U.S. system of research and development, including the government-university partnership, has always been marked by wide diffusion of authority and little central coordination. Observers have long considered the decentralization of the system a major strength, although the desirability of a more coordinated national science policy has been debated for three decades. The legislation that established the National Science Foundation and its policy-making body, the National Science Board, assigned them a role in coordinating federal science, but they have never pursued it. It is perhaps unrealistic to expect NSF to attempt to coordinate the scientific activities of older agencies of equal rank and greater size.[32]

The Executive Branch

The federal science agencies are coordinated at several levels within the executive branch. Of the largest sponsors of research, NSF and NASA are independent subcabinet agencies. The others are within cabinet-level departments, each with its own hierarchical structure. The annual budgets are reviewed and combined into the

TABLE 2 Review Processes Used by Several Federal Agencies

Agency	Review System	Processes	Choice of Peer Review
Department of Agriculture	External for basic research proposals. Formula funds to agricultural experiment stations sporadically reviewed internally and externally.	Mail review when external review used	Usually used, except for new competitive grants for which use is legislatively mandated
Department of Defense Air Force Office of Scientific Research	External only for certain programs (chemistry, mathematics). Mostly internal.	Mathematics: mail reviews; chemistry: panel	Traditionally used at discretion of scientific officer
Army Research Office	External and internal followed by internal funding decision	Mail review	Committee of National Research Council selects reviewers
Office of Naval Research	Internal, except in Biological Sciences Division	Mail review when external evaluation used	At discretion of scientific officer on individual proposal basis. Traditionally external for Biological Sciences Division.
Department of Energy	External in some programs; internal in others	Mail and/or panel when external	Program director's discretion
National Aeronautics and Space Administration	Internal	Mail if external review needed	Reviewing office or field installation through Office of University Affairs
National Institutes of Health	External, dual system	Technical review by study sections meeting as a panel; then panel review by national advisory councils	Legislatively mandated
National Science Foundation	External	Mail, panel, or combination of mail and panel, depending on program	Traditionally used

SOURCE: National Commission on Research, Review Processes: Assessing the Quality of Research Proposals (Washington, D.C., 1980).

President's overall budget by the Office of Management and Budget (OMB). Thus OMB is the focal point of decisions in the executive branch on the coordination of the budget for science and the administration of support.

The Office of Science and Technology Policy, the President's science advisory apparatus, is the principal science adviser to OMB. The form of the office has changed periodically since President Eisenhower established it in 1957; it assumed its present shape in 1976 under P.L. 94-282. It has significant influence on the administration's budgets for science and technology and on related policies emerging from OMB. The act that created the office also reestablished the Federal Coordinating Council on Science, Engineering, and Technology, which had first been set up by Eisenhower in 1959.[33] Theoretically, the council is a mechanism that permits the science agencies, under the leadership of the Office of Science and Technology Policy, to consider broad issues and make recommendations to it and to OMB. In practice, the council is limited in what it can achieve. Both tradition and the law strictly limit federal agencies' unilateral dealings with their fellow agencies, with Congress, or with their many constituencies. This executive discipline is enforced by OMB and carefully monitored by Congress.

Congress

Congress plays a leading role in federal involvement in science and technology. In this role it can call on the General Accounting Office, the Office of Technology Assessment, and the Congressional Research Service for help in coping with the complex system it has created and superintends. The pluralistic nature of congressional command has increased with time. The committees responsible for the overall missions of the departments have generally continued to handle the appropriations and oversight of the science agencies within those departments. More than a score of committees in Congress now have direct jurisdiction over one or another aspect of the federal science agencies.

In recent years, authorizing committees have come to share more fiscal control over science with the appropriations subcommittees. Some of the science agencies depend on authorizations that must be renewed periodically and that set ceilings on the appropriations. These controls permit the committees to hold hearings on the performance of the agencies and to propose statutory changes in their organizations and missions.

The legislative process is such that debate and inquiry about science can be initiated in many committees with jurisdiction over only a small part of the enterprise. New legislation or regulations emanating from such activities can have profound effects, sometimes unintended or unsuspected by the authors. This same diffusion of action in Congress may also at times be a virtue. One example is the dual referral of legislation proposing regulation of recombinant DNA technology, which resulted in extended hearings in which many scientists participated. Many observers believe that the resulting cooling-off period helped to avoid controls on research that would have unnecessarily hampered progress in the new biotechnology industry.[34]

Despite the fragmentary way in which policy is created and changed, Congress has been sensitive to the needs of academic science. It has not tampered with the essential scientific freedoms or imposed restrictions on international communications or the interactions needed to preserve the universality of science. The original concept that scientific merit, judged by peer review, was to be the prime determinant of the allocation of resources has been adhered to.[35] At the same time, the sum of the actions of so many makers of law and providers of means at times weighs heavily on the universities, which have difficulty in responding effectively to an annual cycle of increasingly complex decisions.

The Universities

The university partner comprises some 300 institutions that award doctoral degrees in science and engineering. For more than a decade, however, more than five-sixths of federal support for scientific research on campus has gone to about 100 universities that are the leaders in research. Conferring of Ph.D. degrees is also concentrated: 50 of these universities confer 60 percent of the doctorates awarded in all fields.[36]

The universities do about half the nation's basic research and educate the scientists and engineers who pursue careers in research. In this combination of research with graduate education the universities are unique. A second feature of the institutions is their diversity. They have different origins, financial auspices, governing boards, curricula, and ideas of education, to say nothing of differences among the individuals who comprise the faculties and student bodies.

A third important feature of the universities is the physical growth and financial dependence resulting from their partnership with the government. Financial dependence on the government has forced universities to participate in a host of social changes that affect their functioning and finances. This does not necessarily imply that they would have resisted such changes, but it is certain that most would have preferred more flexibility in achieving the desired objectives. Many of the universities have grown large and complex. In addition, they all must fulfill obligations for teaching, research, and service. This combination of factors has put them under considerable stress.

Academic Researchers

Academic researchers have also been under stress for some time. The stress arises in part from the intense competition for research project grants in a time when the number of worthwhile proposals far exceeds federal funding ability. A related problem, the allocation of project funds to direct and indirect costs, has long pitted academic investigators against their administrators and the administrators against the government. Furthermore, federal requirements for accountability for the use of project grants strike investigators and administrators alike as far more burdensome than necessary and have set both against the government.

Besides these causes of stress, faculty researchers and their prospective colleagues see declining opportunity on campus. The number of full-time-equivalent scientists and engineers engaged in research and development in colleges and universities reached a new high--some 83,000--in 1980,[1] but the numbers conceal a change in the pattern of employment. The proportion of scientists and engineers who are tenured or on tenure-track in the colleges and universities is declining. The number of academic researchers under 35 who are on postdoctoral appointments without opportunity for tenure more than doubled between 1973 and 1979.[1] The decline in new openings for tenured faculty reflects general fiscal stringency as well as declining rates of growth in enrollments and a projected drop in undergraduate enrollments.

Summary

The government-university partnership in research and advanced education in science and engineering today is a very large enterprise. It involves some 300 doctorate-granting universities and federal funding of research and development on campus at a level of $4.6 billion in 1982. The enterprise also is highly decentralized. On the federal side are many congressional committees as well as funding agencies and offices of the executive branch. On the academic side are universities of diverse character housing faculty investigators at work on many thousands of federally sponsored projects.

The size and diversity of the system are certainly strengths, but they cannot guarantee its continued productive functioning. For that we need alertness to problems and mutual understanding of viewpoints by the parties--the government, the universities, and faculty. The partners share important objectives--it is the route to achieving them that is difficult to agree on.

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2
The Forum on Government-University Relationships

An idea that caught the interest of the Committee at its first session was the proposal of the National Commission on Research for a continuing forum to facilitate communication between universities and government in science. Tensions between government and the universities in matters relating to contracts and grants have been the subject of lively, often strained, discussion for some three decades now. Periodic studies and conferences explore the subject, but the tensions persist unabated. The belief has grown that a new approach is needed.

After much discussion both within the Committee and with key people outside, it was concluded that a forum of the sort proposed by the National Commission on Research should be created. Among the issues explored was the question of whether the functions conceived as appropriate for the Forum were already being performed. The answer proved to be no.

WHAT THE FORUM IS AND IS NOT

The Forum is not to be thought of as an elitist super board of strategy, a kind of ultimate policy council, or a Supreme Court. It is a device for improving communication on key policy issues among participants who have varied goals--a means of getting past their initial hostile attitudes and misconceptions and ensuring that they understand one another's assumptions and positions. It is an instrument for conflict management, the finding of common ground, the prevention of unilateral surprises, and a movement toward consensus.

It is a means of continuous examination and reexamination of issues. One-shot debates on controversial issues predispose participants to come "loaded for bear," knowing that they have a brief time to attack their opponents and defend themselves. In contrast, the Forum will be designed for reflective consideration of issues over time. This does not imply that the Forum will avoid confrontation. It will deal with conflict on a continuing basis. And its existence will not, of course, prevent university presidents and agency officials from pursuing negotiations on their own.

The Forum will not be a device for one-sided advocacy. All relevant sides will be aired. The primary purpose is to achieve a mutual understanding of motives and goals and to open a way toward achievement of consensus.

The quickest way to destroy the effectiveness of the Forum would be to allow it to become identified as an instrument of special pleading for the universities. It would cease to be a forum. Unless government can participate wholeheartedly, knowing that its views and purposes will have equal standing, the whole concept fails. The Forum must be an arena for dialogue, for statesmanship.

The Forum will be governed by a core group (see description below), which is responsible, through the President of the National Academy of Sciences (NAS), to the NAS Council. The core group will select the issues to be placed on the agenda, giving due weight to the concerns of the constituent groups, and will assign priority to the issues that threaten a healthy relationship between the government and the universities in science and technology.

Obviously, the core group could not have intimate, firsthand knowledge of all the issues coming before the Forum; it would not be expected to. The members of the core group are not the Forum; they are the conveners and will bring into the Forum individuals on all sides of any given question who are directly concerned with the issues.

After due consideration of an issue, the Forum will, as a rule, report back to its various constituencies. By constituency we refer to any group that has a legitimate interest in the government-university relationship in science and engineering. Among the constituencies would be working scientists and engineers, laboratory directors, university administrators, scientific and engineering associations, university associations, those concerned with industrial research, government agencies dealing directly with scientists, engineers, and their universities, government agencies concerned with patterns of funding and accountability, and relevant committees of Congress.

Reports by the Forum to its constituencies will state all sides of the issue, describe the differing assumptions, definitions, objectives, and values that led to the conflict, and indicate the extent to which mutual accommodation has been achieved. It would not hand down a verdict, but may give the opinions of the discussants as to the next steps that can be taken on the road to consensus.

Although the Forum will deal primarily with government-university disputes, it will inevitably have to address itself, on occasion, to conflicts within universities or within government. Although such conflicts are beyond its jurisdiction, it may in tangential ways contribute to their resolution. It cannot ignore them.

The focus of the Forum will be science (including the social sciences, as in the National Science Foundation) and engineering. The Forum charter is drawn, however, so that the enterprise might eventually encompass other fields. (The charter appears at the end of this chapter.) Certainly the Forum will not neglect the parallel interests of other fields in the problems with which it deals.

Meetings of the Forum in which there is formal debate and review of all sides of a controversial issue will normally be open to the public. But the Forum will also hold off-the-record sessions to permit various constituencies to give preliminary expression to grievances without the constraints of public discussion. Since the Forum makes no official recommendations (and since, even if it did so, they would not be binding), it should be free to meet with any constituency in total informality. The university researchers with whom we have talked have stressed the importance of the core group's establishing relationships of trust and easy communication with key government agency personnel who play a decisive role in agency policy. It will be important to develop a comparable relationship with appropriate committees of Congress.

THE CORE GROUP

A good deal of time was given to the question of which groups should be represented in the Forum. It was not difficult to identify appropriate participating elements (the universities, the executive branch, Congress, scientific organizations, and others), but it was exceedingly difficult to decide how representives might best be chosen from those elements. How, for example, would one elect or select a limited number of representatives from the numerous university and scientific associations? Or from Congress?

This consideration led to the idea of a core group of seven individuals chosen for their breadth, distinction, and credibility, to function not as representatives of anything other than the health of science and engineering in the university context and the integrity of the government-university relationship. These individuals would have to be well and favorably known to more than one constituency. Each constituency would have to feel that there were members of the core group who understood its interests and would not stand silent if those interests were unfairly dealt with. It is particularly important that the core group have credibility with working scientists and engineers, university administrators, key members of Congress, and those executive branch agencies most involved in the support of science and engineering.

Members of the core group should be expected to give up to one-fifth of their time to the venture; the Forum chair up to half. Members will serve terms of three years and may be reappointed. The initial appointments will be for staggered terms to assure continuity of leadership. In the opinion of the Committee, all members should be appropriately compensated. In any given year one or more of the core group might consist of senior figures who would be resident at the site of the Forum on sabbatical, between positions, or immediately following retirement.

The process for selecting the core group will be as follows: The President of the National Academy of Sciences will identify criteria, including requirements for balance. He then will solicit final nominations from the endorsers (see below), from the Committee on Science, Engineering, and Public Policy, and from other interested persons or organizations. The President will then select and appoint the core group with the advice and consent of the Council of the National Academy of Sciences.

SPONSORSHIP AND ENDORSEMENT

The National Academy of Sciences, with its unique position between government and the private sector, will sponsor the Forum. Organizations and agencies inside and outside government that have participatory interests in the government-university partnership will be asked to serve as endorsers of the Forum.

The primary role of the endorsers is suggested in their name. Without committing themselves to any organic relationship to the Forum or accepting responsibility for its activities, and without any compulsion to refer issues to it, the endorsers simply express their approval of the launching of the Forum and their goodwill toward it. This is a weightier relationship than it may appear to be. The continuing affirmation of belief in the value of the Forum and participation by the agencies and institutions most concerned with its purposes will be the main force sustaining it.

Members of the Committee have talked with a number of potential endorsers, and the concept of the Forum has met with broad interest. The groups and institutions consulted are the following:

Nongovernmental:
- National Academy of Sciences
- National Academy of Engineering
- Institute of Medicine
- American Council on Education
- National Association of State Universities and Land-Grant Colleges
- Association of American Universities
- American Association for the Advancement of Science
- Industrial Research Institute
- Social Science Research Council
- National Academy of Public Administration
- American Council of Learned Societies
- American Association of Engineering Societies
- Business-Higher Education Forum

Governmental:
- Office of Management and Budget
- Office of Science and Technology Policy
- Department of Agriculture
- Department of Defense
- Department of Energy
- Department of Health and Human Services--National Institutes of Health
- National Aeronautics and Space Administration
- National Science Foundation
- General Accounting Office

The Congress is missing from this list because its formal endorsement is not practical, either to seek or to obtain. At the same time, congressional awareness of the existence of the Forum and confidence in its functioning will have a critical bearing on the value of this new instrument.

RELATIONSHIP TO THE NATIONAL ACADEMY OF SCIENCES

The National Academy of Sciences did not seek a key role in the creation of the Forum. This Committee, after extensive consultations among researchers, university administrators, and government people, concluded that the NAS was by a long margin the most widely acceptable locus for the Forum. It was on this basis that the President of the NAS agreed that a proposal for sponsorship be placed before the NAS Council. The Forum's charter has been formally approved by this Council.

The charter provides for governance of the Forum by the core group with the oversight of the President and Council of the National Academy of Sciences. The NAS will act as the host of Forum meetings, but the Forum will differ in an important respect from the committees of the National Research Council, which is governed by the Academy complex. It will not be making studies that result in policy recommendations. This will spare it the necessity for multiple clearances and will protect the NAS from too close involvement with the issues taken up by the Forum.

Lest this measure of independence arouse concern within the NAS, one should note that the Forum will not be able to function without the goodwill of its institutional host (or for that matter, the goodwill of its endorsers). Moreover, in the charter the NAS Council reserves the right to review any reports of the Forum. The protection against its becoming a runaway organization is complete. The Forum will report periodically to the National Academy of Sciences and to its endorsers.

It will be particularly important, as indicated earlier, to ensure that the Forum does not become a special advocate for universities, since the NAS cannot be in such a position.

The NAS has agreed to shoulder the initial burden of securing funding for the Forum. Endorsers will be asked, although not required, to make contributions as a symbol of their commitment to the venture.

A staff will be required to assist the core group, arrange meetings, and prepare the background statements, analyses, and other documents emanating from Forum meetings. The Forum will also require the services of a skillful executive director who is familiar with the issues and parties involved. An important function of the Forum staff will be building an accurate base of information on the issues.

Numerous issues will be commended to the attention of the Forum. Only those amenable to solution through discussion will be chosen. Part II of this report details a number of such issues and suggests those for which the Forum may be particularly helpful. Persistence and continuity will be required for solutions to these problems.

Each problem will involve a different cast of participants, who must be chosen carefully. Biases must be balanced and all the relevant and important points of view considered. The Forum will convene those people whose positions relative to an issue are such that they can effect change and contribute to improvement of the government-university relationship.

Every sentence in the preceding paragraphs of this chapter was distilled from the many discussions that were necessary to reach consensus on plans for the Forum. It proved not to be a particularly controversial subject, but long discussions seeking consensus tend to produce cautious and precise language. It would be unfortunate if the caution of the language left the reader with the impression that the Committee approached this project in a pedestrian spirit. Nothing could be further from the truth. We see the Forum as a high-risk/high-gain venture. The risk is that we may create one more ineffectual institution--a sin we do not take lightly. The gain would be that we might produce a social invention of lasting value.

It is characteristic of our intricately organized, pluralistic system that subsystems clash. We permit, even welcome, conflicting purposes. Pluralism assumes such conflict and asserts that much of it is healthy. But we know that prolonged conflict among subsystems can undermine purposes shared by all who care about the health of the larger system. And we believe that there are noncoercive ways of dealing with such conflict. It's worth a try.

CHARTER*
FORUM ON GOVERNMENT-UNIVERSITY RELATIONSHIPS

Mindful of the long-standing and critical importance of the continuing partnership between the federal government and the universities in support of scientific research and the generation of new scientists and engineers, and of the tensions that inevitably arise in that relationship, the Council of the National Academy of Sciences hereby authorizes the creation of the Forum on Government-University Relationships. The purpose of the Forum shall be to facilitate communication between universities and the government, and with others as appropriate, about such key policy issues as those relating to the administration of instruments of support, the maintenance of necessary facilities and equipment, accountability, the education of scientists and engineers, the free flow of scientific knowledge, and the like. The scope of the Forum's business shall include the facilitation of discussions on problems related to its purpose and the preparation of background papers analyzing and clarifying areas of conflict or misunderstanding. The Forum will not make policy recommendations. In carrying out its purpose, the Forum shall hold itself open to use, among others, by working scientists and engineers, laboratory directors, government agencies concerned with funding and accountability, government agencies dealing directly with scientists, engineers, and their universities, scientific and engineering associations, university associations, and university administrators--and to representatives of industrial research when they have concerns that bear on the government-university relationship.

I.

SPONSORSHIP AND ENDORSEMENT

1. The National Academy of Sciences is the sponsor of the Forum.
2. The National Academy of Sciences, through its President, shall seek endorsements from private and government institutions as appropriate.

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*The charter of the Forum on Government-University Relationships was approved by the Council of the National Academy of Sciences in November 1982.

II.

GOVERNANCE

1. The Forum shall be governed by a core group, known as the Forum Council, which shall be responsible through the President to the Council of the National Academy of Sciences. The Forum Council shall be composed of seven members chosen for breadth, distinction, and credibility, in the manner described below. The Chair of the Forum Council is expected to give up to half of his or her time to the work of the Forum, and the other members of the Council approximately one-fifth each.
2. The members, and the Chair, of the Forum Council shall be appointed by the President of the National Academy of Sciences with the advice and consent of its Council, upon the basis of his judgment as to their distinction and credibility, and considering the advice of the private and public institutional endorsers of the Forum. Because engineering and medicine are important elements of university research, the President of the National Academy of Sciences will consult with the Presidents of the National Academy of Engineering and the Institute of Medicine with respect to nominees in these fields. Replacements for the members of the Council shall be made by the President on the same basis. The members of the Forum Council shall serve staggered terms of three years and be eligible for reappointment. Council members shall receive such compensation as appears to the President of the National Academy of Sciences to be appropriate to their commitment to the work of the Forum.
3. The Forum Council shall hold such public meetings for the discussion of key issues as it may deem advisable from time to time; and the Forum Council is responsible for the issuance of such papers as are appropriate to the conduct of the Forum's business.
4. The Chair of the Forum shall report annually to the Council of the National Academy of Sciences and will provide the Council with its background papers, minutes, and summaries as they become available. The Council of the National Academy of Sciences shall determine an appropriate review mechanism for Forum reports.

5. The Forum Council shall be provided by the National Academy of Sciences with such staff and facilities as may be approved by the President. The budget of the Forum would be proposed to and approved by the Council of the National Academy of Sciences, after consultation with the Forum Council.

Part II
Problems Facing the Partnership

3
Graduate Education in the Sciences and Engineering

The future vitality of science and technology in this country depends critically on graduate education in the universities. Through graduate education the scientific community continuously renews itself and its ability to produce the scientists and engineers--at all degree levels--so important to the nation's well-being.

During the years that followed World War II, with extensive support from the federal government, the U.S. university emerged as an important instrument of national purpose. Its combination of basic research, research application, education for careers in the sciences and engineering, and service is uniquely effective among the world's educational institutions. Our scientific eminence and productivity affirm the wisdom of federal support for the scientific-technological enterprise. They also suggest that a balanced national policy would include support not only for research but also for the graduate education with which it is inextricably linked in the universities.

Because of the tight linkage of research and education, sound policy requires attention to the educational roles of university scientists, to the quality of their student colleagues, and to the physical and intellectual environment in which they work. No society that relies as heavily as does the United States on technical know-how and the specialized knowledge that supports it can afford to neglect the health of the complex relationships that make that knowledge possible or the people who form the relationships.

SCIENTIFIC AND ENGINEERING MANPOWER

Modern societies depend on broadly diversified manpower, including research scientists and the technologists who translate the findings of research into useful applications. Most who succeed at independent research hold Ph.D. degrees or are doctorate-level professionals, many trained in medicine or engineering, who have had post-graduate training in research roughly equivalent to the experience of the Ph.D. Most teachers of science or engineering in our universities are in one of these two categories.

Relatively few of the people educated to do research persist in extended careers in truly creative research. It is impossible, moreover, to determine who will succeed at research in advance of tested performance. Thus the production of research scientists is inherently a relatively speculative and expensive process. Society benefits, however, because the education generally proves valuable to anyone having a career requiring knowledge of the scientific method and use of specialized scientific knowledge. Industry and government depend on such professionals to develop new products, expand existing markets, provide services based on high technology, and manage and administer scientific and technological enterprises.

Scientists and engineers in the United States number about 3 million at present (including those who are not working).[1] In 1978 about 12 percent of them held a doctorate, about 28 percent a master's degree, 58 percent a bachelor's degree, and 2 percent other earned degrees.[2]

The 645,000 scientists and engineers who were engaged in research and development in this country in 1980 make the United States second only to the Soviet Union in absolute numbers[2]* and in relation to the total labor force. The United States was surpassed by the USSR in the 1970s. Our position relative to Japan and West Germany has also declined in recent years in terms of the ratio of scientists and engineers to labor force, which has grown faster in those countries than here.

ASPECTS OF GRADUATE EDUCATION

We have stressed the tight linkage of graduate education and academic research. Academic scientists depend on graduate students to augment their capacity for scientific

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*The USSR had between 1.3 and 1.4 million R&D scientists and engineers in 1980. Japan had 273,000 in 1978, and inquiry. Conversely, intensive research activity provides by far the best milieu for training young people for careers in research or in many other areas of science and technology. In 1980 close to 90 percent of the graduate students in science and engineering were enrolled at the nation's 450 doctorate-granting institutions, about 300 of which offer Ph.D. degrees in science and engineering. These 450 institutions represent about 15 percent of the 3,150 U.S. colleges and universities. Furthermore, 50 of the most research-intensive universities grant about 60 percent of the Ph.D.s in all fields.[3]

Graduate students in the sciences or engineering must usually contend with a number of economic problems. They invest 4 to 10 years in postbaccalaureate study for the doctoral degree; if they wish to pursue a career in independent research, they may spend up to 5 more years in postdoctoral training. These are years in which the student otherwise could be earning more money in a full-time career. In addition to foregoing this income, the student must meet the high costs of graduate education. These financial considerations are important in determining which students will complete their doctorates and pursue careers in research and teaching. The disparity in salaries offered by industry and universities is large and growing; its effects are visible in the numbers of engineers and computer scientists who are eschewing doctoral education and academic careers for jobs in industry.

The universities are most directly responsible for maintaining the excellence of their faculties and the quality of their instruction. They are primarily responsible also for inculcating scientific discipline in young people who will become leaders in research and the other areas of science and technology. Responsibility for our future pool of technical manpower, however, extends beyond the universities and the federal government. The education and preparation of students before college depend on family, local schools, and other influences. In this light, the degree to which many nations, including the Soviet Union, Japan, and West Germany, are stressing scientific and mathematical proficiency in their secondary schools is extremely important.[2] The suggestion that scientific illiteracy is rising in the United States cannot be ignored in projections of how well we may meet the need for essential specialists in coming generations.

West Germany had 111,000 in 1977. Figures are in terms of full-time equivalent work in R&D.

THE FEDERAL ROLE

The growth of federal support for academic research and development after World War II was paralleled by strong growth in graduate enrollments and advanced degrees awarded in the sciences and engineering. Full-time graduate enrollments rose from 78,300 in 1960 to 249,000 in 1980. An additional 134,000 students were enrolled part time in graduate programs in 1980, bringing the total for that year to more than 383,000. Enrollments in the two largest fields of science--social sciences and life sciences--continued to grow during the 1970s, but those in other fields leveled off. By 1980 graduate enrollment in the sciences and engineering overall had virtually stabilized.[4] Master's degrees awarded in the sciences and engineering rose from just over 20,000 in 1960 to 56,700 in 1977, the peak year, and declined slightly to 56,000 in 1980.[1] Doctorates awarded rose from about 6,400 in 1960 to a peak of 19,550 in 1973 and declined to about 18,200 in 1980.[1,5]

The growth in enrollments and advanced degrees awarded after 1960 had several causes. The postwar baby boom led to a much larger population eligible for graduate school, and generally higher levels of education and affluence led a larger fraction of the eligible population to pursue higher education.[6,7] Perhaps among the most important factors affecting growth rates was federal assistance for students in the sciences and engineering. The federal initiatives were designed to meet projected demand for college and university professors and for scientific and engineering manpower.[8]

The major programs of this period included NSF fellowships and traineeships, offered in all fields but aimed at disciplines poorly supported by other mission agencies; graduate fellowships and research training fellowships, administered by the Office of Education at DHEW under Title IV of the National Defense Education Act of 1958; NIH fellowships and traineeships in the life sciences and psychology; Public Health Service fellowships and traineeships; NASA traineeships, predominantly for engineers, mathematical and computer scientists, and physical scientists; and AEC fellowships and traineeships, aimed at the physical sciences and engineering.[9] Another important contributor to the growth of enrollments after World War II was the GI Bill of Rights.

These programs were authorized and administered separately and without common goals, but together they created a de facto federal policy toward scientific and engineering education. The policy emphasized manpower development in specific fields rather than support for graduate education or institutions per se.[6,10,11] Federal programs of assistance for graduate students were established incrementally to fill existing or projected deficits in technical manpower. Agencies appeared to recognize the link between academic research and the education of scientists and engineers, in that they tended to fund research assistantships in grants and contracts awarded to principal investigators and universities.[12]

A different approach to supporting graduate students emerged in the mid-1960s as part of a shift in federal policy toward aiding underprivileged socioeconomic groups. The Economic Opportunity Act of 1964 created, among other things, the work-study program (used primarily for undergraduates until recently). This program of federal wage subsidies enabled universities to employ low-income students at a fraction of the students' wages. Students' eligibility for work-study programs was based on their financial status, not their field of study. The work-study program was expanded by the Higher Education Act of 1965. This legislation, administered by the Office of Education, also created the guaranteed student loan program, available to low-income graduate and undergraduate students in all fields.

These two laws retained the focus on direct financial aid to individual students (rather than institutions) established previously in the graduate education programs aimed at manpower development. And they reflected a continuation of the relatively disjointed, mission-oriented pattern of federal support of higher education that had developed in the postwar period.[10]

During the era of strong federal support in the 1960s, agencies offered an array of mechanisms that encouraged students to pursue graduate education. Two such mechanisms--fellowships and traineeships--are awarded on the basis of merit. Fellowships are awarded directly to individual students on the basis of national competition and for use at the university of their choice. Training grants also are competitive, but are awarded to specific graduate programs, which use them to pay training costs, such as the costs of equipment and administrative services, and to support graduate-student trainees. The institution, not the awarding agency, selects the students who receive traineeships.

Fellowships and traineeships are similar in their financial provisions for students, but they differ in their effects on students' selection of graduate schools. Portable fellowships foster a marketlike selection process in which top students judge the relative quality of graduate programs. With training grants, federal agencies decide which graduate departments deserve support and give them funds to support good students.

These merit-based mechanisms differ in concept from service-related support mechanisms, such as research assistantships, or need-based mechanisms, such as loans. Research assistants are graduate students who work on specific research projects and are supported directly from the research funding. Decisions on research assistantships are made in two steps: first, by agencies and peers who select the projects to fund and, second, by the grant recipients who choose the students to work on their projects. In loan programs, the federal government, through lending institutions and universities, subsidizes low-interest loans to students on the basis of income criteria rather than academic merit or area of study.

These federal programs provided financial assistance to record numbers of graduate students in the late 1960s and early 1970s. In 1969, the peak year for federal fellowships, traineeships, and training grants, 40,400 graduate students in the sciences and engineering, more than one-fifth of those enrolled full time, were supported at least partly by these mechanisms. In the same year, 122,700 graduate students (in all fields) were supported by GI benefits and 110,000 took out federally insured student loans.[13] These diverse forms of federal aid for graduate students, relatively strong federal funding of academic research and development, and the prospect of expanded job opportunities for scientists and engineers helped to prompt the expansion of graduate programs and to boost graduate enrollments and production of advanced degrees in the sciences and engineering to their high points in the early 1970s.

TRENDS IN GRADUATE EDUCATION

The data on graduate enrollments, federal support, and degrees awarded in the sciences and engineering since World War II have deficiencies that prevent detailed analyses of causal relationships. It is possible, however, to identify general trends in these relationships, whether causally related or not.

Since the early 1970s, the growth rates of enrollments and advanced degrees awarded in the sciences and engineering have decreased. These declines began about five years after the government significantly reduced its support of academic R&D in general and of graduate training in particular.[6,12] Beginning in 1967, many federal agencies began to reduce the numbers of graduate students they supported through fellowships, traineeships, and training grants in all fields but the life sciences and psychology (see Figure 1). Federally funded fellowships in all fields (science and nonscience), for example, declined markedly, from 51,000 in 1968 to 6,000 new and continuing fellowships in 1980-1981. The five-year lag between federal cutbacks and reduced awards of advanced degrees corresponds roughly with the average time it took to complete a Ph.D. in the late 1960s.

Graduate enrollments in most fields remained fairly constant during the 1970s; only in the social sciences, health sciences, and engineering were enrollments still growing by 1980 (see Figure 2). However, the ratio of doctorates awarded in the sciences and engineering to baccalaureates awarded six years earlier fell from about 12 per 1,000 in 1970 to 6 per 1,000 in 1980.[1,5,14] The numbers of Ph.D.s awarded in the life sciences were still rising by 1980 (see Figure 3). Doctorates awarded in the social sciences and mathematical and computer sciences declined slightly during the 1970s. The most significant declines in doctorates awarded have been in the physical sciences (from a peak of about 3,900 in 1971 to 2,500 in 1980) and in engineering (from a peak of about 3,500 in 1971 to 2,500 in 1980).

Other trends coincide with reductions of federal financial support for graduate students in the sciences and engineering. The proportion of Ph.D. recipients who relied partly on personal earnings while in graduate school rose from 25 percent in 1971 to 40 percent in 1980; the proportion that depended partly on family contributions or loans rose from 29 percent in 1971 to 62 percent in 1980.[5] The proportion of graduate students in the sciences and engineering who were enrolled part time in doctorate-granting institutions increased from 26 percent in 1974 to 31 percent in 1980.[4]

Also coincident with the decline in federal support is a rise in the percentage of foreign students enrolled in graduate programs in the sciences and engineering (see Figure 4). Non-U.S. citizens made up about 15 percent of the full-time graduate students in such programs in 1974

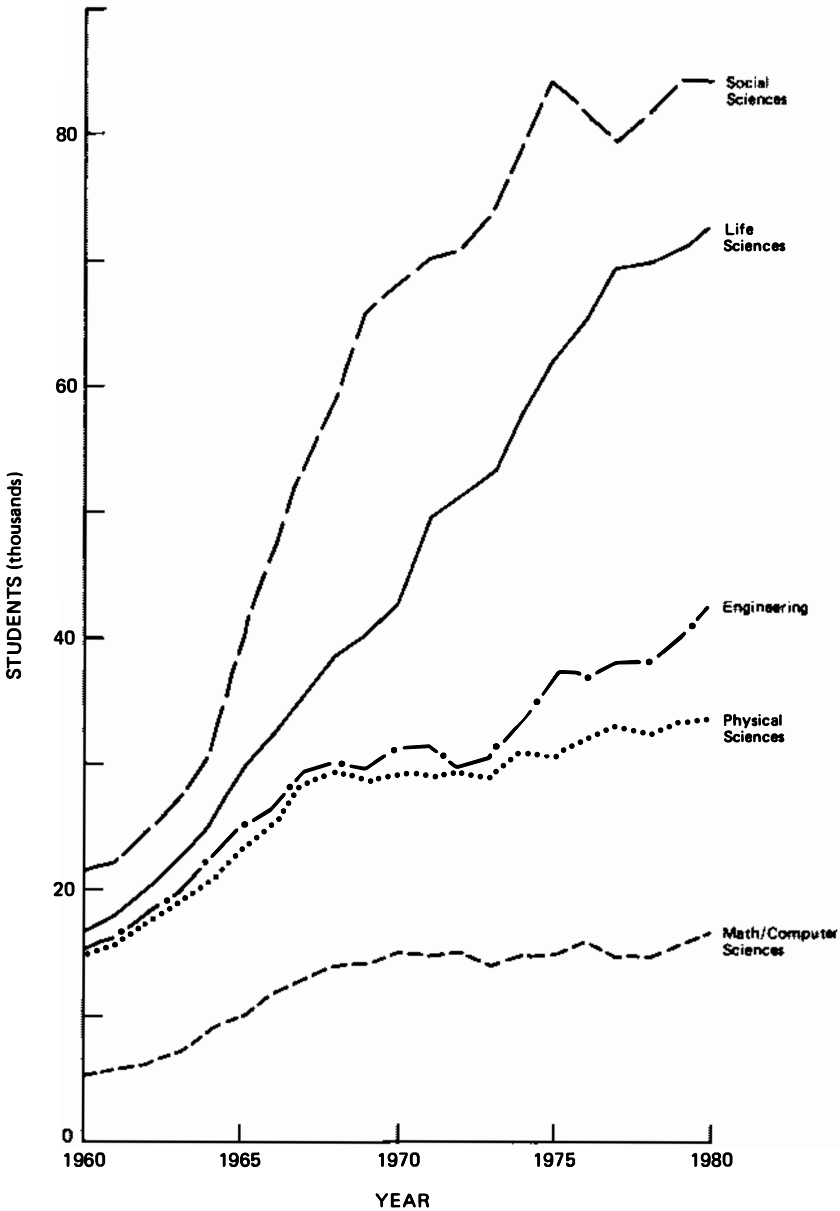

FIGURE 1 Percentage of full-time science/engineering graduate students supported by federal fellowships, traineeships, and training grants, by field and year, 1960-1969.

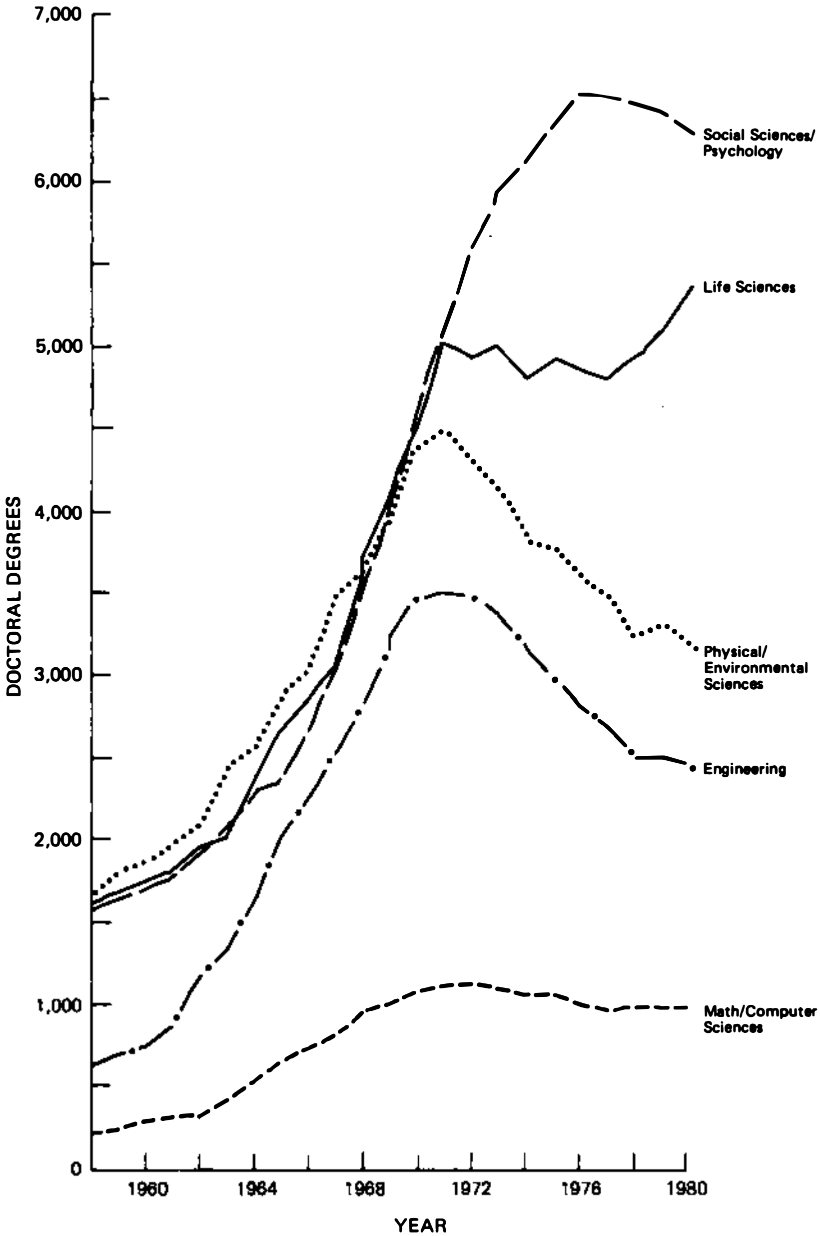

FIGURE 2 Full-time graduate enrollments in science/ engineering at U.S. institutions, by field and year, 1960-1980.

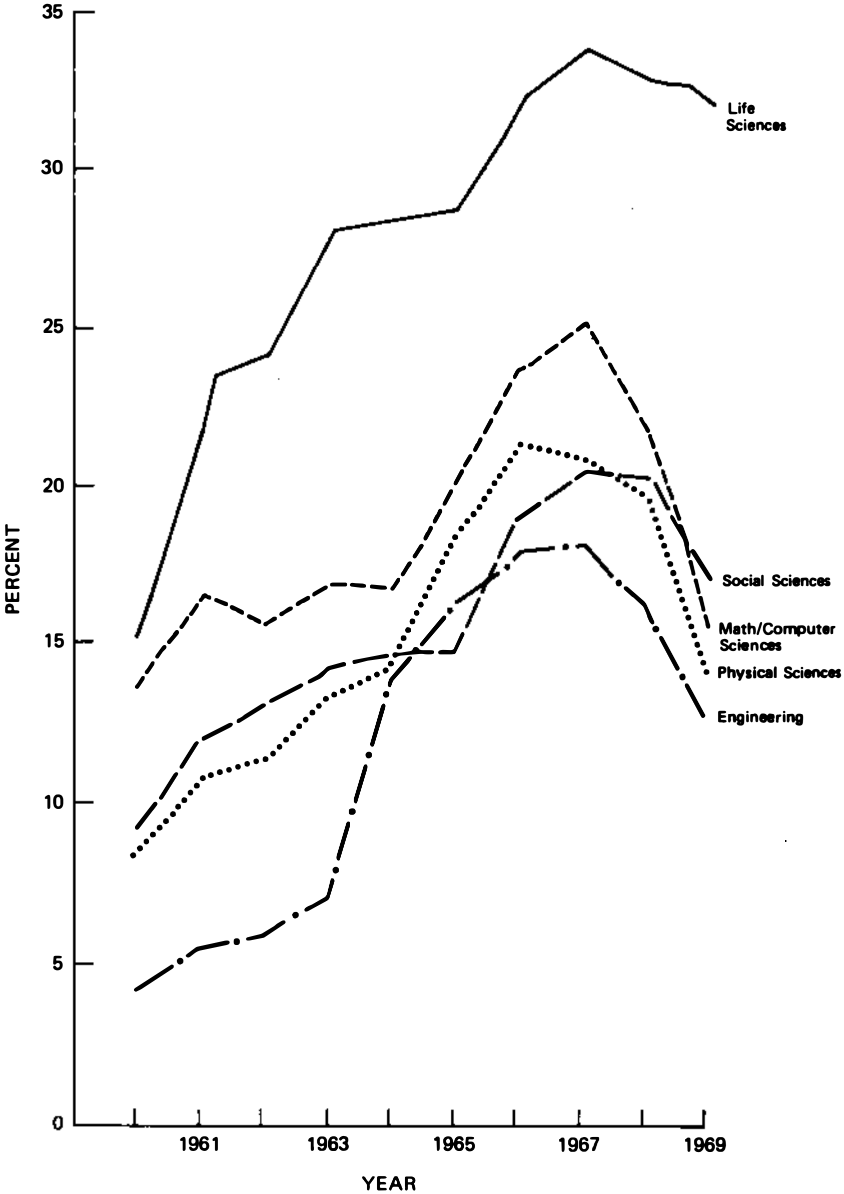

FIGURE 3 Doctorate degrees awarded by U.S. universities, by field and year, 1958-1980.

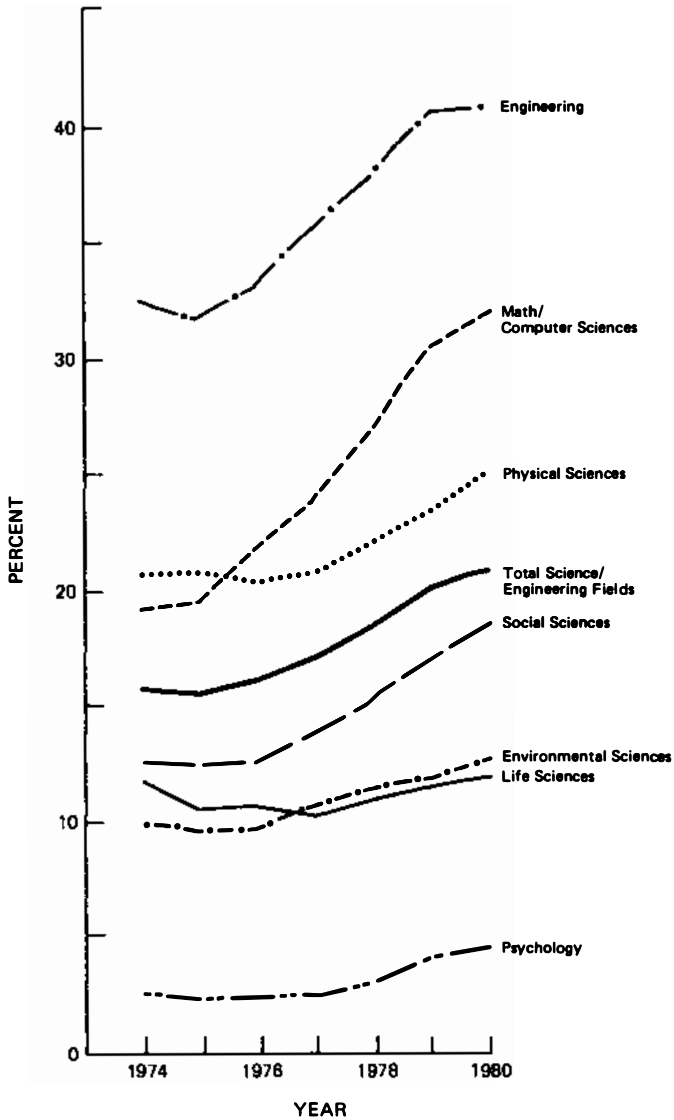

FIGURE 4 Foreign citizens as percentage of full-time science/engineering graduate students enrolled at U.S. doctorate-granting institutions, by field and year, 1974-1980.

and 25 percent in 1980. In 1980 foreign students received 46 percent of the doctorates in engineering awarded by U.S. universities, 27 percent of those in the mathematical and computer sciences, and 23 percent of those in the physical sciences.[5] The number of engineering doctorates conferred on foreign students actually declined during the five years ending in 1980. The proportion increased because of a sharp decline in the number of U.S. citizens seeking doctorates in engineering. The decline results largely because industry offers B.S. and M.S. engineers such high salaries that fewer and fewer of them are attracted to doctoral study.[15]

We do not know which, if any, of these trends in graduate education in the sciences and engineering are related directly to changes in federal support. Disciplines seem to vary, however, in their apparent sensitivity to such support.[4] The social sciences appear to be the least sensitive. Their share of enrollments and advanced degrees awarded has always been among the highest, but historically they have received a relatively small share of federal fellowships, traineeships, and research assistantships. Even relatively severe cutbacks in federal assistance to the social sciences did not significantly reduce enrollments or degrees awarded.

The physical sciences and life sciences seem more sensitive to changes in federal support. Graduate students in these fields historically have relied on such support. Enrollments in the physical sciences leveled off and degrees awarded dropped after federal fellowships and traineeships were reduced in the early 1970s. A relatively high level of federally supported research assistantships may have helped to maintain enrollments. Students in the life sciences have been relatively well funded by federal training grants and research assistantships over the past two decades, and enrollments and degrees awarded have remained high, especially in the biological and health sciences.

Factors in addition to federal support of graduate students may be relevant to trends in graduate enrollments and degrees awarded. Examples include the state of the economy and changes in industrial activities. Some observers believe that graduate students themselves drive the system by their choices of field, degree level, and career. The only certainty is that we do not understand the dynamics of the system very well.

EMPLOYMENT OUTLOOK

Graduate enrollments can be expected to some extent to reflect employment prospects for scientists and engineers, which were still good in 1981 relative to the rest of the labor force. Unemployment overall was 7.6 percent in 1981 compared with about 1.1 percent for scientists and engineers and 0.8 percent for doctoral scientists and engineers.[2] Engineers and computer scientists at all degree levels were in short supply in industry, government, and educational institutions in 1981; shortages of computer scientists at all degree levels and of doctoral engineers were expected to persist through the 1980s.[11]

Salaries in industry relative to academe are high enough to persuade computer scientists as well as engineers to stop their academic work before the master's degree. Salary disparities are one reason for the shortage of doctoral people in these fields who are devoting themselves to university teaching.

Another concern is the declining number of tenure-track openings at colleges and universities. The decline varies with the field of study--it does not apply, for example, to engineers and computer scientists--and could be affected by the anticipated retirement of faculty appointed in the period immediately after World War II. Overall, however, the proportion of doctoral scientists and engineers under 35 and working at educational institutions fell from 27 percent in 1973 to 19 percent in 1979. Reductions were especially pronounced in the mathematical, physical, and computer sciences, reflecting in part the better prospects in industry.[2] Over the same period, the number of scientists holding postdoctoral appointments rose from 5,700 to 10,200. Of these, 82 percent were at educational institutions in positions without opportunity for tenure.

FINDINGS

1. The United States has built a system of high quality for advanced education of scientists and engineers. The federal government has been a major contributor to the growth of the system, primarily through its support of academic research, but also through programs of support for graduate students designed to meet needs for technical manpower. The government's commitment to support of graduate education, however, has been aimed

primarily at specific manpower shortages; it has been much less explicit than the federal commitment to academic research, even though academic research and education are tightly linked in our universities and even though well-educated people are indispensable in the pursuit of scientific knowledge and its application to practical problems.

Support of graduate education in the sciences and engineering requires federal participation, explicitly provided for in allocations for research and development.

2. Our system of graduate education is pluralistic and decentralized, with multiple sources and mechanisms of support and multiple beneficiaries. It is a flexible system, adjusting to shifting scientific priorities and opportunities, allocations of resources, and personal choices. The interdependence of the variables that affect the system is poorly understood, and federal support of graduate students has not been shown to be the controlling factor. It is insufficiently appreciated, moreover, that the system cannot be contracted as rapidly as it was expanded without risk. Decisions made hastily and unilaterally by the government to decrease further its support for graduate education can have harmful repercussions in some areas of scientific manpower and in research and the stability of universities as well.

Continuing government-university study is needed of the dynamics of the U.S. system of graduate education in the sciences and engineering, particularly the incentives that affect students' choices of field of study, level of degree, and career. Such studies are difficult and costly, but they would enhance the design of more effective policies for graduate education than exist today.

3. The universities, government, and industry have proved unable to predict supply and demand for technical manpower very accurately. The 4 to 10 years of postbaccalaureate study required to educate a scientist or engineer through the doctoral level makes stable funding for graduate training very important. The time factor also severely limits the extent to which the numbers of graduate students can be adjusted to respond to shifts in demand for specialists in narrowly defined fields. To protect

against instability in the employment market for technical manpower, scientists and engineers must be educated broadly so that they will have the flexibility to respond to national needs. At the same time, continuing attention must be given to long-range requirements for scientists and engineers.

Federal support of graduate education in the sciences and engineering would best be geared to long-term manpower considerations rather than the short-term behavior of the labor market.

4. Most graduate students have modest means, at best, and depend solely on themselves to meet the high costs of graduate education. Financial support for graduate students, therefore, remains an important consideration in planning for scientific manpower in light of the attractiveness of careers in alternative fields. Experience over many years indicates that it is best that such support continue to be available in different forms from different sources. This pluralistic approach has helped to offset some of the threat to our system of graduate education and research presented by deep cuts in federal fellowships.

Federal and other financial support for graduate students in the sciences and engineering is most effective when provided by many sources in a variety of forms, including research assistantships, portable fellowships, training grants, work-study funds, and loans.

The need is great for more productive dialogue between government and the universities on issues of graduate education in the sciences and engineering, a subject critical to the future of the nation's scientific-technological enterprise.

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4
Research Capacity

A valuable consequence of the federal investment in academic science during the 20 years following World War II was the rapid growth in research capacity--the human, physical, and financial resources needed to respond promptly to scientific opportunities and to sustain the long-range commitment essential to scientific and technological leadership. The mechanisms used to fund this growth and to operate the enlarged system that resulted are ideal for most purposes, but they are not without flaws. The project grant, which has always been the backbone of the system, was not designed to sustain institutional research capacity. To maintain their research capability universities also depend on some discretionary funding. Such funds, however, have been shrinking for more than a decade. In this chapter we discuss research capacity in two parts: general research support and equipment and facilities.

GENERAL RESEARCH SUPPORT

The successful buildup of academic research capacity following World War II resulted from a fortunate combination of circumstances. The Research Resources Evaluation Panel established by the National Institutes of Health in 1976 has described the process:[1]

> The universities were able to respond vigorously to the greater availability of research funds, in part because at the same time there was a great growth in enrollment and instructional needs. The combination of new funds for research and new funds for instruction accounted for the relative

> ease with which this response was accomplished. Some semblance of institutional balance in the development of various disciplines could be maintained because of the simultaneity of these influxes. The federal and nonfederal funds often allowed complementary development. Institutions were able to diversify, to develop strengths in more fields, and to establish broader coverage within fields. Perhaps the most significant factor was the institutional confidence inspired by the investment of public and private funds for their research and instruction missions. Institutional leaders were able to move boldly, rather than conservatively and defensively. This had a tremendous impact on their planning for development.

As early as 1964, the National Academy of Sciences noted that the growth in project grant support was creating "serious imbalances" in the universities.[2] The Academy called for expansion of "institutional or general research grants . . . now being made on too modest a scale by the National Institutes of Health and the National Science Foundation." A dozen years later, in 1976, the President's Biomedical Research Panel pointed out: "The institutions need flexible funds to modulate the stresses and strains in the project system . . . , so that capacity built in the earlier stages of development of the research base will not be eroded or rendered useless. The need for local discretion to respond to opportunities and emergencies is and will be a continuing problem that some form of institutional grant can address."[3]

Current Problems

Funding of academic science by peer-reviewed project grants provides a method of quality control that is unparalleled. The success of this system, however, has tended to overshadow its intrinsic inability to sustain the institutional research capacity on which it ultimately relies. Research support provided to universities by project grants does not cover a variety of persistent scientific needs. They include:

- Equipment that is used by more than one investigator or by graduate students and cannot be justified for any single project.

- Support for the exploration of promising new ideas to develop an adequate basis for project proposals.
- Start-up funds needed by young investigators to establish a record of performance that will permit them to compete successfully for project grants.
- Temporary support for established scientists who are changing the field of their research or are contending with delays or gaps in project funding.
- Replacement and renovation of worn or obsolete equipment and facilities (a special problem examined in the second part of this chapter).

Over the past 15 years, the ratio of institutional support to research project grants has changed markedly. In 1967, the government supplied just over $1 billion in science development grants, training grants, grants for construction, and other types of funding that contribute to research capacity.[4] Such funding constituted 44 percent of total federal obligations for academic science in 1967. By 1980 these kinds of federal funds had declined to $669 million, or 14 percent of total obligations.[5] To be sure, the higher percentage in the earlier years reflects a period of expansion, and the slowdown reflects a belief that research capacity had reached an adequate level. Still, funds for institutional support today are generally considered to be below the level needed to maintain the infrastructure and provide discretionary support. The need for the latter resource is particularly important as project grant funding becomes limited. Currently, only NIH provides general research support grants based on the overall success of the university in competing for federal research support.

Universities recognize their responsibility to maintain sufficient research capacity to take advantage of the talents of faculty investigators. For this purpose they expend a significant fraction of their own resources. These resources, however, must also meet the many other institutional needs of a modern university. In addition, funding from nonfederal sources, such as tuition and state appropriations, has grown steadily tighter in recent years. When combined with the need to maintain both plant and personnel built up over the period of extensive federal funding of research at academic institutions, these factors are creating considerable difficulty for many of the nation's major universities.

The National Commission on Research concluded in 1980 that "The present array of funding mechanisms provides inadequately for venture capital [to pursue new ideas, for example] and research capacity maintenance. Institutional resources alone cannot meet the need. Deterioration of the productivity of the research enterprise may well be inevitable if the problem is not addressed."[6] The commission cited the NIH Biomedical Research Support Grant program as a successful mechanism for institutional support that "might be extended to other fields of research."

The commission also noted the difficulties with continuity and stability of funding created by heavy reliance on research grants and contracts. It pointed out specifically:[6]

> Part of the continuity problem is associated with delays in renewal of support for ongoing programs. Such delays create funding gaps. When this occurs, either work must cease or support must be transferred from some other source. Universities commonly look to internal sources to underwrite the project temporarily, if eventual renewal of the project seems assured. At best, this leads to the burdensome paperwork of cost transfers to the renewed contract; at worst, it leads to nonreimbursement of costs incurred in the funding gap if the contract is not renewed or if it fails to include the gap within the new contract period or to authorize pre-award costs. On the other hand, if work were stopped and personnel dismissed when funding gaps occur, research progress would be significantly disrupted and delayed. It should also be noted that cost transfers associated with funding gaps are frequently at the root of accountability problems in the administration of research funds.

Biomedical Research Support Grant

NIH was given statutory authority to provide general research support in 1960, and the Biomedical Research Support Grant program assumed its present form in 1976. The program provides for institutional appropriations determined by a graduated formula based on the total NIH project funding that a university receives. The university decides how to use the funds, subject to NIH guidelines and congressional oversight.[7] Allowable uses include:

- Pilot research
- Support of new investigators
- Unexpected research requirements and emergencies
- Continuation of research during temporary interruption of grant support
- Emerging research opportunities
- Setting up of new laboratories
- Improvement of investigators' research skills
- Investigations in new fields and in fields new to the investigator
- Central, shared research resources

The funding ceiling for the Biomedical Research Support Grant program is set by statute at 15 percent of total NIH appropriations for research grants. The percentage actually awarded declined from an average of almost 8 percent in the late 1960s to 1.9 percent in the 1980s.[7] Awards for fiscal 1982 totaled just over $44 million and were distributed among 516 institutions. The maximum award was $326,001; the mean was $85,311.

A recent assessment of the Biomedical Research Support Grant program notes in part: "While the dollars involved are a small percentage of the total federal support for research, the flexibility is most precious, especially in light of the current economic climate in which our institutions struggle under increasing financial restrictions. . . . We feel that flexibility needs to be maintained by protecting and increasing the proportion of flexible funding here and elsewhere in the federal budget."[8]

The usefulness of general research support is recognized by the government in its reimbursement of costs incurred by independent research and development (IR&D) in industry. The IR&D approach is not available to universities. Industrial contractors, primarily to DOD and NASA, can perform IR&D at their own initiative and can recover part of the costs from the government as overhead on cost-reimbursable contracts. Recovery is subject to agreement on which IR&D projects are relevant to the agency's mission. In 1979 major contractors recovered $762 million in IR&D costs from DOD and NASA.[9]

Concerns About General Support

General institutional support of academic research is not free of problems.[6,7] Federal agencies responsible for mission-oriented research, for example, are interested mainly in specific projects whose quality is ensured by peer review. In this light, institutional support tends to attract relatively little interest, especially when the agencies' funds are limited. Furthermore, disposition of institutional funds is controlled largely by the university that receives them. This loss of the control that agencies enjoy with project grants may raise federal concerns about quality assurance and accountability.

The shift of control from national, peer-review mechanisms to local administrators also concerns individual investigators. Questionable local decisions, for example, could stress relations between university administrators and investigators whose project grants generate institutional funds and those whose grants do not. Individual investigators also are wary of reductions in project support in favor of general support.

EQUIPMENT AND FACILITIES

Deterioration and obsolescence of research equipment and facilities in our universities threaten the quality and productivity of U.S. research and education. Growing deficiencies in these major elements of research capacity were pointed out in 1971 in a study by the National Academy of Sciences of 10 scientific and engineering disciplines.[10] Subsequent studies have provided confirmation.[4,11-13] The deficiencies in equipment and facilities* vary in degree from field to field and from university to university, and the data are insufficient to establish the overall magnitude of the problem. Nevertheless, that there exists a steadily growing problem is widely recognized both inside and outside academe.[4,8,11-17] Alleviating it will require the dedicated efforts of government, industry, and university administrators and scientists, and in today's economic climate each will face difficult choices.

*Equipment is defined as instruments and other hardware used to conduct research. Facilities include fixed equipment, such as reactors and radiotelescopes, as well as laboratories and other structures.

Equipment and Research

Frontier research often depends on the most sophisticated facilities and equipment. Major advances in equipment have led to extraordinary leaps in understanding and entire eras of scientific progress. The spectrograph and the vacuum pump of the nineteenth century, for example, opened the atomic era of physics. The cyclotron began the modern era of nuclear and particle physics. Microwaves and lasers led to a renaissance in atomic and molecular spectroscopy. Nuclear magnetic resonance, electron microscopes, and x-ray analysis support advances in molecular biology, geology, materials science, and other fields. The synchrotron light source undoubtedly will open new possibilities not only in the physics of condensed matter and atomic and nuclear physics but also in chemistry and biology.

The modern era of scientific progress has featured a matching of the vision and imagination of experimentalists with steady escalation in the capability and sophistication of instrumentation. The costs of equipment, however, have risen correspondingly. The rapid progress also has meant that equipment can become scientifically obsolete while still in good operating condition. These are two of the factors that have made state-of-the-art equipment--the best generally obtainable--less widely available in the universities than is justified by scientific opportunities.

Equipment and Education

Equipment is fully as important in education as it is in research. Sound education in the sciences and engineering, both graduate and undergraduate, demands instruction in modern techniques involving operating experience with modern laboratory equipment. Public and private funds for education and research are not spent to best advantage when modern equipment is absent. Both government and industry, moreover, have a stake in training graduates in the skills and understanding they can develop only by work with state-of-the-art equipment. Good equipment should not be justified only in research. Educators have expressed repeatedly the importance of equipment used solely for teaching.

Students recognize the value of good equipment. This is particularly true of graduate students, on whose talents and commitments depend much of the present and all of the future of science. Students exposed to well-equipped industrial laboratories seek careers in industrial research rather than in research and teaching in less well-equipped universities. Industry needs good scientists, but universities must compete with industry to attract capable young faculty. Some observers are concerned that graduate students, at least in the physical sciences,[18] are beginning to choose doctoral work confined to theory. One of the reasons is inadequate experimental equipment. We need theorists, but we also need first-rate experimentalists.

Technology Transfer

The equipment and associated technical support available to a research project determine the limits to which the experimental parameters can be explored. Success in research, therefore, depends to a substantial degree on the ability of instrument designers to extend the limits of exploration. Often the experimentalist's needs cannot be met by state-of-the-art equipment, so that new technologies must be created and old ones refined and extended. Although these advances are made initially with a specific need in mind, they often prove to be widely applicable in industry and academe alike. The development of the modern computer, for example, was influenced by the needs of the nuclear physicist and the need to solve the nonlinear equations of hydrodynamics involved in meteorology, oceanography, and the multiple requirements of the military. Today the whole of science, industry, and commerce are beneficiaries of this now nearly universal technology.

Commercial instrument makers play an important role in expanding the use of equipment and technologies adapted or derived from developments in the laboratory. When equipment is developed that is important to many laboratories, instrument companies will try to make it available off-the-shelf. Superconducting magnets and dye lasers are examples. A principal force behind such developments is the instrument-oriented investigator and the associated technical support staff, who are in a position to realize both the scientific need for new technology and the feasibility of commercializing it.

Providing equipment for advanced scientific research puts demands on industry to upgrade the performance and quality of its products. Equipment manufacturers may transfer new technology to industry, medicine, and other fields directly from the laboratory or as a result of demands made by a laboratory on industry. Regardless of the route taken, the impact can be great. The point is illustrated by a study involving CERN, the 13-nation center for particle physics near Geneva. J. B. Adams of CERN, testifying before the House Committee on Science and Technology in 1980, outlined the results:[10]

> A few years ago, an economic study showed that the contracts for equipment placed by CERN did indeed have a considerable effect on European industry. Over 100 firms were investigated who had manufactured all kinds of technical equipment for CERN and it was found that for every dollar spent by CERN through its manufacturing contracts with the firms, the firms had subsequently gained four dollars in sales of equipment or services due to new technologies, improved manufacturing methods and even organizational changes within the firm directly related to the original CERN contract. Spin-off, it seems, is not just a simple matter of non-stick coatings for frying pans but a general improvement in the performance of industry in its competitiveness brought about by the demanding needs of laboratories like CERN which touch every aspect of the manufacturing process.

The Equipment and Facilities Gap

Many academic scientists in this country today feel handicapped by their inability to maintain their present equipment, to secure state-of-the-art equipment, and to create new equipment as their investigations may require. Still, the gap in equipment and facilities cannot be assessed precisely. A study by the Association of American Universities assessed needs in six areas of research in 15 universities (7 private and 8 public) that accounted for 22 percent of total federal obligations to universities in fiscal 1979. The study found:[11]

> An estimated $765 million will be needed by the 15 universities for research facilities and major equipment over the next three years. These funds will be required just to sustain the current level

> of activity of existing faculty; they do not reflect expansion based on new faculty appointments.

This estimate is in current dollars, unadjusted for future inflation. New construction accounted for about 60 percent of the total projected needs.

A broader estimate was given in March 1982 by Donald N. Langenberg, Deputy Director of the National Science Foundation and Chairman of the Interagency Working Group on University Research Instrumentation. He told the House Subcommittee on Science, Research, and Technology:[17]

> There is an emerging consensus in universities, the federal government, and private industry that there is a critical and growing need to replace obsolete and worn-out apparatus and laboratory facilities in the nation's research universities. Although its precise dimensions are not known, there is strong, qualitative evidence that the problem is pervasive and large in scope. A rough, but reasonable, estimate of the lower level of the deficit is $1.0 billion. Upper boundaries of the problem have been placed in the $3.0-$4.0 billion range.

It should be emphasized that these are estimates of funds required to provide state-of-the-art research equipment in academic laboratories. They do not include multimillion-dollar projects at national laboratories that are used extensively by universities. Nor do they include the costs of bringing technical support up to strength and of operating and maintaining the equipment.

Another study[12] by the Association of American Universities found that the median age of the instrumentation in 10 research universities was seven years, twice that of the instrumentation in two leading industrial laboratories. The initial cost of advanced research equipment, moreover, has increased faster than the general inflation rate. The research division of IBM found that the cost of a group of 126 items of research equipment with state-of-the-art capability increased at an annual rate of 16.4 percent between 1975 and 1981.[13] The consumer price index rose about 9.9 percent annually over the same period.

In general, the cost of doing research has risen substantially, in real terms, as science has become increasingly instrument-intensive. As instruments become more sophisticated and costly, the costs of maintenance and operations increase as well. In addition, technical support personnel must be more highly trained and skillful to be able to operate the equipment and keep it in good repair.

An appreciable part of the cost of academic research is accounted for by changes in working spaces and construction required to house equipment and research staff. The Association of American Universities notes[11] that laboratory renovation is needed with "considerable and increasing frequency." Construction problems include "buildings constructed for an earlier age, which are difficult and costly to repair and modernize. Some are wholly inappropriate settings for modern instruments that require specialized environments to operate effectively. . . . Shortages of support facilities, including animal care rooms and greenhouses, are pressing problems as well."

The impact of rising costs and aging and obsolete equipment and facilities is intensified by declines in federal funding. The proportion of NIH research project support allocated to permanent laboratory equipment declined from 11.7 percent in 1966 to 5.7 percent in 1974.[12] At NSF, the proportion fell from 11.2 percent in 1966 to an average of 7.1 percent during the period 1969-1976. These declines occurred in a period when project grant support, in real terms, was essentially level. The declines are important in light of academic reliance on federal support. In fiscal 1980, colleges and universities spent between $350 and $400 million on separately budgeted research equipment; the government supplied two-thirds of the funds.[20] Federal funding of academic R&D plant has been declining as well. The total in fiscal 1981, in real terms, came to less than one-third of the amount in 1960 and less than one-tenth of the amount in 1966, the peak year.[9]

An example of instrument-related erosion of research effectiveness can be seen in an NSF panel's evaluation[21] of nuclear research associated with university accelerators. The panel concluded that three laboratories deserved favored treatment because of their productivity and promise. These three were investing more than 20 percent of their budgets in instrumentation; the percentage for the laboratories not chosen was about 10 percent.

The universities' need for equipment is illustrated by the response to a new funding program of the Department of Defense. DOD has earmarked $30 million per year for academic instrumentation for five years beginning in 1983.[13] By November 30, 1982, the deadline for filing applications, DOD had received about 2,500 grant applications amounting to more than $640 million. NIH and NSF have also established instrumentation programs, although on a more modest scale. In all of these programs, the scientific merit of the research for which the instrument is to be used is a principal criterion for the award.

Adaptations to Deficiencies

Academic administrators and scientists adapt to deficiencies in equipment and facilities, but their flexibility is limited. Many critical research problems, for example, simply cannot be solved without sophisticated equipment. While some problems can be solved with less advanced equipment, significant penalties in efficiency and costs are incurred. And some equipment wears until, although still operable, it is too costly to maintain and may even be dangerous to use.

Procedures that facilitate sharing of scientific equipment by faculty have grown more common as a result of rising costs and stringency in funding. They vary from arrangements between departments to universitywide, computer-maintained systems.[22] A survey of sharing procedures made in 1978 developed weighted national estimates for some 675 institutions.[23] The results showed that more than one-quarter of them had established such procedures and an additional one-fifth had plans to do so. Sharing of scientific equipment has limitations, however. Nearly half the respondents in the survey termed their systems only "fairly successful"; more than one-fourth thought their systems were too new to evaluate for success or failure. A subsequent study based on 1981 data for 38 universities and four science and engineering subfields for equipment costing $5,000 or more revealed that 87 percent of the departments sampled had established common research facilities for sharing expensive equipment. It further showed that in individual laboratories research equipment is shared extensively within and among research groups and that the extent of sharing of items is proportional to the equipment's cost.[20]

When faced with declining funding and rising costs, principal investigators and agency officials tend to invest the available funds primarily in people at the expense of equipment. This strategy is conservative in the short term because it preserves the research team. For the short term only, ingenuity in choosing and designing experiments and in adapting equipment may suffice to maintain the strength of research. But in the long term, even the best scientific team cannot do first-rate work with worn and obsolete equipment.

Lack of adequate space is a major hindrance to the acquisition of equipment. Space for equipment can be generated to some extent by reducing office space, but the resultant overcrowding can easily become an impediment to research and, most immediately, to teaching.

The ultimate adaptation to a contraction in equipment and facilities is a contraction in the scientific enterprise. This contraction is both qualitative and quantitative. Fewer investigations at the frontiers of science will be conducted. Fewer bright young people will enter science and engineering as they perceive reduced opportunities for a productive career in research.

FINDINGS

1. The Committee believes that the concept of a funding mechanism designed to sustain the research capacity of universities has merit. The long-established Biomedical Research Support Grant program of the National Institutes of Health is a successful example of such a mechanism. Because the grant is proportional to the total NIH project funding awarded to the institution on the basis of peer review, the NIH formula favors universities with research programs of proven quality as measured by their levels of federal support. This approach meets one of the nation's principal concerns: to use the available funds to support the best research most effectively.

The quality of university research would be improved by extending to all federal funding agencies and departments the concept of the Biomedical Research Support Grant of the National Institutes of Health as a means of providing a small amount of general research support. Such support would be allocated most effectively by each university within a general framework established by the government in consultation with the universities and the scientific community.

The Committee believes that general research support is so important to the national research effort that serious consideration should be given to expanding it, even if this requires shifting 1 to 3 percent of funds from project grants to institutional grants.

Project grants, with their peer-review features, must remain the dominant form of federal support, but even a small shift from categorical to institutional grants could significantly benefit academic science. The pace of progress in areas such as the biological and communication sciences and the national mandate for accelerated effort in the engineering and physical sciences at a time of severe constraints on resources make institutional funds more critical than ever before. The Committee appreciates the concerns of federal administrations and academic scientists about institutional grants. Nevertheless, the current array of external funding mechanisms is inadequate to sustain the research infrastructure, and the universities alone cannot fill the gap. At the least, this issue is sufficiently important to warrant its consideration by the Forum.

Institutional grants naturally should incorporate means of ensuring accountability. Our universities vary, however, in needs and operating practices. Thus, within the broad mission constraints of federal agencies, every effort should be made to avoid undue federal direction in the local use of funds awarded as general support.

The federal presence in support of research goes beyond the funds expended. The establishment of a federal policy that recognizes the cost-effectiveness of modest general research support proportional to the support generated by peer-review mechanisms could encourage similar action by industry and other private funding sources. The Committee's support for an increase in joint research programs involving industry, universities, and governments is stated in Chapter 5. The complexity of such ventures calls for just the type of institutional support we endorse.

2. The deterioration and obsolescence of scientific equipment and facilities in the nation's universities perhaps cannot be measured precisely in dollars, and the deficiencies are greater in some fields and some institutions than in others. The problem and the threat they pose to education and research, however, are recognized

by government, industry, and the universities. The problem has several origins, a major one being lack of planning. The government has invested substantially in academic research equipment and facilities, especially during 1950-1965. Neither the government nor the universities, however, made adequate commitments for sustaining these major elements of research capacity. Academic science has great momentum and remains strong, but it faces gradual erosion if the decline in equipment and facilities is not checked.

The problem cannot be solved solely by diverting part of currently available federal research funds to equipment and facilities. Nor is it realistic to expect to solve it solely by massive federal investment, although long-term federal funding certainly is necessary. The history of the problem indicates that new approaches are needed to close the gap and forestall its recurrence. In devising these approaches, government, industry, and the universities will have hard choices to make.

<u>The deterioration of scientific equipment and facilities in the nation's universities calls for a joint, corrective effort by government, industry, and the universities. This effort would entail, in the short term, replacement of worn and obsolete equipment by state-of-the-art equipment and, in the long term, a sustained, comprehensive program providing for construction of facilities and development, acquisition, maintenance, and operation of modern equipment.</u>

Federal Options

The plans of federal funding agencies ideally would have both short-term and long-term components. The short-term component would provide for the acquisition, operation, and maintenance of some minimum quota of equipment and facilities needed for research at the frontiers of science. The long-term component would provide for orderly replacement of worn and obsolete equipment by state-of-the-art equipment as well as more advanced instruments needed for work at research frontiers.

We noted earlier the action of the Department of Defense in earmarking $30 million per year for academic instrumentation for five years beginning in fiscal 1983[13] and the smaller instrumentation programs of NIH and NSF. Another short-term federal option would be to acquire, maintain, and make available to users advanced and unique instruments at centers at which research and development on instrumentation is an important part of the program. Such action would be one way to avoid the lack of important instruments in the United States.

An option for the longer range is federal funding of consortia to develop, maintain, and make available for general use the more expensive advanced instruments. This approach is used now, for example, for multimillion-dollar facilities at national laboratories. We have in mind equipment costing roughly from $50,000 to $1 million. The consortia would comprise groups of investigators within universities or from neighboring universities. They would be formed to meet common needs for equipment to be used in frontier research already authorized or to be proposed.

Another approach, now being used by the National Science Foundation, is the formation of regional centers for particular types of equipment. The distances that users are willing to travel to regional centers, however, decreases rapidly with decreasing sophistication and cost of the apparatus. A long journey to use an apparatus for a short time will not in most cases be attractive or economical. A second consideration is the impact on graduate education and on the attractiveness of a field when major parts of experiments must be performed off campus.

Industrial Options

The importance of the academic equipment and facilities problem to industry warrants the development of programs that would make industrial state-of-the-art equipment available to universities. Such programs could be designed to respond to the needs of joint, industrial-academic research efforts. In addition, programs permitting students and faculty to use equipment and facilities in industrial laboratories have worked well in many cases.

Two sections of the Economic Recovery Tax Act of 1981 are designed to encourage industry to collaborate with colleges and universities and help to upgrade their equipment. One section provides tax credits for the costs of industrially sponsored academic research, including the costs of the associated equipment. The other section provides tax credits for industrial donations of equipment to colleges and universities. Although these sections of the act have distinct limitations, they have stimulated much industrial interest. The act's impact on industrial funding and donations of academic research equipment, however, has been limited thus far, particularly because of the depressed economy.

University Options

More efficient management by universities is essential to a long-term solution to the equipment-facilities problem. They may need to increase their use of arrangements such as interdepartmental centers that permit a unified approach to acquisition and development of equipment needed by investigators from more than one department. Special arrangements also may be required to facilitate cooperation among scientists from different institutions.

A common academic practice is to absorb the cost of equipment and facilities in the year they are acquired rather than distributing it over future annual budgets. Depreciation methods are rarely used, and equipment users are rarely charged in full. Maintenance and replacement are often not covered adequately in the financial plan. The use of appropriate depreciation schedules, as in industry, would yield a more realistic financial picture. It also would permit more complete recovery of the costs of equipment and facilities through user charges. Adoption of the industrial procedure, or one intermediate between it and present practice, would require the cooperation of the sponsor whose funds are used to acquire the equipment. It would also require that agencies supporting investigators who use the equipment provide funds to cover user charges.

Alternate means of financing equipment and facilities have been developed at several universities. They include revenue bonds, industrial development bonds, municipal bonds, and tax-exempt commercial borrowing. The Committee agrees with the Ad Hoc Working Group on Scientific Instrumentation assembled by the National Research Council that such measures are worth careful attention.[13] The working group recommended the organization of a series of regional workshops designed mainly to inform academic scientists and administrators of new ways to use their resources more effectively. The Committee endorses that recommendation and encourages federal agencies to cooperate in the effort.

More extensive use of depreciation and alternate means of financing academic equipment and facilities do not in the end create new money, and they are not free of problems. Procedures designed to permit recovery of equipment use charges under grants and contracts, for example, may limit the access of students to sophisticated equipment for educational purposes. We believe, therefore, that the costs and benefits of these untraditional approaches require careful consideration, perhaps under the auspices of the Forum.

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5
Industry-University Relations and the Federal Interest

New relations between industry and the universities have been established during the past few years. In many disciplines, including engineering, the physical sciences, and some areas of the life sciences, industrial support of research, faculty, and graduate students is the most rapidly growing segment of funding, although it is still a small percentage of the total. This trend is based on fundamental needs on both sides--advanced research and scientific advice and support for industry; diversified funding and understanding of industrial applications for academe.

Industry-university relationships interact significantly with relations between the government and universities in research and education, the primary focus of this Committee. The Committee did not emphasize industry-university relationships in its deliberations, but did examine certain aspects of this growing collaboration. The issues are complex, evolving, and will need continuing review.

The federal government and industry share objectives--well-educated students and a scientific and engineering knowledge base for technology--that are best attained through academic institutions. At the same time, the government, industry, and the universities have interests and attitudes, peculiar to themselves, that are mutually exclusive or may appear to be so. Expansion of industrial-academic connections, therefore, should be pursued in such a way that the integrity of both parties is ensured and the interests of the government protected. Resolution of issues that arise may well require the improved communication and mutual understanding that the Forum is designed to provide; the Forum's core group, in consequence, must be sensitive to the views and needs of industry as well as to those of government and the universities.

BACKGROUND

The estimated level of industrial support of academic research and development was $275 million in 1982;* federal funding of academic research and development was $4.6 billion in 1982.[2] Industrial support is now growing more rapidly than federal support. Nevertheless, although industrial support will become a larger fraction of total academic support, it is unlikely in the foreseeable future to amount to more than 10-15 percent of the total,[3] according to the judgment of both federal and industrial analysts.† (In 1979 industry funded about 2.7 percent of academic R&D in public institutions and 3.7 percent in private institutions.)[5]

Industrial support of academic research is focused on certain disciplines relevant to its interests.[1] Principal among these are engineering, computer science, chemistry, and some areas of biology, such as genetic engineering. Industry shows less interest in other physical sciences and the broad life sciences, and little or no interest in mathematics and social sciences, except perhaps in economics. This pattern is very different from that of federal support, which extends to all scientific disciplines. NSF support, for example, is concentrated in the sciences rather than engineering, and NIH

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*The National Science Board indicates that industrial support for university R&D--generally put at 3-4 percent of the total--is underestimated. The board's educated guess is that the figure is around 6-7 percent, or $400-$450 million in 1980-1981.[1]

†A pinnacle of industrial support has been achieved by the Massachusetts Institute of Technology (MIT) through its traditionally close relations with industry. Its experience is as follows: industrial research support increased from $6.7 million in 1977-1978 to $20.3 million in 1981-1982; federal support increased from $102 million in 1977-1978 to $157 million in 1981-1982. The respective growth rates over this four-year period are 203 percent and 54 percent.[4] Even in this extreme case, however, industrial support is only about 13 percent of federal support for R&D at MIT.

support is focused on basic life processes and disease-specific research, rather than on genetic engineering or medical instrumentation.

From the general standpoint of industry, the most vital product of academe is well-educated graduates. Industry depends on a continuing supply of such graduates to provide new manpower for its enterprises. Although industry itself provides additional education and training, even for its most advanced people, it recognizes that the primary function of education resides in academe. As a result, in addition to its direct support of academic research and development, industry as a whole contributes about $1.1 billion a year to institutions for support of higher education.[6] As a rule, few strings are attached to this support. It comes in many forms, such as scholarships and fellowships, endowed professorships, matching of employee grants, and contributions to building funds and endowments. The $1.1 billion includes contributions from corporate foundations established in many companies for tax and operational purposes. An additional $400 million in grants to universities is supplied annually by independent foundations established originally by funds from business and industry, such as the Ford, Johnson & Johnson, and MacArthur Foundations.[7]

During the past two decades, industry has further recognized that education in science and engineering must be coupled to fundamental research if it is to be up-to-date and effective in preparing students for industrial careers. This first realization has been augmented by a second--that fundamental research is a necessary underpinning for the complex technologies used by industry. Furthermore, industry is attracted to academe by the narrowing gap between the time when discoveries are made in academic laboratories and the time when industry perceives them as important and worth pursuing commercially.

Thus industry has increased its direct support and involvement in academic research. It is this involvement, stimulated recently by industrial-academic activities in biotechnology, that has become a principal focus of comment and examination by faculties, policy makers, public interest groups, and congressional committees. Interest has been excited specifically by a number of long-term collaborative research arrangements set up during the past few years by companies and universities. Typical arrangements include Harvard University-Monsanto, Washington University-Mallinckrodt, Harvard Medical School-Seagrams, MIT-Exxon, Carnegie Mellon University-

Westinghouse, and Massachusetts General Hospital-Hoechst A.G.

MAJOR ISSUES

Although issues in academic-industrial relations have been debated widely, they are resolved only in individual cases.[8,9] The specific mores and requirements of the partners have dominated the resolution of issues between them, and there are as yet few general guiding principles. Existing agreements have been negotiated, however, with the intention of protecting the partners' interests. As experience with these agreements accumulates, they should provide a workable set of principles for the future. More important to this report is the interaction of governmental rules, regulations, and concerns with industrial-academic relations and the issues that arise in consequence.[10]

Commingling of Resources

Among the principal issues is the use of publicly funded facilities for private purposes, as in the use of equipment and laboratory space acquired with government funds to do industrially funded research. Most participants recognize such commingling of resources as a major complication, even when the industrial research project is charged fees for using government facilities. Federal requirements for reporting, accounting, and periodic reports and proposals for renewal may be seen by industry as a substantial diversion of effort from research. In addition to the administrative burdens they impose, federal audit requirements focus on inputs to research, whereas industry is less interested in strict audits. Like federal program officers, industry focuses on the outcomes of research.

Proprietary Rights

A second important issue is the disposition of proprietary rights resulting from academic research when industrial and government funds are commingled. Recent scientific advances of academic origin with almost immediate technological application highlight this problem. Such advances include recombinant DNA, computing design algorithms and software for microcircuits, computer programming languages, and developments in materials science. Proprietary rights stemming from such advances involve patents and, to a lesser extent, copyrights.

Patent policies vary among the federal agencies and departments and vary state by state among public institutions. The Patent and Trademark Amendments of 1980 (P.L. 96-517) set federal policy broadly. The act permits retention of ownership by academic institutions and small businesses even when patents evolve from research funded largely by federal contracts and grants. A principal feature of this and other federal requirements is the government's control over exclusive licensing by the owner for the commercialization of inventions. The government typically retains march-in rights and in some instances retains ownership if government funds are involved in any way at all.

March-in rights permit the government to require that an exclusively licensed invention be licensed nonexclusively, if it is not being commercialized and such commercialization is judged to be in the public interest. The point at which the exercise of march-in rights is justified can be debatable. On one hand, delay in exploiting an invention may in fact result from placing private interest above the public interest. On the other hand, delay may result from the licensee's reasonable wish to protect an investment in commercialization by waiting for suitable market conditions.

In any event, the existence of march-in rights can raise uncertainty about already risky investment in research and development to an even higher level, thus potentially retarding the commercialization objectives desired by all. The uncertainty might be reduced to a level that encourages commercialization by establishing a minimum threshold of federal funding at which such regulations would come into play, but attempts to develop a clear statement of such a de minimus threshold have not succeeded. The federal government has ruled, however, that inventions made in research not federally sponsored would not be subject to the conditions of the act (P.L. 96-517) if the scope of such research falls outside the scope of the government-sponsored research in question. Application of such criteria by government has not yet been extensive enough to permit evaluation of their effect on industry-university relations.

Expanded Initiatives

Federal, state, and local goverments have taken initiatives to encourage industry-university relations. Among existing initiatives are the incentives in the Economic Recovery Tax Act of 1981 for contributions of equipment by industry to academic institutions. While the act contains incentives for industrial investment in research, it contains no special incentives for such investment to be made in academic institutions. A measure introduced in the 98th Congress, the National Engineering and Science Personnel Act of 1983 (H.R. 1310, Title II), would provide federal matching funds for industrial funding of research in academic institutions. Many states have established special incentives for industry to locate near academic institutions with arrangements to encourage interactions of various kinds. For example, industrial research and "high-tech" venture parks aided by governments are growing in Arizona, California, Georgia, New York, North Carolina, and other states. Federal, state, and local initiatives are affecting industries and universities, but the degree is difficult to assess, particularly in this early stage of what appears to be a major trend. The issues range from the possible effects of specific incentives to which incentives are appropriate from the viewpoint of the public interest.

Potential Problems

Industrial-academic relations potentially could have untoward effects within universities. Some such effects could spring from the special requirements of industry, such as the handling of proprietary information. Secrecy is not congenial to the academic environment. Some faculty and graduate students practice it, however, to sustain claims of precedence; military secrecy was widely practiced on campus during World War II and for a decade thereafter and still is in a few special situations. Regardless of the reluctance in academe to keep information confidential even for short periods, some institutions and individuals may agree to do so to attract industrial funding.

Many scientists are concerned that arrangements involving confidentiality will impede the progress of science. In addition, commercialization of academic research may divert faculty loyalties and motivations from their institutions, their teaching responsibilities, and the pursuit of knowledge to commercial objectives. Commercial influences can affect the choice of research topics by students and faculty, the relationships among them, and the course of scientific investigations. Finally, funding from different sources imposes differing requirements on individual activities and so may affect faculty morale and cohesiveness. To the degree that these are legitimate concerns, government sponsors may worry that industrial-academic cooperation will isolate creative scientific resources from the larger community and so make them less effective in pursuing government objectives.

FINDINGS

1. The Committee concludes that more extensive and closer relations between industry and academe are potentially beneficial to all parties. On the academic side, exposure to practical, marketplace needs, diversification of funding sources, and availability of advanced, modern instrumentation can improve the soundness of research and broaden its scope. On the industrial side, the flow of graduates and the scientific base supporting commercial technology can be sustained and augmented. These results would contribute to the economic and security interests of the United States.

2. The Committee finds that industrial and federal funding of academic research are usually incommensurate and nonsubstitutable. Industrial support generally is focused on different modes of research from federal support and fluctuates with economic conditions and with the fortunes of individual companies. Experience has shown that companies tend to support academic research in subjects relevant to their missions. Industry views its support of broad scientific activities as coming through the taxes it pays to governments. The goals of industrial and federal funding also tend to be disparate. The commonalities in these matters are exceeded by the differences.

The federal government and industry share objectives--well-educated manpower and a scientific and engineering knowledge base for technology--that are best attained through universities, but industrial funding of academic research and education cannot be expected to substitute for federal funding, particularly in support of basic research across all scientific disciplines.

3. The Committee believes that many different patterns for industry-university arrangements could be appropriate for various situations. The specific needs and requirements of the partners should take precedence, so long as the public interest is served. Furthermore, we endorse the view noted in a joint letter from the National Science Board and the National Science Foundation to the Committee: ". . . major initiatives for exploring the full range of possible cooperative activities must come from the academic and industrial sectors themselves."[11] The Committee also urges avoiding regulatory barriers to industrial-academic relations unless serious abuses become evident. The President's 1981 Annual Science and Technology Report to Congress makes the point in the somewhat different context of overall regulatory reform, but it is equally applicable: "The traditional approach to regulation adds a further dimension of risk and uncertainty to that already facing industry in its decision-making on R&D investments and technology innovation."[12]

Further encouragement by federal, state, and local governments of industrial support of academic research is warranted. Particularly critical is the clarification of proprietary rights when industrial and federal funds are commingled; a clear statement of de minimus conditions for government quitting of claims, including march-in rights, against inventions would help to encourage some forms of private support without jeopardizing public interests. Other steps could include:

- Federal matching funds or tax incentives beyond those now available for industrial support of academic research.
- Federal, state, and local tax incentives, in addition to those now provided, for industrial donations of laboratory space and equipment.

4. The Committee recognizes the concern that the handling of trade secrets and proprietary data entailed by some industrial-academic agreements could hamper freedom of scientific communication and so impede the progress of science and the ability of universities to perform research on behalf of the government. Many

government-university and industry-university agreements permit a short delay for patent and publication reviews before manuscripts are submitted. If the delay is short compared to the time required for publication, if the material to be published is complete in that it includes all relevant information about methods and techniques, and if the university's ultimate right to publish is absolute, then scientific communication should not be impaired seriously by such agreements. However, the potential for inhibiting scientific communication is of real concern, is difficult to determine, and needs to be examined further as experience is gained. Agreements that permit parallel submission of manuscripts to sponsor and journal, as recommended by the Panel on Scientific Communication and National Security,[13] could avoid some of these difficulties.

The Committee believes that it is possible to fashion industry-university collaboration without damaging freedom of scientific communication and scientific progress, providing contractual arrangements do not result in extended periods of secrecy, do not limit discussion of experimental methods and techniques, and do not infringe upon the university's ultimate right to publish. However, careful attention by the participants in such arrangements is required to ensure against adverse effects.

5. We cannot dismiss concerns that industrial motivations may divert faculty loyalties and disrupt cohesiveness, compromise the pursuit of knowledge, and affect the choice of research topics and the course of scientific investigations. Each of these effects can result from commercial interest. It is the responsibility of the parties involved to be aware of these dangers and to build in safeguards against them. Perhaps the soundest safeguard is the integrity of the scientists themselves, buttressed by codes of ethics and standards of behavior advocated by faculties and institutions. Similarly, industry should recognize the legitimate bounds on its influence and not exceed them. Full and open discussion and agreement on these matters is an essential prerequisite to industry-university arrangements.

6. The Committee notes that questions of propriety in industry-university relations will be handled differently among institutions because of the differences in their missions and the extent to which they are supported by

public funds. Even so, several states have found acceptable ways to allow and even encourage commercial interests to use state-financed university facilities, intellectual property, and human resources. These activities and the driving forces behind them may provide useful models for federal activities involving industry-university relations.

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6
Cost Sharing and Indirect Costs

Indirect costs and cost sharing have stirred continuing debate in the government-university relationship. Although these topics are often discussed separately, they have been interrelated in the evolution of federal policy; for most persons involved, assumptions about one affect beliefs about the other.

The basic problem is disagreement on what the costs of research should include, how they should be shared, and why. The problem is compounded by disagreement on the reality of indirect costs. The recurring struggle over these matters so far has produced only added complexity in accountability procedures and stresses in the government-university relationship. The stresses, predictably, increase with tightening budgets or major shifts in federal priorities.

Although the sums involved are large, the problem has rarely been treated as an issue of policy. Instead, we have seen repeated technical and procedural skirmishes that yield no common understanding of underlying policy. Beliefs often seem to override facts. The principles used for cost sharing and indirect costs often are either not understood or not accepted by affected parties in the government and the universities. Inflation intensifies the problem. Conflicting claims on limited resources threaten to make who gets how much seem more important than adherence to principles of equity and allocability.

Cost Sharing

The costs of federally sponsored research are shared by the government and the universities. For the university, cost sharing may be mandatory (required for eligibility

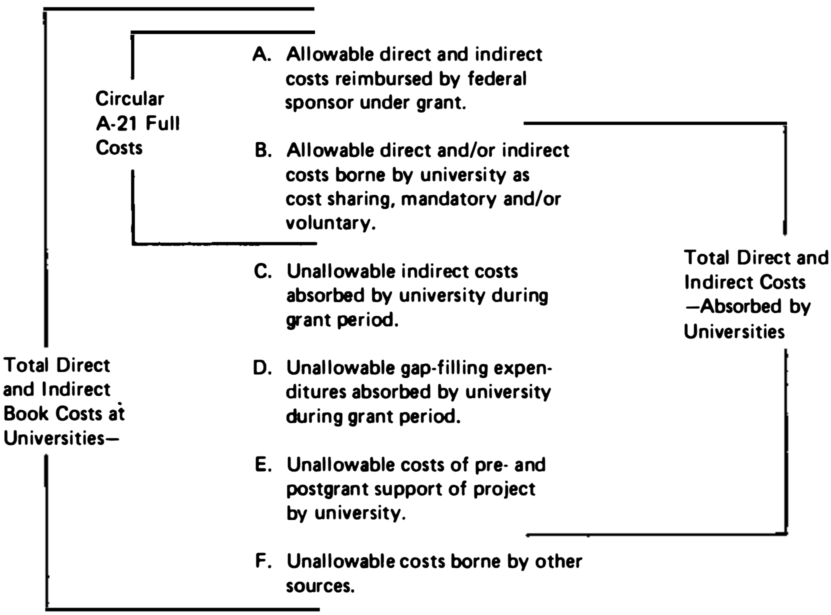


FIGURE 5 Cost sharing and categories of project costs.

SOURCE: Adapted from Kathryn Smull Arnow, "University Research Grants Management: Accountability Viewed as an Exchange--the U.S. Case," Research Policy 10: 46-78 (1981).

for federal support), voluntary, or a combination of the two. If it is mandatory, the university's share is usually specified as a percentage of total costs. Figure 5 identifies the categories of project costs at universities, distinguishing between total costs and costs allowable under federal cost principles. Categories B through F in the exhibit all represent cost sharing, but the government often recognizes only category B.

Federal appropriations statutes require cost sharing on all research grants to educational institutions. It must be documented for each project, except for grants awarded by the U.S. Department of Housing and Urban Development and the independent agencies, which permit documentation on an institutionwide basis. In addition, some programs require that the recipient provide matching funds. Circular A-110 of the Office of Management and Budget gives the requirements for acceptability and documentation of cost sharing and matching by universities.[1]

Indirect Costs

The costs of research are classified as direct or indirect. Direct costs are those that can be identified with one activity or can be attributed to it with relative ease and high certainty. Project equipment and supplies and salaries for project staff are examples of direct costs. Indirect or pooled costs are those incurred for purposes in common that cannot readily be identified with one project. They include costs attributable to several projects but not easily allocated among them as well as costs incurred by the overall operation of the organization. Centralized research facilities and services, utilities, operation and maintenance of buildings and equipment, libraries, and administrative costs, including the salaries of the president, deans, and accountants, are examples of indirect costs.

Apportionment of Indirect Costs

Both direct costs and indirect costs are real costs of research, but they are treated differently under the principles of accounting. Because indirect costs cannot be attributed readily to individual activities, they must be apportioned among activities, including research projects, in some equitable way. The methods of apportionment necessarily involve compromises; no single method will be optimal for every project. OMB Circular A-21[2] prescribes the methods for apportioning indirect costs. Circular A-21 also gives general criteria for determining the allowability of costs, whether direct or indirect, describes specific criteria for some 44 categories of costs, and stipulates that costs allocable to a federally sponsored agreement must (1) be incurred solely to advance the work under that agreement; or (2) benefit that agreement and other work of the institution in proportions that can be approximated through the use of reasonable methods; or (3) be necessary to the overall operation of the institution and therefore assignable in part to sponsored projects.

The apportionment methods in Circular A-21 are based on the principle of averaging. Costs are distributed over activities in proportion to their size, using measures such as salaries, space assigned, or population served.

Figure 6 shows the allocation process. Indirect costs are identified from the institution's accounting records and apportioned among its functions (research, instruction, and service). The amount of indirect costs allocated to research is then divided by the base chosen to reflect relative project size (usually modified total direct research costs) to yield an indirect cost rate given as a percentage. This rate is used to calculate each research project's share of the indirect costs allocable to research.

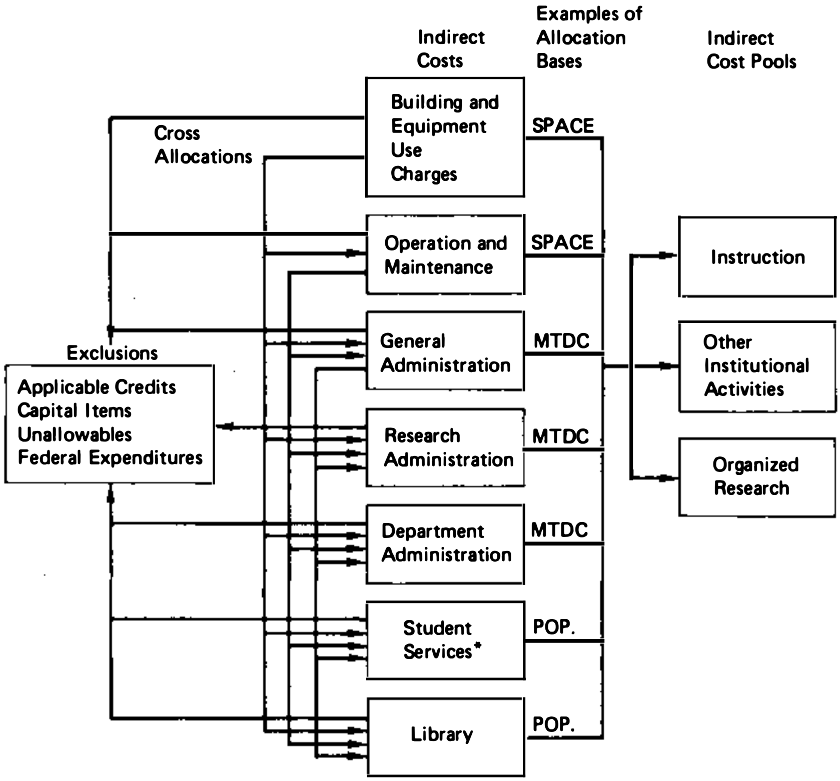
Direct *vs*. Indirect Costs

The distinction between direct and indirect costs is not based on standard definitions or solely on the goods or services involved. Universities differ in their ability to assign costs directly to projects because they differ in organization, research environment, and financial systems. One institution may treat machine shop services, for example, as a direct cost, while another may treat it as an indirect cost. This is one of several reasons why comparison of the indirect cost rates of universities is very misleading.[3,4] Exhibit 1 lists the major reasons why indirect cost rates vary.

Each university is reimbursed for the federal share of indirect costs at a rate calculated for that institution by federally prescribed or approved methods using federally audited costs. Because the apportionment methods by nature are imprecise and because universities usually do not budget or accumulate costs in their accounting systems in exactly the form required, approximations must be used and judgments made at numerous points. Federal review of the university's rate proposal identifies differences of opinion about such decisions. They are resolved either by negotiation between the university and the federal audit agency or by formal dispute resolution.

Direct and indirect costs differ in their visibility and the assignment of responsibility for their management (see Table 3). Direct costs usually are managed by the investigator or department. Indirect costs, by contrast, are the responsibility of intermediate and higher levels of administration, although they may reflect upward or downward pressure from investigators. Existing controls on indirect costs can be obscured in the institutional budgeting process and in the use of indirect cost rates based on campuswide average costs.

Step 1: Identification of indirect costs
Step 2: Allocation of indirect costs among institutional functions



Step 3: Derivation of Indirect Cost Rate

Indirect costs allocated to organized research	÷	Modified total direct research costs or research direct salaries and wages	=	Research indirect cost rate (%)

*Normally allocated fully to instruction.

FIGURE 6 Indirect cost calculation overview for universities.

SOURCE: Adapted from Peat, Marwick, Mitchell & Co., Study of the Indirect Cost Rates of Organizations Performing Federally Sponsored Research (Washington, D.C., November 30, 1977).

EXHIBIT 1 Why Indirect Cost Rates Vary

Indirect cost rates vary over time and among universitites. Some of the reasons:

- Each university supports its research activities with a unique and shifting mix of services.
- Research activity expands or contracts at different rates among institutions, and the associated indirect costs change correspondingly.
- The disciplines emphasized in research vary among universities and can change within a given institution. Different disciplines may require different kinds of facilities and support, which generate different mixes of indirect costs.
- Indirect cost rates are affected by the age, quality, and level of operations and maintenance of research facilities and structures and by the method of financing them.
- Indirect cost rates vary with location. Research on campus influences costs differently than research off campus. The costs of labor and the consumption and costs of utilities differ in different parts of the country.
- Universities are organized differently, especially in terms of services, so that costs treated as direct costs by some institutions are treated as indirect costs by others.
- Procedures for accumulating and allocating indirect costs vary among universities because their accounting systems are designed to meet differing overall institutional needs.
- Universities vary in the sophistication of their cost allocation methods. Some simply follow the federal guidelines prescribed for use in the absence of more rigorous methods. Others develop methods especially suited to their circumstances to ensure equitable allocation of costs.
- Universities use different types of indirect cost rates (e.g., provisional/final; predetermined fixed rate; fixed rate with carry forward).
- Universities vary in the diligence with which they seek to recover their indirect costs from the government.

SOURCES: Comptroller General of the United States, Indirect Costs of Health Research: How They are Computed, What Actions Are Needed (Washington D.C.: General Accounting Office, July 27, 1979); Coopers and Lybrand, Computing Indirect Research Costs: A Non-Technical Guide for College and University Presidents (New York, 1982); Raymond J. Woodrow, Indirect Costs in Universitites (Washington, D.C.: American Council on Education, March 1976).

The general treatment of indirect costs in universities is standard in the accounting profession and used widely in other organizations. While the differences in budgeting and accounting for direct and indirect costs affect attitudes and understanding about indirect costs, they do not reduce the reality of these costs, the need for incentives for controlling them, or the need for equitable reimbursement of them.

HISTORY OF INDIRECT COSTS AND COST SHARING

The history of the treatment of indirect costs is tortuous and intertwined with the history of cost sharing.[3,5] Key developments are summarized in Appendix B. They are the consequences of several trends:

- In its attempt to ensure that federal funds are used only for the intended purposes, the government has sought increasing precision in accounting for direct and indirect costs.
- Both the universities and the government have had difficulty adjusting to the growth of research in the universities. Institutions initially were able to conduct federally sponsored research without recovering indirect costs, but their ability to do so faded rapidly as the demand for research expanded. Incremental costing (reimbursement of only those costs easily identifiable with the project) was not feasible for the universities when their participation in federally sponsored research became substantial.
- The original premise of providing federal support for research at no gain/no loss to the performer[5] has remained the normal basis for procurement arrangements, but it is less widely accepted for grant support. Indirect cost rates for research grants were fixed at specified levels for many years; when this approach was replaced in 1966 by reimbursement at a negotiated rate based on actual costs, mandatory cost sharing was introduced.
- The basis for requiring universities to share costs on research grants has gradually broadened. At first the principle was that they should share the risks of investment in research as an incentive to undertake only high-priority research and manage it prudently. More recently, cost-sharing requirements also have reflected both the belief that federal support benefits

TABLE 3 Differences Between Direct and Indirect Costs

Feature	Direct Costs of Research	Indirect Costs of Research
Relationship to project	Readily identifiable as specifically incurred for project.	Necessary for functioning of research projects in university setting and benefit more than one project or more than one institutional function; not economically isolatable in terms of a specific project.
Allocability to project	Fully allocable	Allocable only in proportion to the ratio:

		separately budgeted research ÷ total institutional activities
Principal point of control	Principal investigator	Institution
Principal participants in review and negotiation of award	Informally: Agency program staff and principal investigator work out acceptable budget. Formally: Agency and institution reach agreement.	Cognizant federal audit agency (1) audits institution's claim of all indirect costs incurred and the institution's proposal for a rate and (2) negotiates a federally approved rate. The rate is normally renegotiated annually. Agency awards indirect costs on basis of approved rate.

the institutions and the desire to stretch limited federal resources.[6,7]

• The distinction between grants and contracts has gradually changed. Grants initially were more flexible than contracts but now are often as restrictive as contracts, despite the reforms called for in the Federal Grant and Cooperative Agreement Act of 1977.

• Agencies' policies and reasons for the cost sharing they require vary widely, and discrepancies also occur between their policies and actual practices. To a certain extent, cost sharing has come to serve as an entrance fee for participation in the federal research-support system;[6,7] in some cases this rationale creates a form of cost competition, even though competing proposals have different goals and involve different research problems.

• An uneasy (but extraordinarily productive) interdependence of the government and the universities has emerged. The intertwining of research and graduate education, which has been so important to scientific progress in this country, has increased the vulnerability of the universities, and therefore of the nation, in times of contracting research support.[8]

• The growth of research in universities has increased both the emphasis on research performance and the pressures on faculty members to acquire external research support for themselves and their students. The high value placed by the institution on the research performance of its faculty typically exceeds its ability to support that research with its own funds. The disparity creates strains within the academic community. Although most investigators prefer to compete for research support at the national level, more or less free from local priorities and politics, many feel strained by the consequent relentless burden of entrepreneurship.

POINTS OF VIEW: COST SHARING

It is the policy of most, if not all, universities to provide some voluntary support for federally sponsored research, using either their own funds or funds from other sponsors. Universities and colleges in 1982 provided approximately $1.6 billion from nonfederal sources for research and development.[9] The institutions have objected, however, to the requirement for cost sharing on all research grants, to the requirement that it be documented for each grant, and to the emphasis on the precision of such documentation. Universities also question the validity of the arguments for cost sharing.

Over the years, many officials of federal agencies and leaders of higher education have opposed mandatory cost sharing. In 1969, for example, Dr. Leland J. Haworth, Director of NSF, stated:[10]

> In considering policies of mandatory cost sharing and of arbitrary ceilings on overhead, which are inextricably related, the federal government must recognize that colleges and universities are carrying on research and educational activities that are essential to the welfare of the community and it must not insist on practices which place unnecessary burdens on the institutions' other academic activities. I believe that both arbitrary cost sharing and arbitrary indirect cost ceilings do place such burdens. Accordingly I would suggest that cost sharing not be retained as a formalized legal requirement. As I have pointed out, institutions are voluntarily contributing to research costs in total amounts greater than is required of them, and the legal requirement only adds to the administrative burden of both the government and the recipient institutions without any discernible, significant benefits.

In 1972, the Government Procurement Commission[11] recommended to Congress that mandatory cost sharing be eliminated on research and development projects except if the performer would clearly benefit--for example, through commercial sales. In 1976 the Federal Paperwork Commission,[12] responding to the costly and unproductive documentation of cost sharing, reiterated the recommendation of the Government Procurement Commission that mandatory cost sharing be eliminated.

Despite these recommendations, required cost sharing has persisted and in some cases increased. The percentage required by NSF and NIH has been generally modest but has ranged as high as 50 to 60 percent in some equipment grant programs. In the Research Division of the National Endowment for the Humanities, the obligation varies from program to program with minimums now ranging from 20 to 40 percent of total costs. The 1979 revision of OMB Circular A-21 imposed additional documentation of cost sharing.

In 1980 the National Commission on Research, in its report on accountability,[13] recommended elimination of the documentation of statutory cost sharing on research grants. In its report on funding mechanisms[14] the commission also recommended that Congress, the agencies, and the universities reexamine the rationale for cost sharing and matching requirements in federal support of research in universities. The goal was to ensure that any such requirements serve the mutual interests of the government and the universities.

Responses to the Committee's outreach letter (Appendix A) indicate widespread agreement among both university and government representatives that documentation of cost sharing and mandatory cost sharing on all research grants are unnecessary, costly, and should be eliminated.

Officials of federal agencies expressed disparate views to the Committee on the general concept of cost sharing. Some favor cost sharing because they believe federal support of research confers a major benefit on the universities. Others see the appropriateness and level of cost sharing as a function of the purpose of support--for example, to meet the government's direct responsibilities, to accelerate development to meet pressing needs, or to expand fundamental knowledge.

Some federal officials make a philosophical distinction between procurement (contracts) and assistance (grants) in their views on cost sharing. But most believe that the rules should permit universities to share costs to varying extents, using a variety of categories of cost, depending on the type of support. Several agency representatives who support cost sharing conceptually find that documenting it is not cost-effective and question the need to demonstrate formally that costs have been shared.

The federal budget for fiscal 1981 proposed removing project-by-project cost sharing from the language of several agencies' appropriations statutes. The revised language would have permitted the universities to share costs in the aggregate, thereby reducing the reporting burden. However, only the appropriations for the Department of Housing and Urban Development and the independent agencies passed the Congress. The other agencies received their spending authority by continuing resolution. Continuing resolutions were also in effect for fiscal 1982 and 1983.

POINTS OF VIEW: INDIRECT COSTS

Academic scientists and administrators and federal agency staff and officials view indirect costs differently because of the differences in their responsibilities. The persistent friction results not only from differences in viewpoint, however, but also from distrust, ignorance, or disagreement concerning the premises for calculation and reimbursement of indirect costs.

Views of Faculty Members

Faculty members often challenge the fairness of reimbursing universities for indirect costs. Some believe that only direct costs are real costs of research. They consider payment of indirect costs a subsidy for higher education and a diversion of support from research. They believe that universities can and should use their own funds to operate the organization and provide the facilities.

Other academic scientists accept the premise that federal sponsors should pay a proportional share of indirect costs, but doubt that these costs are scrutinized as rigorously as direct costs in the external peer-review processes of NIH and NSF. Indeed, some feel that the processes used to determine indirect cost rates promote inefficiency or at least fail to constrain growth in administrative and support staff of universities.[15] They also question the need for certain administrative practices required by federal sponsors. Some investigators understand and accept the process by which indirect cost rates are determined and assessed, but are frustrated and dismayed by the combination of escalating costs and shrinking opportunity to obtain research support.

Many faculty members believe that academic administrators are insensitive to the difficulties caused by rising indirect costs. They also believe that administrators are reluctant to provide ways for faculty to participate in decisions on indirect costs and unwilling to explain such matters adequately. Not all faculty members are interested, however. Some deny a responsibility to become familiar with indirect costs or to take part in setting policies for them.

Views of Academic Administrators

Most academic administrators, some of them faculty members, have a different perspective. They view indirect costs in terms of the university's ability to perform its several functions, including research. They consider indirect costs as real as direct costs. They believe that underrecovery of indirect costs is weakening the research strength of many universities and inhibiting the development of others. Administrators also are concerned about the growth in externally imposed administrative burdens and the impact of escalating costs of utilities and general inflationary trends. They find inappropriate and divisive the encouragement of faculty members, by federal agency staff, to seek waivers or sharing of indirect costs. They often consider faculty members naive about the research expenses incurred by the institution. They think many faculty members are unwilling to learn enough about indirect costs to help to control them.

Views of Agency Officials

The policies of federal agencies that sponsor research have long reflected acceptance of the reality of indirect costs and the fairness of reimbursing the universities for a fair share of these costs. Staff members of the agencies, however, differ widely in their conversance and agreement with the premises and procedures involved. Some have views much like those of some faculty members. Others are convinced that the government should reimburse universities for a fair share of indirect costs, but lack confidence in current procedures for deriving the federal share. Since a difference of one percentage point in the indirect cost rate can make a difference of a few hundred thousand dollars of reimbursement for a major university, the subject commands considerable attention.

The federal agencies have become increasingly concerned about indirect costs as their budgets for basic research have tightened and as the indirect cost rates of universities have risen over the past several years. Agency officials also are concerned about the conflicts between academic scientists and administrators over indirect costs. They urge that these differences be settled without involving the federal agencies. NSF recently issued internal guidelines to ensure that its practices and communications with investigators do not exacerbate these intrainstitutional differences.

Views of Industry Leaders

Industry leaders who responded to the Committee's outreach letter urged that the federal government bear the full costs (direct and indirect) of the academic research they sponsor and recognize it as a good bargain. They hold that even with full reimbursement, the federal agencies are using on behalf of society, free of charge, the institutional framework and environment built over decades to attract outstanding faculty scientists and the brightest students.

Some industry leaders think that control of indirect costs needs careful study. They point out the need to distinguish between real growth in indirect costs and growth reflecting the shift in the mid-1960s from incremental recovery toward full reimbursment. They urge better understanding of the causes of the increases before any realignment of the responsibility for paying for them is considered.

Other Sources of Complexity

The lack of widespread understanding of indirect costs is by no means the only problem. Conflict also arises because some of the methods for recovering indirect costs inadequately accommodate a fact of university life: the integration of teaching and research.

The parties also disagree on the priorities to be assigned to different activities. Each institution must choose, for example, the levels of technical services and housekeeping to maintain, the extent to which salaries of faculty members are included in grants, the amount of administrative support to provide to scientists, and the amount of support to provide for travel to scientific meetings. The priorities assigned to these and other research-related activities need to be evaluated and adjusted periodically by university scientists and their administrators. Similarly, federal priorities assigned to support of different disciplines or problem areas and to mechanisms and the degree of administrative control need to be reviewed and adjusted regularly by the government in consultation with the universities.

Agency Differences

Federal agencies use a common set of principles for determining costs and negotiating the governmentwide indirect cost rate for each university, but they use different systems for reimbursing indirect costs. These differences affect the review of proposals, the selection of projects to support, budget negotiations, postaward administration, and relationships among the parties. In addition, the two federal audit agencies interpret the common set of principles differently. They differ, for example, in what constitutes acceptable documentation standards and in their willingness to accept special analyses to support allocation methods.

NIH makes separate awards for direct and indirect costs; NSF and almost all other agencies make one award for total costs. In the NIH system, the amount granted for direct costs is not influenced directly by either the indirect cost rate or a change in that rate. The system shields peer reviewers from possibly misleading comparisons of the indirect cost rates of universities. The NSF system gives agency and external reviewers a clearer picture of the total costs of a project but may introduce bias into the selection process if indirect cost rates are compared inappropriately. Many investigators believe that proposals from universities with high indirect cost rates compete at a disadvantage under the NSF system. Some believe that the separate awards for direct and indirect costs at NIH remove an incentive for institutions to control indirect costs.

Agencies also differ in the adjustment of awards to accommodate changes in indirect cost rates. NIH allows both annual revision of indirect cost awards during the life of multiyear projects and response to changes in indirect cost rates during an award year. Most other agencies do not allow adjustments in grant awards in response to changes in the indirect cost rate during an award year. For contract awards in contrast to grant awards, most agencies accept requests for increases to cover changes in indirect cost rates during the award year, but they do not guarantee that funds will be available to cover increases in total costs.

University Differences

Universities vary in their indirect cost rates and their use of funds reimbursed for indirect costs. Exhibit 1, as noted earlier, identifies the most significant sources of variation in indirect cost rates.

The differences in universities' use of funds received as reimbursement of indirect costs are a significant source of misunderstanding and intrainstitutional conflict. The federal government has an interest in the indirect costs the universities claim, but once the indirect cost rate has been negotiated and the costs reimbursed, the federal interest has been satisfied. The institution's subsequent use of the reimbursed dollars is not a federal concern, although for state universities it may be a concern to the state legislature or state comptroller.

Some universities label federal indirect cost reimbursements as such and allocate part of them among research units or investigators, sometimes on a formula basis. Some public universities are required to place the reimbursement in the general income fund of the state treasury. Some institutions treat the reimbursed funds simply as revenue, for distribution through the regular budgeting process. All of these approaches are legitimate. They differ considerably, however, in their effects on the institution's flexibility in managing its budget and on investigators' views about indirect costs.

STUDIES OF INDIRECT COSTS

Several major studies of indirect costs have been made. In 1969 a General Accounting Office report[16] reaffirmed several needs: for flexible principles rather than a uniform formula for indirect costs; clarification of the nature and extent of cost sharing; more consistency in agencies' cost-sharing rules; and more specific accounting standards in cost determination in universities. Also in 1969, Peat, Marwick, and Mitchell issued a report[17] advising against the use of a uniform indirect cost rate and rejecting the idea that indirect cost rates could be interpreted as indicators of institutional efficiency. In 1976, a report by the President's Biomedical Research Panel included a section on the impact of federal funding on research institutions.[18] The panel recommended:

> That the federal government adopt the policy of full cost reimbursement for the costs of federally sponsored research conducted in academic institutions, affiliated research centers and other

> non-profit institutions as one step toward developing an equitable and fair method of meeting the cost of federal research conducted in these institutions and toward assuring the health and financial stability of the institutional base on which the nation depends for its research effort.

The panel also said that:

> Federal research support primarily serves the national interest by paying for a service otherwise unobtainable: research that will benefit the whole nation through advances in medical science and health care. In this context, funds are paid for direct and indirect costs of conducting research and are not in the nature of a donation or gift to the university. Hence, the requirement of cost sharing under which a recipient must bear a portion of the total cost is inappropriate because support for research is the *quid pro quo* for the service obtained by the government to meet public needs.

In 1977 Peat, Marwick, and Mitchell[19] studied a select group of universities, nonprofit organizations, and industries in terms of the federal cost principles applicable to each, their costing policies and practices, and their reimbursement experiences over a five-year period. The report concluded that the cost principles imposed on universities are more constraining in terms of allowability of costs, apportionment methods, and accounting system costs than those that the other organizations are required to follow. The report also concluded that the differences among the organizations invalidate rate comparisons, that growth of indirect costs in universities closely parallels national economic trends, and that all organizations studied were making efforts to reduce indirect costs. The report expressed strong concern that preoccupation with indirect cost rates may obscure the more fundamental issue of deterioration in the health of the national R&D capability through impairment of the basic research effort in the universities.

In 1978 the General Accounting Office issued a report,[20] based on 25 research projects in six institutions, criticizing the universities' management of federal funds. The report emphasized the problems of accounting for personnel costs, the use of varying bases for determining indirect cost rates, the subjectiveness of indirect cost pools, the determination of departmental administration costs and records, and determination of use and depreciation charges.

In 1979 the General Accounting Office issued a report[4] in response to congressional concern that indirect costs in health research were increasing rapidly. The report described the system used to compute these costs and showed why they were increasing. It explained why indirect costs among universities cannot be compared meaningfully and demonstrated inconsistencies in principles and practices used to determine indirect costs. The report concluded that, if the government is to limit its payment of health research costs, it should do so through some formal ceiling on federal reimbursement, such as by requiring universities or other grantees to pay some minimum fraction of total costs, rather than by a restriction on indirect costs.

In 1981 a study[21] by the Advisory Committee to the Director of NIH recommended that NIH explore two ways to respond to the growth of indirect costs: (1) eliminating retrospective adjustment of indirect costs, coupled with administrative simplification, and (2) redefining eligible indirect costs (e.g., eliminating some and introducing others), coupled with significantly reducing administrative burdens (e.g., effort reporting and documentation of cost sharing).

The NIH committee expressed strong reservations about a uniform indirect cost rate. It recognized that the reduction of services for research would necessarily follow a reduction in the reimbursement of indirect costs, particularly if the federal regulatory burden were not also reduced. Nevertheless, in 1982 the budget proposed by DHHS for fiscal 1983 limited the reimbursement of indirect costs to 90 percent of the negotiated rate for extramural research grants of NIH and the Alcohol, Drug Abuse, and Mental Health Administration. The limit was described as a temporary measure to permit easing of a sharp, unanticipated reduction in funds for research project grants under the President's 1983 budget. As the year progressed, there emerged in DHHS a second objective: to limit the reimbursement of indirect costs incurred by departmental administration more severely than required by OMB Circular A-21.

The universities objected vigorously to what they viewed as unilateral abrogation of rate agreements negotiated in good faith. Congress responded in the fall of 1982 by inserting language in the appropriation bill for DHHS, the continuing resolutions, and the authorization bill for NIH to make clear its intent that indirect costs be reimbursed according to existing regulations. The report of the House Appropriations Subcommittee on Labor, Health, and Human Services[22] stated that the committee was persuaded that indirect costs are legitimate costs of biomedical research and should be adequately reimbursed. The committee also expressed concern about the widespread perception that the government may be bearing more than its fair share of these costs. The committee requested a review and report on the matter by the Secretary of DHHS, including consultation with the universities and other research organizations most directly affected.

CENTRAL ISSUES: COST SHARING

Validity of Rationale

We have already described the evolution of the basis for mandatory cost sharing--from sharing the risk of investment in research and encouraging prudent management to payment for benefits presumably received, to stretching federal resources.

The substantial effort and expense involved in preparing research proposals and the rigorous, competitive review of such proposals at federal agencies suggest that mandatory cost sharing plays little, if any, role in ensuring that only high-priority research is proposed. Prudent management is in the university's best interest, especially in light of constrained resources, and is also imposed by federal guidelines and the terms of specific agreements.

It is certainly true that academic research has greatly expanded as a result of federal support and that research capacity increases a university's ability to attract faculty, students, and other support. The principal beneficiary of successful research, however, is the public. As nonprofit institutions chartered for public purposes, the universities gain no economic profit. The concept of mandatory cost sharing as a payment for benefits received from performing research for the public good seems questionable.

The system for support of science in this country was designed to ensure that scientific merit would be the dominant criterion in selecting the projects to support. The Government Procurement Commission recommended in 1972 that the potential for cost sharing not influence placement of contracts or grants for research and development.[11] Yet the incentive to require more sharing has risen as the growth of the federal research budget has faltered. There is plainly a potential conflict between the goal of increasing mandatory cost sharing as a means of stretching federal resources and the goal of supporting excellence.

Nature and Extent of Cost Sharing

The extent to which universities support research and development with their own funds is not widely recognized. We noted earlier that colleges and universities provided approximately $1.6 billion for this purpose in 1982.[9] The academic contribution also is reflected in data[8] on separately budgeted R&D expenditures for science and engineering in 71 research-intensive universities. In 1979 their average contribution was $6.8 million (16.6 percent of such expenditures) for public universities and $3.3 million (7.0 percent) for private universities. Since these figures exclude departmental research (internally supported research that is not separately budgeted) and are restricted to science and engineering, they underestimate the universities' full contribution.

A principal concern of the universities is to retain the flexibility to choose the categories of expense in which they contribute to research. Arbitrary limits on indirect costs would remove this flexibility. Given the differences among universities in their treatment of specific costs as direct or indirect, restriction on expense categories for cost sharing complicates an already difficult management task. Similarly, mandatory cost sharing on a project-by-project basis can affect the institution's ability to set its internal priorities among research activities. The institutional cost-sharing agreements arranged by NSF and NIH have alleviated this problem to some extent.

Cost-Effectiveness of Requirements

The preceding paragraphs raise doubts that mandatory cost sharing on all research grants provides real benefit. In addition, such a requirement imposes the costs of identifying sources of funds for cost sharing, documenting it, auditing it, and resolving disputes about it. Cost sharing also complicates the documentation and calculation of indirect costs, increasing the cost of that process as well.

CENTRAL ISSUES: INDIRECT COSTS

Control of Costs

Some believe that indirect costs are out of control and that universities have no incentive to contain them. Indirect costs as a percentage of the total cost of a research project grant at NIH rose from a mean of 15 percent in 1966 to 25.5 percent in 1976 and to 29.5 percent in 1981.[23] This fact is a source of concern in all quarters. Its interpretation, however, must take account of several important factors:

• Indirect costs as a percentage of total costs in 1966, the year often used as a baseline, represented substantially less than the actual indirect costs of universities. A 1962 NSF study reported [24] that the federal share of indirect costs was approximately twice the amount reimbursed under the flat 15 percent limit then in effect. The increases for several years after the shift to reimbursement of actual costs (in 1966) reflect the phasing in of the new policy.

• Indirect costs as a percentage of total research costs for NSF, unlike the trends at NIH, showed little change between 1977 and 1981, although noticeable differences were found among fields.[25] Overall at NSF the figure rose from 23.5 percent in 1977 to 24.9 percent in 1981. For NSF engineering awards, however, it increased from 23.8 percent to 28.1 percent. For biological, behavioral, and social sciences awards it increased from 23.8 percent to 25.1 percent. For NSF awards in other fields, it remained essentially constant.

• Different categories of expense are subject to different rates of inflation. Certain indirect costs, such as utilities, construction, and negotiated wage rates for craftsmen, have risen faster than academic salaries, which normally are charged as direct costs.[19]

- Some administrative costs charged as indirect costs result from federal statutes or regulations. Universities wishing to accept federal research support are obliged to incur the costs of meeting these requirements, which have increased markedly in the past 15 years (although the fraction of universities' indirect cost rates due to administrative costs has remained essentially constant since 1968).[26]
- Some increases in indirect costs reflect the growing sophistication of U.S. biomedical research in terms of computation, equipment, and other factors. It is becoming more expensive to sustain the institutional foundation for launching the next generation of research.

These factors indicate a much slower rate of rise in indirect costs than is often cited. It is important to recognize, moreover, that universities have strong incentives to control indirect costs. For most institutions, federal research support is less than one-third of the total budget; at only three of them does it exceed 50 percent.[6] Since indirect costs are shared proportionately among academic activities, the universities bear the major burden of the indirect costs. At all institutions, constraints on resources, pressure from faculty and students, broad administrative oversight, and, for public institutions, state controls provide incentives to contain costs.

In response to these incentives, scientists and their universities have taken steps to reduce costs and improve efficiency.[27] Scientists have increased their sharing of equipment and supplies and have gone to great lengths to stretch their resources. Universities have made major capital investments to reduce energy consumption and modernize communication systems. They have improved conservation practices, reduced maintenance, and deferred renovation and modernization, but they have little control over externally set rates for utilities and the wages of certain workers.

Documentation Requirements

All previous attempts to "improve" the indirect cost system have led to increased requirements for documentation, but have not reduced costs to the government or the universities. Documenting compliance with federal requirements imposed for the sake of fiscal accountability and various social goals is costly and has led to expansion of university bureaucracies.[12,28,29] At the same time, the growth of the research enterprise has demanded a more complex management structure, and that, too, has increased costs and complicated documentation. Some requirements, such as time and effort reporting (see Chapter 7) and segregation of costs of related projects, are costly and generate data of little real value.

We need a cooperative effort to develop economically justifiable methods of documentation that fit the academic environment and ensure incentives for the wise use of funds. Ways to relieve the burden on scientists must be found if the vitality of academic research is to be retained.

Pluralism

Whatever systems are developed for identifying, allocating, and reimbursing costs will have to accommodate diverse universities, agencies, and scientists. Some universities are large; some are small. Some are developing their research capacity; others are already mature. Some have already developed costing systems to provide accurate bases for claiming full reimbursement; others are doing so now. A few agencies are receiving increased funding for academic research, but most are coping with level or decreasing funding. Traditions and budget strategies differ among agencies, just as their missions differ and their congressional overseers are not always of one mind. Some scientists are sophisticated managers and enjoy administrative tasks. Others crave freedom from such burdens and find debilitating and distracting the business end of their roles as fund raisers and accountants for research. They also need assurance that their purpose and that of the universities are essentially one. No single approach to indirect costs is likely to satisfy all parties completely. The goal is an array of arrangements that foster the objectives of the relationship and limit nonproductive costs.

FINDINGS

1. The Committee recognizes that universities voluntarily contribute substantially from nonfederal resources

to the support of research. We agree with the widely held belief that they will continue to share the costs of research whether or not they are required by statute to do so and without the documentation now required. The Committee also recognizes that documentation of cost sharing itself imposes costs and complicates both the reporting of faculty effort and the calculation of indirect costs. On these matters we concur with the recommendations of the Government Procurement Commission,[11] the Federal Paperwork Commission,[12] and the National Commission on Research.[13,14]

Joint funding is appropriate for some activities. We believe, however, that matching or joint funding should be required only for specific programs, not applied generally.

The administrative costs of research and some of the friction in the government-university relationship would be reduced by eliminating from the appropriation acts the general cost-sharing requirement affecting all research grants and by revising Office of Management and Budget circulars and federal agencies' manuals to eliminate the administrative requirement for documentation of cost sharing, except for programs specifically designed for joint funding.

2. Progress toward resolving the recurring struggles over indirect costs has been thwarted by the confusion of indirect costs with cost sharing. The Committee is convinced that progress requires separate treatment of two fundamental questions: What are the total direct and indirect costs of research? Who will bear what fraction of the costs of research and why?

Resolution of the conflict over indirect costs requires that representatives of all parties to the government-university relationship:

- Develop consensus on criteria for determining the actual costs of research, regardless of who pays.
- Examine current and alternative methods for apportioning costs among functions of the university and among individual projects.
- Agree on methods for determining and apportioning costs.
- Agree on the rationale for sharing of costs by government and the universities.

3. Universities differ in organization, the work they do, and the services they provide. These differences affect the magnitude of costs and whether they are classified as direct or indirect.

Imposition of a uniform indirect cost rate on all universities would be both unsound and inequitable.

Universities also differ substantially in their reliance on federal grants and contracts. These differences affect the extent to which recovery of indirect costs is relatively simple and noncritical or complex and critical for the university and for the government.

A wider choice of mutually acceptable methods for treating indirect costs is needed. Such methods should include some that offer simplicity in accounting procedures in exchange for less than full recovery of costs.

The Committee notes, for example, that a simplified method, analogous to the current option for small universities,[2] could be constructed for universities whose federal research support exceeds $3 million per year but is a minor fraction of their total budget. The Committee also finds attractive the standard deduction option recommended by the National Commission on Research for handling the costs of faculty administrative activities.[13] We suggest that this approach may offer advantages for other subcomponents of indirect costs, provided it is optional.

4. The Committee recognizes the deep concern about control of indirect costs in general and especially those associated with NIH grants, for which the ratio of indirect costs to total costs has been rising faster than at some other agencies. Many people are convinced that the ratio of indirect to total costs must not continue to rise. Such concerns have led to recurring proposals that indirect cost rates be limited by either a ceiling or a percentage limitation on the negotiated rate. These solutions, however, do not address the factors that cause indirect costs to rise. The pressures that contribute to a rise in the ratio of indirect to total costs are complex, and simplistic or arbitrary solutions to the problem are more likely to harm than to improve the health of academic research and development.

Among measures that would help control costs are:

- Identification and analysis of the factors that contribute to changes in the ratio of indirect to total costs.
- Development by universities of ways to treat more categories of expenses as direct costs, to the extent economically feasible.
- Study of the cost and cost-effectiveness of federal regulations affecting universities and other research performers.
- Improvement of the visibility of the total costs of research to all parties involved.
- Joint examination, by academic scientists and administrators, of the reality of indirect costs, the methods of accounting for them, and the need to recover them to be able to support productive research and educate scientists and engineers.

Development of better methods and incentives for cost control requires a joint government-university approach involving representatives of all parties concerned. The Forum on Government-University Relationships is a possible mechanism for addressing these issues.

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7
Accountability

Accountability has become a major source of disagreement within the government-university relationship. The importance of science and technology to national goals and the constraints on federal research resources over the past 15 years have stimulated heightened attention to:

- The choices of research to be supported and the methods used to make these choices.
- The quality and productivity of the research.
- The use of federal funds for the purposes intended.
- The efficiency of management of federal resources by research performers.
- The financial and scientific integrity of the research performers.

Accountability for federally funded research has two aspects: financial and administrative accountability and accountability for scientific performance. The main problems arise in four areas: differences in the parties' confidence in the validity and necessity of the accountability requirements; differences in the interpretation of the requirements; differences about the cost-effectiveness of the requirements and their effects on the research process; and differences in the priority given to invest ment of limited resources in accountability procedures.

Although universities are the primary performers of federally supported basic research, both universities and basic research are minor parts of the total federal investment in research and development.[1] And even in most of the research-oriented universities, federal must be accommodated within the larger context of the other's overall missions and management.

The long-term, exploratory nature of basic research introduces complications and uncertainties into processes for accountability. Creative activities aimed at discovery are difficult to forecast, to circumscribe, and to evaluate. Changes in ideas and approaches are the rule, not the exception. Indeed, the closeness of the outcome to the original objectives is not necessarily the best way to judge basic research. Accountability procedures that are effective for applied research, development, service, or production can be ineffective or counterproductive for basic research. Nevertheless, since federal research support is appropriated from public funds and allocated on the basis of judgments strongly influenced by scientific peers, the government must have ways to ensure that the funds are used for the intended purposes.

Also important is the nature of universities. That they have multiple missions is well recognized. It is less well understood that academic work often serves more than one of these missions at the same time. Universities also tend to be decentralized--decision making is broadly distributed. They are structured to give substantial autonomy to faculty members to encourage creativity and fresh approaches to problems. Individual investigators often pursue interrelated lines of research and have more than one source of research support. Universities themselves depend on multiple sources of support and are therefore accountable to multiple entities. These characteristics all complicate accountability processes.

The problems that are occurring have additional roots. The participants in the relationship differ in their understanding of the purposes of federal support. The government's categorical purposes and scientists' primary interest in expanding knowledge are not fully congruent. Propriety and reasonableness are interpreted differently by university and agency scientists on one hand and by administrative and audit staff on the other. The parties also differ in their views on the basis for federal reimbursement of research costs, some assuming incremental reimbursement and others full reimbursement (see Chapter 6). And confusion arises over the procurement (contract) and assistance (grant) approaches to federal funding.

FINANCIAL AND ADMINISTRATIVE ACCOUNTABILITY

The goal of financial and administrative accountability is to ensure that funds are spent in accordance with the terms of the agreement, without diversion, waste, or fraud. The National Commission on Research described the specific issues:[3]

> . . . the bearing of the expenditures to the purpose of the award, management effectiveness, economy and efficiency, including the stewardship of resources, and the integrity of financial operations. Additional expectations are for fair and ethical practices, proper locus of control, compliance with applicable laws and regulations, prudent scientific management, and a reasonable and equitable apportionment of costs in activities with joint purposes.

The principal federal requirements for financial and administrative accountability are found in OMB Circular A-21,[4] OMB Circular A-110,[5] and, for contracts, also in the federal procurement regulations (see Exhibits 2 and 3 for brief descriptions of OMB Circulars A-21 and A-110). In addition, individual agencies have specific rules, and each agreement can include unique conditions. Universities are expected to establish internal controls to ensure that requirements are met. The volume and complexity of the requirements preclude making the individual investigator fully responsible for compliance. Furthermore, the contractual arrangements are between the government and the institution, not the individual. Universities historically have tried to shield their faculty from having to know all the requirements. The result is that the distinction between requirements of the university and those of the government is not always clear to the investigator.

In the early days of the partnership, the government made accommodations to the nature of the university. It recognized in particular that universities are not organized to exercise the kind of fiscal controls used by commercial firms. Commercial standards for allocating costs were not imposed on universities, and approximations were acceptable in lieu of more rigorous methods. A use charge for equipment was allowed, for example, rather than the more complex depreciation method, which requires a full and frequently updated inventory. Some of these trade-offs are described in Appendix B.

EXHIBIT 2

OMB Circular A-21: Cost Principles

Promulgated by: Office of Management and Budget

Addressed to: Heads of executive departments and establishments of federal government

Purpose: To establish principles for determining costs applicable to federal grants, contracts, and other agreements with educational institutions.

Applicability: All federal agencies that sponsor research and development, training, and other work at educational institutions shall apply the provisions of A-21 in determining costs incurred for such work and shall use A-21 as a guide in pricing fixed price or lump sum agreements.

The principles do not apply to federal financing in the form of fellowships, traineeships, or other fixed amounts based on such items as educational allowance or published tuition rates and fees.

They do not apply to capitation awards or to awards under which the institution is not required to account to the government for actual costs incurred.

Intent: To provide that the federal government bear its fair share of total costs, determined in accordance with generally accepted accounting principles (except where restricted or prohibited by law). Agencies are not expected to place additional restrictions on individual items of cost.

Role: A means of assuring:

- Productive and efficient use of public funds
- Accountability to agencies which provide research support
- Prudent and economical research administration
- Equity and reasonable allocation of costs to the sponsored research agreements
- Protection of the research environment and the independence of educational institutions

Content:

- Policy guides
- Definition of terms
- Basic considerations, including:
  --Composition of total costs
  --Allowability, reasonableness, and allocability of costs
  --Applicable credits (e.g., for discounts and federal financing)

EXHIBIT 2 Continued

- Basis for distinguishing between direct and indirect costs
- Criteria for assignment of direct costs to sponsored agreements
- Criteria for distribution of indirect costs among institutional functions
- Basis for selection of distribution methods and order of distribution
- Identification and assignment of indirect costs to specific categories (e.g., departmental administration, operations, and maintenance)
- Determination and application of indirect cost rates (including simplified method for small institutions)
- General principles for establishing allowability of 44 selected items of cost, whether treated as direct or indirect. Salaries and wages are one of the 44 cost items covered. The "effort reporting" requirements are introduced to establish allowability of such charges for personal services.
- Requirements for official certification that expenditures are for appropriate purposes and in accordance with provisions of application and award documents.

As federal support of academic research increased and as the universities' costing practices grew more sophisticated, federal interest in fiscal accountability increased. In 1966 came the removal of the limit on indirect cost rates and in 1969 the change to having universities audited by one agency instead of several. A period of occasionally sensational criticism ensued. The government found the financial systems and management practices of some institutions inadequate. For example, in 1978 the Inspector General of DHEW reported that $3.5 million (0.23 percent of the federal funds examined in university audits) was not properly charged and that an additional $86.5 million (5.7 percent of the total funds examined) was set aside for adjudication because it could not be audited under existing regulations.[6] The universities found some of the federal accountability procedures excessive, not cost-effective, and poor indicators of the effectiveness of academic research. The manifestations of these disagreements primarily included struggles over effort reporting, indirect costs, and documentation of cost sharing and cost transfers, but deficiencies in universities' systems for cash management and for acquisition, control, and accountability for equipment and supplies were also cited.[3]

EXHIBIT 3

OMB Circular A-110: Uniform Administrative Requirements

Promulgated by: Office of Management and Budget

Addressed to: Heads of federal executive departments and establishments

Purpose: To promulgate standards for obtaining consistency and uniformity among federal agencies in the administration of grants and other agreements with institutions of higher education, hospitals, and nonprofit organizations

Policy Intent: To replace varying and often conflicting requirements imposed as conditions of grants and other agreements with uniform standards and requirements

Applicability: To all federal agencies, except as statutes expressly require otherwise

Not applicable to contracts entered into and administered under procurement laws and regulations

Not applicable to technical assistance services, general revenue sharing loans, loan guarantees, insurance, or direct payments to individuals

Exceptions: Exceptions from requirements of A-110 may be granted by A-110 in unusual circumstances if not prohibited by law. More restrictive requirements may be applied to a class of recipients when approved by OMB. Additional requirements may also be imposed on recipients with a history of poor performance with due notice of reasons and necessary corrective action.

Content: Responsibilities of agencies regarding implementation of A-110 and clearance of all record-keeping requirements by OMB

Set of 15 attachments setting forth specific standards and requirements for:

- Use of banks and other institutions as depositories of funds advanced
- Bonding and insurance
- Retention and custodial requirements for records
- Program income related to projects financed in whole or in part with federal funds
- Cost sharing and matching
- Standards for financial management systems
- Financial report requirements
- Monitoring and reporting program performance
- Requirements for methods of payments to recipients
- Criteria and procedures for revisions in financial plans
- Closeout procedures
- Suspension and termination procedures
- Standard form for applying for federal assistance
- Property management standards
- Standards for procedures for procurement of supplies, equipment, construction, and other services with federal funds

Financial and administrative accountability in universities has been the subject of several reports.[3,6-8] Much of the concern has focused on effort reporting, the locus and extent of control over the conduct of research and research budgets, and the segregation of individual research projects for administration and accountability. Universities and investigators have become increasingly concerned over what they perceive as overregulation and decreasing flexibility in the conduct of science. Some federal officials, on the other hand, have become increasingly concerned that the inadequacy of universities' accountability systems is undermining the agencies' stewardship of public funds.

Effort Reporting

Perhaps the most pervasive and controversial issue in financial accountability is effort reporting. The term originally referred to a requirement for detailed documentation of faculty efforts. It was introduced in 1967 as one of the criteria for allowability of charges for personal services under OMB Circular A-21. The requirement has since been modified, and effort reporting has become a generic term for various methods prescribed by the government to provide accountability for salaries and wages charged directly or indirectly to sponsored agreements.

Accountability for charges for salaries and wages is particularly important because these charges account for a major fraction of the direct-cost budgets of research agreements. Also, the federal share of indirect costs depends largely on the assignment of salaries and wages among the university's functions of research, instruction, and service (see Chapter 6 for a description of the allocation process).

The government has sought ways to reimburse its fair share of the costs of research while not unintentionally supporting other university functions. It has therefore sought documentation to relate salary charges with work performed under research agreements. The government also sees salary documentation as a way to ensure the validity of the university's apportionment of indirect costs among its functions. Almost all federal research agreements with universities are on a cost-reimbursement basis (only costs actually incurred are eligible for reimbursement). For this reason the government's requirements address actual costs rather than budget estimates, and auditors focus on the validity of charges.

The requirements for salary documentation have been patterned largely after the industrial model--frequent, after-the-fact reporting of time or effort expended. This model fits poorly in the academic environment, in which faculty and other professionals operate on the basis of work assignments, not effort expended. Time and effort are considered in assigning workloads, but the test of accountability is performance, not hours worked or effort expended.[9] Furthermore, because most faculty work simultaneously serves several purposes, allocation of activity among projects and the functions of the institution cannot be precise. The government and the universities differ in their acceptance of the inherent uncertainties in these allocations.

The debate over effort reporting has been long and at times acrimonious. Appendix C gives a brief history of the evolution of the requirement and the perspectives of those affected by it.

Cost Transfers

A second frequently cited problem in accountability is cost transfers, the shifting of charges from one account to another. Cost transfers among university research accounts occur frequently for several reasons.[10] Support is provided in discrete project awards of limited duration. An investigator's research program is likely to be funded by several such awards from different sponsors. Some or all of the investigator's projects may be scientifically related. Some research costs may be assignable as legitimately to one source as to another. University funds are often used temporarily to cover costs when award notices arrive late.

While cost transfers are not prohibited, OMB Circular A-21 does forbid transfers to avoid restrictions, cover deficits, or for convenience. Furthermore, Circular A-21 requires that any costs charged to an agreement must be allocable to it. Auditors examine the documented charges and the timing of transfers to test whether the charges are consistent with the purposes of the grant and comply with regulations. They view late transfers of charges for salaries and wages as signs that the institution's salary documentation system may be inadequate.

The disagreements about cost transfers reflect differences of opinion on how federally sponsored research projects are related and how they will be managed. Academic and agency scientists usually agree on the relatedness of projects and the prudence of retroactive reallocation of charges, especially to accommodate the scheduling of work. Auditors, however, generally expect clean segregation of the costs of separate projects and view cost transfers as suspect.

Attempts to Improve Accountability

A number of attempts have been made to improve accountability, and OMB Circular A-21 has been revised several times (see Appendix B). It was revised in 1979 after about four years of discussions between the universities and the government, particularly the Department of Health, Education, and Welfare (DHEW, now DHHS), the audit agency for most of the universities.

Both parties had sought revisions. The government wanted tighter procedures, more uniform methods of cost allocation among the universities, and explicit controls to bar the possibility of double charging or paying any individual for more than 100 percent effort. It also seemed to want to reduce federal reimbursement of indirect costs: A revision of A-21 proposed by the agency, for example, would have eliminated certain categories of allowable costs entirely.

The universities sought clarification of the requirements of Circular A-21 that auditors in different regions were interpreting differently.[11] They sought improvements in the effort-reporting requirements and proposed a method better adapted to academic work. They wanted to be able to charge certain costs, such as interest costs incurred in the acquisition of research equipment and facilities. They also sought exemption from cost-accounting standards then being developed for all defense contractors and designed mainly with commercial firms in mind.

The 1979 revision of Circular A-21 increased the specificity and uniformity of some of the costing requirements but exempted universities from the cost-accounting standards applied to commercial defense contractors. The revision reduced the extent to which certain costs could be allocated to research. It denied some of DHEW's requests for further elimination of allowable costs and denied the universities' request that other costs be allowed. The revision also changed the effort-reporting requirements significantly. In particular, it eliminated two of the three effort-reporting methods and introduced a new one. The new method was modeled after the one proposed by the universities but different in ways that made it much less acceptable to them. The revision introduced a requirement that universities account for 100 percent of an employee's workload if any part of it was charged directly or indirectly to a federally sponsored agreement. It also introduced more stringent requirements for review of salary distributions by persons with first-hand knowledge of the work performed, but it reduced the required frequency of effort reporting for faculty and professional staff. Many universities found the 1979 revision acceptable not because it responded to their request for improvement, but because it rejected DHEW proposals that would have caused severe losses. Neither was DHEW fully satisfied with the revision.

As the universities began to implement the revised requirements, a number of faculty members objected strenuously. Indeed, some who recalled previous debates about effort reporting were outraged.[12] In 1980 the National Commission on Research recommended a simpler, less costly method of documenting salaries and wages.[3] Government-university discussions resumed, this time with some direct participation of faculty. In 1981 the Association of American Universities (AAU) and the Council of Scientific Society Presidents (CSSP) submitted to OMB a proposal for revising the effort-reporting requirements. In August 1982 OMB issued a formal revision of Circular A-21.[4] It eased the effort-reporting requirements, incorporating much of the AAU-CSSP proposal, and made interest an allowable cost under certain conditions.

During the three years preceding the 1982 revision, the debate over effort reporting--often heated--was complicated by several factors. Some federal audit staff were overzealous in implementing A-21 requirements. Some institutions implemented A-21 too conservatively to avoid the possibility of sensational criticism and large disallowances. Many faculty members were unaware of the effort reporting that A-21 had been requiring since 1968, so the 1979 revisions came as a jolting surprise to them. Finally, some faculty made exaggerated claims about the requirements of the revised A-21.

Although the 1982 revision of Circular A-21 does ease the situation, real and lasting improvement may require entirely new methods of effort reporting. Fortunately, the revised circular allows some flexibility to experiment in this regard.

Another key move to improve accountability processes was the issuance of OMB Circular A-110 in 1976.[5] Its purpose was to standardize and simplify federal grant requirements. Before then, agencies had separate, often different, sometimes conflicting requirements, which sorely complicated the universities' ability to ensure compliance and the investigators' ability to manage research.

Other changes have been and are being made in federal audit processes used in universities. One of the audit agencies (DOD) is completing the pilot phase of a shift to auditing universities' management systems rather than individual contracts. The federal government appears to be moving to reduce its auditing of university expenditures and to concentrate instead on sectors in which misuse of funds is more likely. Under one proposal, universities, rather than being audited by federal auditors, would be required to arrange for an annual audit of their federal expenditures by an outside party, probably in accord with federal specifications. The frequency and scope of these audits is currently being discussed, along with the costs and who shall pay them. A shift to third-party audit will not reduce costs unless the scope and frequency of the audit are modified.

University concerns in these developments focus on their continuing need for accountability requirements suited to their work and organization, the cost of accountability processes, and the need to limit agencies' latitude to interpret federal cost and management principles (Circulars A-21 and A-110) more stringently. The government wants expeditious correction of deficiencies in university systems found through audit and prompt negotiations to resolve questioned costs.

Two additional efforts are under way to improve the government-university relationship while ensuring accountability. These are the AAU-NSF Experiment in Post-Award Administration and an exploration by NIH of the fixed obligation grant as an additional mechanism of research support.

The AAU-NSF Experiment in Post-Award Administration

The AAU-NSF Experiment in Post-Award Administration, which has run for about two years in 15 universities, is an attempt to streamline and improve accountability processes. This experiment (which was scheduled to end March 1, 1983) redefines the project grant relationship by moving from the traditional procurement-oriented approach and the accompanying controls toward a relationship intended to encourage creative and productive management by the grantee. It eliminates some of the post-award restrictions attached to the project grant, such as the requirement for prior approval by the agency to incur certain costs or to shift funds among budget categories. It uses accountability methods that emphasize the grantee's flexibility to allocate resources to achieve optimal research outputs rather than control of the grantee's choices of cost inputs. NSF is less involved in the conduct of the research, but its role in judging the merits of proposals and results remains the same.

The experiment introduces flexibility in the beginning and ending dates of awards. It does so by allowing pre-award costs to be charged to the grant under certain conditions and at the grantee's risk and by allowing the grantee to authorize a no-cost extension for a limited period under certain conditions. The experiment also uses the concept of relatedness to counter the fragmentation of projects that is a major cause of audit questions about cost transfers. A principal investigator with more than one NSF grant, with the concurrence of university officials, can determine which NSF projects are scientifically related using NSF criteria. The investigator may then allocate the funds provided by NSF in whatever way seems sensible so long as it does not significantly change the scopes of the related projects.

Response to this experiment in postaward administration has been quite favorable. University faculty and administrators have urged that the approach be expanded to other agencies. NSF and the General Accounting Office have audited the experiment with encouraging results and made suggestions for improvement.[13,14] Benefits have included the ability to start projects more quickly and efficiently, the ability to respond flexibly and quickly to changing project needs, and a reduction in time and effort required to manage NSF grants. NSF has recently announced that the revised grant terms used in the AAU-NSF experiment will be extended to all grantees.

The Fixed Obligation Grant

The National Commission on Research in 1980 recommended[15] experimentation with new concepts in funding mechanisms, particularly the grant-in-aid managed at the local level. The idea was to reduce administrative complexity and delegate fiscal responsibility to the investigator and grantee institution. The commission believed that the incentives for wise management that are inherent in the competitive research funding system minimize the risk of fraud, abuse, or inefficiency.

In 1980-1981, the Advisory Committee to the Director of NIH studied this recommendation further. The committee recognized that much of the trouble in the government-university relationship stemmed from the methods prescribed for handling federal funds on a cost-reimbursment basis. A task force under the committee explored the implications of replacing the cost-reimbursement basis with a fixed-amount approach for some types of award.[16]

In its simplest form, the fixed obligation grant would have many of the attributes of a fixed-price contract but would not have its procurement features, such as the delivery of specific products or outcomes. The preaward process would not change. Once an application was reviewed and the funding agency decided tentatively to make an award, the agency and the applicant would negotiate the overall objectives of the project, the technical reports to be furnished as evidence of progress, and the amount and period of the award.

The negotiations completed, the agency would make the award without imposing requirements for reports or records of expenditures or effort reporting. Only changes in scope, investigator, or institution would require agency approval. The agency would rely on the investigator and the university to manage the funds and on the technical reports to assess performance. Inadequate performance would weigh against future funding of the performer by that sponsor but would not require return of funds already obligated, a penalty rarely proposed even for cost-reimbursement awards. The university's business systems would be subject to review by the audit agency.

During the discussions at NIH of the fixed obligation grant, three issues drew particular attention. One was the use of unobligated balances--funds awarded for a given period but not used by the end of that period. In its purest form, a fixed obligation grant would leave such funds under the control of the investigator and grantee, but this feature is negotiable. NIH staff thought the issue important since unobligated balances being returned to the agency under existing grants comprised a sizable sum that was being used to fund a significant number of new awards.

A second key issue was indirect costs. Contrary to some reports, the fixed obligation grant would not be a pool of funds for which direct and indirect expenditures would have to compete within the university. The intent was that indirect costs would be treated as they are now: calculated and negotiated according to OMB Circular A-21 on an institutionwide basis, with the negotiated rate included in the proposed budget and awarded separately or as part of the total costs, depending on agency practice (see Chapter 6). The fixed obligation grant was designed to reduce the administrative costs of research grants, not to reduce reimbursement of them. The new mechanism also was clearly intended to preserve the key role of the principal investigator in managing the funds.

The third issue was the extent of use of the fixed obligation grant. The task force saw it as an addition to current mechanisms, not a replacement. They thought it particularly well suited to basic research grants of modest size awarded to institutions with well-established management. They saw it as a way to introduce flexibility and streamline administrative procedures for a significant volume of grants.

After its discussions of the task force proposal, the Advisory Committee to the Director of NIH recommended further exploration of the fixed obligation grant.[16] This effort is still under way at NIH. Meanwhile, NSF has used a fixed-amount approach in two of its smaller programs.

It is important to remember that the principal feature of the fixed obligation award is the payment of a fixed amount, rather than reimbursement of costs incurred, and the consequent delegation of fiscal management to the grantee. The details of the award mechanism can be tailored in many ways to fit the work and the relationship between sponsor and grantee.

Accountability Practices of Other Sponsors

Academic research is sponsored not only by the federal government but also by industry, private foundations, and others. Accountability seems not to be a problem in universities' arrangements with other sponsors. The Committee, therefore, commissioned a review of these relationships in the hope of finding ways to improve the government-university partnership.

The review* found in part that dealing with federal agencies is a much more standardized process for the universities than dealing with most other sponsors. The application process is more well defined; learning what to submit, to whom, and when presents little or no problem. The federal government, however, deals with universities much more bureaucratically than any other sponsor. While the government's original model may have been the foundation grant, it has added restrictions to its award arrangements that have required expansion of university staffs to ensure compliance. Federal requirements for performance and fiscal reports parallel the most stringent ones of any of the other sponsors. Under some federal agreements, the reporting requirements have become quite onerous.

The biggest difference in federal support, however, is in audit. Nonfederal sponsors seem to have no published requirements for audit. Some reserve the right to inspect the financial records relating to grant expenditures, but nonfederal sponsors rarely conduct on-site audits. They seem to feel that audits of university expenditures by sponsors are just not cost-effective.

Major universities are usually audited annually by a public accounting firm, by the state, or by both. Because sponsored research and development account for well under a third of the expenditures of most universities, their own funds are the largest fraction of the monies vulnerable to misuse. Universities establish internal procedures to safeguard and manage those funds. In many areas, nonfederal sponsors do not specify the terms and conditions of allowability of costs; instead they ask that the institution treat their funds as it treats its own. They rely on the universities' systems to protect their funds. This is one of the reasons why grants are

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*Cedric Chernick, "Who Gives Best? An Examination of the Grant and Contract Policies of Industry, Foundations, and Voluntary Organizations and a Comparison with Federal Government Practices" (background paper prepared for the Ad Hoc Committee on Government-University Relationships in Support of Science, Washington, D.C., June 1982).

usually made to institutions, rather than to investigators as individuals.

In contrast to this approach, the government assigns each university a federal agency as its auditor. That cognizant agency is responsible for the audit of direct and indirect costs and the negotiation of indirect cost rates. The extent of the audit is such that some institutions have federal auditors on their campuses full time. Each year's direct costs are subject to audit, although audits may not be conducted annually, and the books have to remain open for audit for two, three, or more years.

SCIENTIFIC ACCOUNTABILITY

Scientific accountability for federal funds is provided in many ways. Science as a profession demands disclosure, proof, replication, and rigorous intellectual honesty. The penalty for deliberate violation of the integrity of the research process is disgrace and loss of professional privileges. Universities view faculty research as a principal factor in recruitment, promotion, award of tenure, and the continuing performance evaluation that affects allocation of institutional resources. Scientific and scholarly journals carefully review and select the works they publish. Superimposed on these systems of scientific accountability are those used in the government-university relationship.

The goals of federal agencies' preaward review processes are to select the best research and the best performers. The processes are designed to foster objectivity, to keep the competition open to new applicants, and to limit errors in judgment, all without undue consumption of time and effort. The National Commission on Research report on review processes[17] describes the review processes used by the dominant agencies supporting research in universities (see Chapter 1, Table 2). The most common process is external peer review by practicing scientists who guide the agencies' choices of both research directions and specific projects to support.

In both governmental and nongovernmental scientific review processes, the unequivocal qualification of a reviewer is scientific expertise, and the overriding criterion employed is scientific merit. The preaward peer review processes used in U.S. science have provided quality control, continuous review of progress in scientific fields, safeguards against favoritism or political influence, and assurance that emerging scientific opportunities are recognized and can be seized. Most scientists are strongly committed to the use of scientific experts (peers) in the selection of science to receive federal support. The belief that this system has been an essential factor in the productivity of U.S. science is widely held.

Nevertheless, the external peer review system has been criticized from time to time by members of Congress and members of the academic community.[18] The principal concerns are:

- integrity of the system and accountability to congressional authority;
- principles governing choices of proposals: balance among merit, equity, or relevance to specific national goals;
- selection of the reviewers;
- objectivity of the reviewers;
- wisdom of choices made, especially with regard to unorthodox ideas;
- effect of past productivity on future support;
- opportunity, especially access for young investigators, women, and minorities; and
- costs of the process to the scientific enterprise.

Because peer review is fundamental to the support of science in this country, it has been studied extensively.[18-28] As a result, adjustments have been made to avoid real and apparent conflicts of interest, to broaden the pool of reviewers, to lighten the burden on individual reviewers, and to reduce the cost of the review process.[29] Special programs have been established to expand opportunities for young investigators, women, and minorities. The National Commission on Research, the President's Biomedical Research Panel, and the Committee on Science, Engineering, and Public Policy of the National Academy complex have all encouraged the use of retrospective studies of the effectiveness of preaward review in selecting research to be supported by federal agencies.[17,30]

The explicitness of the criteria used in the review process is important for demonstrating its fairness both to those who are evaluated and to the public. The National Commission on Research[17] recommended consideration of the use of more explicit criteria in overall peer review ratings so that agency program officers could tell which qualities a reviewer used, and in what measure, in assessing a proposal. Although some agencies use such detailed ratings, others use a simple overall score.

A major new problem for peer review is the reduction in federal funding relative to the number of qualified applicants. This change is severely straining the system because of the difficulty of choosing wisely among very good proposals.

While the main basis for scientific accountability in the government-university relationship is preaward peer review, various kinds of postperformance review are also used. The simplest is the review of performance that occurs when requests for continued support are considered. Some agencies take this factor into account more explicitly than others. Postperformance review of a project can permit a judgment of whether best effort has been made, but judgment of the value of a basic research project must be made over a much longer time. Comparison of project outcomes to the original objectives may be interesting, but both positive and negative results are useful, and changes in objectives may mark the evolution of knowledge.

Postperformance review is used also to develop understanding of the factors affecting research productivity as a way of validating the basis of future funding choices. Because the contributions of specific pieces of research are often not clear for a number of years, postperformance assessment of programs rather than projects, and over a longer time, can add another dimension to scientific accountability. Similarly, postperformance review can profitably be done for an entire field. Again, the use of peer judgments is central. It is important to recognize, however, that postperformance review consumes money, time, and effort, placing additional burdens on the agency and on the scientific enterprise. A recent study by the Committee on Science, Engineering, and Public Policy[30] investigated evaluation methods used by industry as well as by federal agencies. The study concluded that neither industry nor NSF has found anything better than some form of peer review for evaluating individual research projects.

Peer review, especially preaward peer review, serves more than scientific accountability. It is an important vehicle of scientific communication and helps shape the direction of science. The relative emphasis on criteria used in preperformance and postperformance reviews must be handled with care because they can easily become selffulfilling criteria that scientists attempt to satisfy. Overemphasis on past performance can stifle the risk-taking necessary to creativity. Using counts of publications as a principal measure of productivity can encourage premature publication, publication of partial results, and use of postdoctoral staff at the expense of the training of graduate students. It may also discourage highly innovative proposals that have a high risk of failure.

Processes of scientific accountability are costly. The most effective forms depend on thorough review, by more than one expert, of work proposed or performed. Such review consumes the time of scientists who could otherwise be doing research. The U.S. system of supporting individual research projects rather than institutions multiplies the need for reviews. Preaward peer review processes have been estimated currently to consume about 575 man-years per year.[31]

Efforts to decrease the uncertainties in scientific accountability must be examined carefully in terms of the cost in scientists' time and the potential for constraining an inherently uncertain endeavor. Simpler, less costly methods have been proposed, but all involve use of more arbitrary measures (such as publication counts), substitution of one reviewer for a group, or replacement of project grants with block grants.[30,32,33] Experimentation with such methods for a limited number of federal grants for basic research might yield economies but would necessarily entail loss of rigor in scientific accountability.

Scientific Integrity

Whatever the formal requirements for financial and scientific accountability, scientists tacitly assume adherence to the scientific method and its requirements of scholarly integrity and observance of ethical standards. But despite the protection provided by the scientific method, instances of deceit or fraud in federally sponsored academic research have come to light from time to time. They have elicited strong response from the scientific community and the public alike. The seriousness of the proven cases has led to intensive efforts to clarify their causes, to learn if the frequency of cases is increasing, and to provide more formal procedures for dealing with scientific fraud.

In addition to many articles in the scientific and lay press, a Subcommittee on Investigation and Oversight of the House Committee on Science and Technology has held hearings to determine whether federal agencies should adopt more formal responses to scientific fraud. DHHS has added a debarment provision to regulations covering research grants[34] and recently applied it to a scientist who falsified data. DHHS regulations[35] also provide for the flagging of applications for research support when misconduct has been alleged, regardless of the source of allegation.

A number of universities have formally reviewed their policies and procedures, both for fostering integrity and for handling misconduct if it should occur. The Association of American Medical Colleges[36] and the Association of American Universities[37] have assessed roles and responsibilities for ensuring integrity in research. The AAU report puts deviant actions by scientists into four categories: falsification of data; plagiarism; abuse of confidentiality; and deliberate violation of regulations (such as those designed to protect research subjects). The report states in part:[37]

> The integrity of the research process must depend largely on self-regulation; it is the responsibility of all who engage in the search for knowledge. This principle has served science in an exemplary way for centuries. Advances are gleaned from rigorous application of scientific methods and in compliance with ethical codes rooted in intellectual honesty.
>
> Deviations from the norm--even serious ones--have usually been dealt with informally and quietly. Although these methods may have generally worked well in the past, experience suggests that it is now appropriate to give serious thought to better methods for preventing and detecting irregularities and to the manner in which universities deal with them.

The AAU report recommends specific responsibilities for universities and investigators. The report of the Association of American Medical Colleges offers guidelines for preventing research fraud and suggests prototype procedures for dealing with alleged fraud.

The Committee has not studied scientific fraud in detail, but we know of no evidence that its relative frequency is increasing. We do know that the scientific population has roughly doubled every decade since World War II, so the numbers of cases of fraud could be expected to have increased. The pressures of the system to publish to gain recognition, promotion, and research funding are facts of life for the academic scientist. These pressures can tempt some to careless and superficial work and thus to premature claims of priority; they may tempt a few to falsify data, plagiarize, or take unfair advantage of information provided in confidence for peer review.

Most scientists recognize the potential temptation, the need for integrity in science, the risks of scientific misconduct, and the temporary nature of gains so obtained. As in any endeavor, there will be some for whom the code of ethics does not take firm root, pressures overcome principles, and shortcuts seem feasible despite their risks and falsity. While the scientific community and the government should not overreact to instances of scientific fraud, they should not ignore possible early warnings of developing danger.

POINTS OF VIEW

The importance of financial and scientific accountability for public funds supporting academic research is widely recognized. Perspectives on how to achieve that accountability, however, differ significantly.

Investigators seek freedom and flexibility in the use of research resources. They wish to preserve their control over the funds they raise for their research and to minimize the drain of bureaucratic tasks. They plead for more prompt and accurate information on their research accounts. They are generally aware of the broad accountability structure, but are often unfamiliar with the regulations. If they do know the rules, their experience with the views of agencies' scientific staff leads them to believe that compliance with the letter of the law is not only unintended but also unrealistic and imprudent in terms of the objectives of research. Investigators chafe under the present requirements for financial accountability. They are wary of change, however, out of concern that it may reduce their competitiveness for support or their role in managing the funds.

Most investigators are strongly committed to external peer review, although they may have concerns about details. The recent decrease in the ratio of awards to proposals, especially at NIH, is causing great distress and closer scrutiny of the review system. Although the system is periodically criticized, serious suggestions that it be abandoned or its functions changed are rare. Investigators seek to improve it, not replace it.

The scientific staff at sponsoring agencies, like academic scientists, often seem unfamiliar with the details of OMB Circulars A-21 and A-110. They sometimes seem oblivious or indifferent to the implications of paying for research by cost reimbursement via project grants. They focus primarily on the scientific imperatives and the productivity of the system. Many academic and agency scientists believe that scientific productivity would suffer if investigators complied fully with the current rules.

Academic administrators want to provide the flexible environment their scientists need, but they also want to comply with the sponsored agreements. They seek better, less costly ways to manage agency funds. They know the negative consequences of erosion of public confidence in the universities' systems of accountability. They want to prevent negative audit findings and disallowances. Although many universities have improved their administrative systems significantly, they find it difficult to obtain the sums needed for such improvements or to assign highest priority to them in increasingly strained budgets. They view with dismay, moreover, the erosion of their independence and the expansion of their administrative staff induced by growing federal requirements.

Federal financial officials emphasize the importance of accountability for public funds. They are concerned that federal audits of universities and other educational institutions have identified large sums that auditors believe were improperly spent, and even larger sums that they could not verify because of inadequate accounting systems and records. They do not want to burden universities with unnecessary rules, but they intend to insist on proper use of federal research funds.

Heads of federal agencies that support science emphasize the need to distinguish between grants and contracts in setting the terms of accountability. They express concern that federal auditors treat all research projects as procurements unless otherwise instructed. They suggest that refinement of the grant relationship may be necessary to improve agreement on accountability. They also suggest that federal cost principles be brought more into harmony with university operations and that requirements be reevaluated to determine if all are actually necessary.

Some industrial leaders suggest that a way is needed to approach funding on the basis of trust and the idea that people close to the action can best decide how to invest money in science. They believe that the nation has put enough futile effort into bureaucratic controls and should now be willing to try reliance on the judgment of the best people and institutions.

FINDINGS

1. Financial and administrative accountability and scientific accountability are fundamentally different. Both are essential, but greater stringency, more detailed procedures, or greater emphasis on one form of accountability cannot compensate for uncertainties in methods for assessing the other.

The flexible, relatively nonhierarchical organization for research of U.S. universities has contributed significantly to the development of this country's eminence in science. The Committee believes that methods for scientific or financial and administrative accountability that are poorly suited to that structure can unintentionally disrupt the academic research environment and so diminish the quality and productivity of research.

Efforts to enhance accountability are best directed toward ensuring the validity and cost-effectiveness of the methods of accountability employed.

2. The Committee believes that the continuing friction over OMB Circular A-21 is a serious problem that must be corrected. The friction has several causes: disagreement about some of the premises of Circular A-21; widespread lack of familiarity with its purpose and content; dissatisfaction over some of its provisions; and the manner in which it has been interpreted and implemented.

While the 1982 revision of the effort-reporting requirements in Circular A-21 will provide some relief, the Committee believes that lasting improvement will require a simpler, less costly, and more valid method of accounting for performance. Also required is the development of consensus on the validity and appropriateness of the policy guides, basic considerations, and specific provisions in Circular A-21 (see also the findings in Chapter 6).

The Committee endorses the salary documentation method proposed by the National Commission on Research and therefore would like to see Circular A-21 further refined to permit the following:[3]

> In lieu of effort reporting, the documentation for salary charges may consist simply of (1) the report of the university of the salaries charged to the sponsored agreement, (2) the explicit certification by the investigator that the direct expenditures for salaries and wages are fair in terms of the sponsored agreement, (3) the assessment by the federal program officer of the reasonableness of the expenditures for the work undertaken, (4) periodic audit by federal or independent auditors of the adequacy of the institution's system for assigning charges to individual projects, and (5) recognition that where projects are closely related or carried on by one or more of the same investigators, the group of related projects, not the individual projects, should be accepted as the basis for the audit.

The Committee agrees with the National Commission on Research that Circulars A-21 and A-110 need thorough reexamination. The point would be, in their words, to:[3]

> assure that these guidelines for financial and administrative accountability (1) incorporate features which not only control against abuse but also facilitate and encourage effective management, (2) are fully consistent with the nature of the research process, (3) accommodate better the academic environment in which they must operate, and (4) are based on better mutual understanding of the purposes of the government-university relationship.

The Committee believes that representatives of all affected parties in the government-university relationship must accept responsibility for familiarizing themselves with OMB Circulars A-21 and A-110 and for reaching consensus on the changes needed.

<u>The Forum on Government-University Relationships could serve to develop the mutual understanding needed to</u>

reach consensus on revision of Office of Management and Budget Circulars A-21 and A-110.

3. The Committee concludes that the accountability problem arises in part because some federal requirements and controls are poorly suited to the grant relationship and because the administration of research support is too fragmented into individual projects. In particular, the Federal Grant and Cooperative Agreement Act of 1977 calls for the use of grants (as opposed to contracts and cooperative agreements) for assistance without major federal involvement in the conduct of the work supported by the grant. The point is to emphasize optimal research results rather than control of cost inputs.

The accountability requirements for grants need to be redrawn to give the institution and the principal investigator the authority and the responsibility for performing the work with the minimal federal involvement called for by the Federal Grant and Cooperative Agreement Act.

In particular, the Committee favors the following modifications:

- Delegate to the grantee the authority to make all modifications that now require prior federal approval, except changes in scope, principal investigator, or the investigator's institution. Allow the grantee institution to use its own management systems to distribute authority and responsibility for decisions so long as federal funds are handled in accordance with sound business practice and the university's policies and the central role of the principal investigator is preserved.
- Allow the grantee institution and the principal investigator to relate or consolidate projects of the same principal investigator or coinvestigators in accounting and management.

4. The Committee believes that for many research grants of modest size, payment by cost reimbursement and the associated accounting and administrative procedures are unnecessary and not cost-effective.

The use of fixed-amount awards, instead of cost-reimbursement awards, would be advantageous for grants of modest size, where they would simplify handling and provide flexibility with negligible risk of inadequate accountability.

5. The Committee is encouraged by the efforts under way to improve the audit process. We believe that further savings could be made if the frequency of both the revision of the indirect cost rate and the audit of direct and indirect costs were changed from annually to every two or three years with optional interim revision or audit in unusual circumstances.

6. The Committee strongly supports reliance on the judgment of scientific peers as the best way to select research for support and to ensure accountability and quality in scientific performance. At the same time, the peer review system should be subject to regular reexamination to ensure that its quality and fairness are maintained, a task to which the Forum might contribute. In particular, the effects of the reduced ratio of projects funded to projects approved on peer review decisions about unsolicited proposals should be carefully monitored.

The system for ensuring scientific accountability could be strengthened by making past performance a more explicit factor in reviews of proposals and making such assessments a matter of record.

7. Deliberate falsification of research data is an intolerable abuse of the scientific method. Nevertheless, despite the protection against fraud provided by the scientific method, cases have come to light from time to time. We know of no evidence, however, that breaches of ethics are relatively more common now than at other times in the history of science. Even so, widely publicized cases of fraud are damaging to science and a source of growing public concern. Scientific fraud is not, of course, peculiar to the government-university relationship, but its impact on that relationship is profound. The Forum should consider the implications of the issue for the government-university relationship, and universities should redouble their efforts to maintain the highest ethical standards.

The primary responsibility for preventing scientific fraud rests with scientists and their institutions. Universities and investigators should make extremely clear their expectations of high ethical standards, should instill in students and new investigators the most stringent scientific ethics, and should ensure effective supervision in all research they undertake.

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Appendixes

Appendix A
The Outreach Letter

To solicit comment on the critical issues affecting the government-university partnership, the Committee sent a letter of inquiry to more than 750 persons in the federal government, universities, industry, and professional and scientific societies and associations. The Committee received 169 responses, many of them representing the views of several individuals or groups. The Committee also received responses to a similar letter, published in Science (March 26, 1982, p. 1546). The text of the letter is as follows:

> In recent years tensions have developed within the universities, and between them and the government, over such issues as reimbursement for the costs of research, the terms of financial accountability, and the regulation of research. To deal with mounting concern over these problems and their impact on scientific research, the National Academy of Sciences has appointed a Committee on Government-University Relationships in Support of Science.
>
> The Committee has divided its work into three tasks: identification of the enduring principles that should guide the evolution of the government-university partnership; examination of the principal problems in the relationship, their origin and potential for resolution; and exploration of a proposal by the National Commission on Research that a continuing body may be needed to facilitate communication between the partners and to address and promote resolution of disagreements over policy and process.

I write to solicit views on any of these areas, but particularly about the following problems that we are studying:

1. How, why, and to what extent the government and universities should share the costs of research;
2. The allowability, apportionment, and control of indirect costs;
3. The terms of financial accountability;
4. The appropriate role of the government in the support of graduate training of scientists and engineers;
5. The adequacy of support to assure up-to-date research facilities and equipment in light of the apparent limitations of the project grant system;
6. The extent to which stability, continuity, and predictability of funding can or should be assured;
7. The problems and benefits that result from our pluralistic system for support of science;
8. The advisability of establishing a more explicit national science policy, including systematic criteria for setting priorities for science and for allocating resources for scientific research;
9. The proper balance between considerations of scientific freedom and government regulation of research;
10. The effects of government policies on university-industry relationships.

Information regarding studies of these or related issues would be extremely helpful to us. We are also interested in specific examples of difficulties encountered in these areas, comments on their relative significance, and suggestions for ways to resolve them.

To be most useful to the Committee, responses should be received by April 30, 1982.

Sincerely,

BURKE MARSHALL
Chairman

A selection of these responses, organized by subject, appears below. A complete list of the respondents with their affiliations follows the selections from the letters.

SELECTED RESPONSES

1. How, why, and to what extent the government and universities should share the costs of research.

ALBERT A. BARBER:

The costs should be shared on the basis of agreement on the extent of mutual benefit derived from the research. Certain engineering DOD contracts, for example, might be expected to have less university sharing of the costs of research than certain research programs carried out primarily for graduate research training. The issue of extent of sharing was unimportant when the costs incurred by universities in support of federally sponsored research were primarily marginal costs. The cost is no longer marginal, and universities cannot be expected to subsidize costs for research programs that are considered to be of primary benefit to the federal government or to serve primarily a public purpose. Without agreement on the issue of mutual benefit, this issue will remain unsettled and there can be no "partnership."

STUART BONDURANT:

With respect to the sharing of the costs of research between universities and the government, I believe that, before the sharing issue is even addressed, there should be understanding and acknowledgment of the fact that by direct and indirect support of research in both the public and private sector the government is inescapably the principal determinant of the quality and vigor of research in this country. Thus, it is my opinion that the burden is on the government to decide as a matter of public policy how much subsidization of research support by the nation's universities is in the national interest.

LEWIS M. BRANSCOMB, JOHN B. SLAUGHTER, AND DONALD N. LANGENBERG:

Since NSF's primary mission is to support the best research ideas in the most important areas of science and technology, it adheres to the principle that the scientific and engineering communities should be broadly involved in determining directions and priorities for research. That is, within the overall policy guidelines established by the National Science Board, NSF helps scientists and engineers conduct research that _they_ regard as essential, rather than determining what research should be conducted within particular fields or how it should be conducted. It does so through institutions where scientists and engineers conduct research, most often universities. These institutions have as one of their major functions the creation of new knowledge through research and scholarly activity and accept as a primary responsibility the creation and maintenance of an environment conducive to such work. Thus, NSF _shares_ responsibility for the vitality of American research with such institutions. It follows that, as a matter of principle, the costs of such research should also be shared by NSF and those institutions.

Of course the problem of translating that principle into detailed and equitable mechanisms has occasioned considerable debate over the years. Various statutory and administrative formulas have been promulgated in an attempt to settle the problem "once and for all." In our opinion, specific formulas are unlikely to satisfy all parties involved simply because the problem of how to achieve equitable cost sharing depends on a variety of detailed and sometimes conflicting considerations.

HARVEY BROOKS:

I see no practical way in which universities can bear a larger share of research costs. Requiring universities to share costs of research is equivalent to a national decision that universities should do less research, something clearly not in the national interest. Both nonprofit research institutions and profit-making research organizations normally receive a "management fee" for the conduct of government or other sponsored research. If such a fee could be dedicated to the internal support of research in universities it might constitute a "next best" solution to the problem of internally allocable academic research funds. It is my view that even if there were no increase in total available research funds there would be strong arguments for taking about five percent of academic research funds "off the top" and allocating them to universities in proportion to their volume of government research to be used as a research fund to be managed and allocated internally by the university not subject to bureaucratic accountability in Washington.

W. KENNETH DAVIS:

Cost-sharing between the federal government and universities is reasonable and proper. However, the rules governing cost sharing should be sufficiently flexible to permit universities to use a variety of categories and to cost share to varying extents depending upon the type of support involved. For example, if the primary purpose of the research is to fulfill a specific government need, cost sharing should not be requested of universities.

KENNETH L. HOVING:

In our society, industry obtains its funds primarily through sales of products in the marketplace. Government obtains its funds primarily through taxes. But universities are not even "nonprofit"; their services are provided below costs, and they cannot levy taxes on anyone or anything. In fact, were it not for state allocations and industry/public donations, all universities would have to severely reduce faculty, equipment, and services. Thus, questions of whether universities should cost-share in research (whether through contributions of faculty time, waivers of indirect cost recovery, etc.) do not recognize these basic facts. Universities have no uncommitteed funds from which to cost-share; all costs not supported by sponsors must be borne from instructional or operational funds. And the more that universities are forced to take funds for research from these areas, the more quickly research efforts will be curtailed, or even dropped. The long-term result can only be a decline in basic research and, ultimately, a decline in technological development. This must, of course, be accompanied by a concurrent decline in national positions in world leadership and economic status.

2. The allowability, apportionment, and control of indirect costs.

JAMES E. BAKER:

Indirect cost rates for colleges and universities have been constantly increasing: as a result, greater emphasis has been given to the accountability of funds by audit. While indirect costs are based on acceptable accounting standards and are established according to Federal cost principles (OMB Circular A-21), there is a concern within the government that the increased indirect cost rates are detracting funds which would otherwise be appled to actual research.

EDWARD J. BLOUSTEIN:

. . . if universities were asked to make concessions on indirect cost rates, the federal government might consider some or all of the following steps that might lessen the burden, and hence the costs, borne by universities in administering sponsored research:

1. Multiyear rates, so that universities can be freed of annual negotiations.

2. Multiyear project awards to lessen the burden on both researchers and administrators, while lightening the paperwork burden on funding agencies. Like my earlier proposals for national institutes and centers of excellence, this step would assure greater stability, continuity, and predictability of funding, at the same time as it promotes administrative efficiency.

3. Elimination of cost-sharing requirements--or, alternately, permitting the merging of cost-sharing requirements across project and agency lines. Cost sharing has increasingly become a device for attacking indirect cost rates already negotiated by the federal government, and any adjustments in rates should be compensated by lessening or eliminating the cost-sharing burden on the universities.

4. Elimination of the time and effort reporting, which is totally contrary to the nature of the academic research enterprise, alienates the faculty from both the university and the government, and creates an uncontrollable and ultimately counterproductive burden on the funding agencies themselves.

What I am suggesting, in short, is that problems involving indirect costs, cost sharing, fiscal accountability, and continuity of funding be viewed as part of an interrelated whole so that they can be addressed not as individual debating points in an ongoing conflict but as part of a coherent policy to further the objectives of externally sponsored research at institutions of higher education.

GEORGE T. BRYAN AND J. PALMER SAUNDERS:

We feel that, in principle, indirect costs should be allowed; however, there is a broad perception among university faculty and administrators that the range, or disparity, among such costs to different institutions may be excessive. Perhaps there should be tighter restrictions and more direct demonstration of need and usage of such funds within each institution. There is at present little understanding on the part of faculty members who obtain federal research funds for his laboratory of how indirect costs are utilized by their institution. It seems appropriate that each institution should be required to demonstrate and verify how indirect costs are utilized and that this utilization should have a direct relationship to research-related activities or programs.

JOHN E. CANTLON:

I never cease to be amazed at the broad misunderstanding and intense dislike of the perfectly reasonable proposition of indirect costs. No private sector supplier of services in this country is criticized for charging the federal government the full cost of their product including the direct costs and the associated incremental portion of the overhead or indirect costs of keeping a costly corporate structure functioning. There can be no fair-minded congressman, agency contract officer, or university faculty member who can fail to grasp so simple a concept. . . .

If 90 percent of the activity in a research lab after 5:00 p.m. is sponsored research and this requires extra heat, light, ventilation, safety oversight, support staff, etc., these are additional indirect expenses for the university that are clearly traceable to the sponsored research. If a university must build and maintain additional physical plant because it is performing $50 million per year in sponsored research, why should student fees bear one-third of the indirect costs in that $50 million? Or why should state legislatures bear the indirect costs on a large overseas research project?

In my view, the present indirect cost rates are carefully audited by the particular oversight federal agency, by the federal auditors, by state auditors, by university internal auditors, and by contract and grant offices, and vice presidents for research are continually explaining them to faculty, postdocs, and graduate students. In the one institution with which I am familiar, these costs are quite reasonable. My guess is that compared with most private corporations with annual budgets of $350 million and who have similar research activities, university indirect cost rates compare rather favorably provided one makes allowances for the different styles of separating direct from indirect charges.

JOHN A. DIBIAGGIO:

In principle the present system of identifying direct and indirect costs is a good one. There is no question that indirect costs should be allowed. However, because of the enormous expenditures necessary to document indirect costs it would probably be possible to obtain consensus among universities on fixed percentage of direct costs. I do not find it inconceivable that identification of indirect costs might be abandoned if their substance could be incorporated in discretionary institutional grants. Much too much energy and attention have been devoted not only by agencies of the executive branches of government, but also by the Congress to the details of identifying and accounting for indirect costs.

IRA MICHAEL HEYMAN:

In the area of indirect costs, I would like to suggest that your Committee consider the possibility that there are programs sponsored by the federal government that should have a fixed overhead rate for all participants with no accountability required. We have a wealth of knowledge about the operation of capitation programs, training grant programs, etc., that could be utilized to cut down on the frictional aspects of indirect costs. It would appear to me that one could argue that two separate kinds of contracts could be defined for federal support--those that involve faculty members and graduate students and for which the "product" is primarily completed graduate degrees (or new scientists)--and those that involve faculty and professional research personnel with a minimum of student involvement and for which the "product" is primarily new knowledge. In the first case we would have fixed and accepted overhead rates without effort reporting, and in the second case we would have the full range of business control mechanisms, including full accountability.

KAREN M. HIIEMAE:

While there has been progress in erasing sources of friction, especially with regard to those conflicts stemming from accountability and reporting requirements (e.g., the regulations on educational cost principles recently proposed by OMB), misunderstandings between university administration and faculty researchers over indirect cost practices have persisted. In many instances, faculty perceive administrators as (1) insensitive to the problems created by escalating indirect cost rates (e.g., reduced competitiveness in future grant procurement), (2) reluctant to solicit faculty input in indirect cost matters, and (3) unwilling to adequately explain or disseminate information regarding institutional policies and procedures. At the same time, university administrators view faculty as naive with regard to the actual expenses incurred by the campus in supporting research and confused in their belief that indirect cost reimbursement represents "profit" to the institution that should be redistributed to those individuals generating the original funds.

Given the intrainstitutional conflicts that can result from such discordant perceptions, issues relevant to indirect cost recovery constitute an important area for Committee examination. The specific role of the basic principles underlying current regulations and institutional practices in fueling the adversarial relationships that currently exist should be evaluated. Their overall adequacy might also be reviewed. However, the Committee might more explicitly focus on ways in which universities can be encouraged to make concerted efforts toward diffusing existing internal tension and correcting misunderstandings within their own ranks.

JAMES D. MCCOMAS:

It is well recognized that the establishment and negotiation of an indirect cost rate is a difficult and time-consuming process, and the suggestion is frequently made that a uniform indirect cost rate be adopted for all universities. Though this is attractive in some respects, it is difficult to see how an equitable rate could be established with the tremendous differences in energy costs, with the tremendous differences in equipment available, with the different labor rates in various parts of the country, and simply because of the difference in the cost of doing business in different locations.

THOMAS E. MALONE:

In general, NIH supports the recommendation of the General Accounting Office (GAO) that if the Congress should desire to further limit federal expenditures beyond the present legislative restriction, this should be achieved through some formal ceiling on federal reimbursement, such as by requiring minimum mandatory grantee participation in total costs, rather than by limiting reimbursement on just the indirect cost portion of research. However, it should be noted that the realities of the budget process have resulted in the imposition in the President's FY 1983 budget of a 90 percent limitation on reimbursement of indirect costs of research at grantee institutions.

GEORGE E. PAKE:

The matter of controlling what some consider to be an apparent growth in indirect costs needs some careful study. Are indirect costs really growing, or are the hard-pressed universities merely becoming more able to identify allowable costs as we shift from incremental costs toward fairer full-cost reimbursements? How much of a possible increase is attributable to OSHA inspections, affirmative action reports, added litigational machinery, etc., that society and government have increasingly forced on the universities? These burdens of our accountant- and lawyer-ridden society seem to me more justly shared by a research-funding government agency than by a young would-be scientist or engineer through his tuition payments.

To sum up: indirect costs are real costs, the university is entitled to full reimbursement for direct and indirect costs of on-going sponsored research, and, if society increases the indirect costs by loading on universities functions other than research and instruction, society should pay the corresponding bill. At that, university research is a terrific bargain.

FREDERIC M. RICHARDS:

A great mistake was made in the late fifties or early sixties when the flat rate reimbursement for indirect costs was given up. We should get back to that procedure as soon as possible. The divisiveness of the present system is approaching disaster proportions.

Indirect cost reimbursement as presently carried out is simply a politically acceptable procedure for general federal support of higher education. Strong statements to the contrary on the part of the universities and the detailed and complex formulas by which these funds are calculated do not contradict this statement. There is a valid reason for the government to support higher education, but it should not be done through the indirect cost component of research support. A mechanism must be found for divorcing these two problems.

3. The terms of financial accountability.

JAMES M. BEGGS:

Financial accountability is essential to the proper stewardship of public funds, but it would be well if the cost principles could be brought more into harmony with the nature of university operations and the current requirements reevaluated to determine if all of them are actually necessary, i.e., useful and meaningful. Resolution of the "time and effort" reporting problem would be a major breakthrough.

RANDALL P. BEZANSON:

Quite frankly, I do not believe accountability is now being achieved. This is not because colleges and universities are failing to undertake the substantial and very costly efforts to establish cost accounting and effort-reporting systems, because in my experience most universities are doing so. Rather, it is because those very systems fail in their objective of achieving accountability. They have tended in large measure to reduce the scientific research effort to a system of mathematical formalism rather than substantive integrity. In the process universities have had to bear costs that will never be reimbursed. Accountability should mean that reasonable judgments are being made and reasonable efforts undertaken. Where actual financial costs can be identified, they should be; where they cannot be, judgments should be based upon the integrity and substance of the research process taken as a whole, as it is now in the context of peer review at many levels. It should, finally, be recognized that no system of administration will be perfect, but that continuing down the road we are now traveling to further accounting specificity will lead only to the shifting of responsibility for scholarship and research from the academic community to the accounting community.

CHARLES A. BOWSHER:

The federal government carries a strong mandate from the public to ensure that funds are spent as intended without diversion, waste, or fraud. But financial accountability is not an end in itself. The federal government must understand that fiscal accountability, especially in regard to basic research, is only a means of verifying that the research is actually carried out. Peer review by competent scientists still appears to be the best method of assuring that high-quality proposals are selected for funding. It also assures that the research is performed under rigorous scientific standards.

JAMES J. BROPHY:

I believe that it is absolutely necessary for universities to demonstrate to the complete satisfaction of the public and the Congress that they are fiscally prudent and accountable for expenditure of public funds. This goal can surely be accomplished, however, more satisfactorily if the present adversarial posture is eliminated. I believe that fiscal audits for accountability should be carried out by third-party private auditors following guidelines set by a single federal agency, perhaps OMB. This approach is analogous to practice in the private sector where publicly held corporations undergo third-party audit using guidelines developed by the SEC.

WILLIAM D. CAREY:

The difficulty here is that government agencies treat financial accountability and performance accountability in different ways and from different value-sets. Auditors do not interact with program officers. The government loses sight of the chief purpose of research support, which is to advance knowledge. If we calibrate how government approaches "accountability," I would say that 75 percent of the approach is on financial management and only 25 percent on technical performance and scientific productivity. This equation is upside down because it pays too little heed to the value of the work that is done. It is the value that matters. That question can be answered only through peer review and the judgments of the responsible agency program officials. I strongly believe that overemphasis on financial control diminishes the flexibility that is necessary in scientific research, which is a search-and-discovery process rather than end-product procurement. I urge that more discretion be granted to investigators in applying research funds, so as to get the most productivity out of them, and that the opinions of program officers on the reasonableness of grant expenditures and research value received be given substantial weight in judging whether financial responsibility has been exercised.

RALPH E. CHRISTOFFERSEN:

Much of the friction over the years has arisen from isses of accountability concerning the use of federal funds. Zealousness of auditors has often been blamed as a cause of the friction, but another important cause results from the basic structure of the federal research program. The government makes each award as a unique, stand-alone fiscal entity. Research universities have hundreds or thousands of awards, each project requiring careful, separate accounting. In practice, projects are often interrelated and directly associated with educational functions. In the conduct of the activities, the degree of efficiency and effectiveness desired by both the government and the institutions is often impaired by the requirement for detailed accounting for each project as a stand-alone entity.

Current exploration and experimentation of alternative, broader awards are encouraging developments that may bring benefits. Consideration of evaluating any infraction in relation to the aggregate volume of federal research of an institution, instead of in relation to an individual project, is also encouraging.

HERBERT DOAN:

We could improve if we could in some way approach funding on the basis of trust and the idea that the people close to the action normally know how best to invest money in good science. The best ideas of how to do this offend the watchdogs in Congress and the accountants and the egalitarians, i.e., block type grants, support of good departments, support of good track records, "loose" support of bright young minds, etc.

It may be we have spent enough futile effort on bureaucratic control methods that the country would be willing to try for maximum effectiveness from our best people and institutions.

ROBERT A. FROSCH:

The confusion over accounting for time arises simply because the accountants have specified that time is the appropriate management measure without understanding that that is very nearly the one thing that they are not interested in purchasing. The problem is complicated by the fact that it is not quite clear what it is that is to be purchased. One would like to purchase research results and educational results but that is so chancy that nobody is in a position to ensure that they are selling them. Therefore, some kind of effort or published result must be used as a surrogate for guarantees, and the simplest surrogate to those who are not acquainted with the difficulty would seem to be the time expended on particular tasks. However it is clear that good research people are normally capable of working on several levels at once, without being troubled by confusion between education and research, especially when what is the subject of education is in fact the ability to do research.

Even in the Office of Management and Budget I doubt that there are accountants who would suggest that the appropriate way to pay a brain surgeon is by the hour rather than the job, or that one really wants to pay a great concert performer by time rather than by performance.

STEVE A. GARBAN:

Every now and then an institution, or a faculty member, will violate the intent of time and effort. All the regulations written to date won't stop that. If a university is poorly managed, as with any business, the possibility of violation exists. The government should spend more time looking at the total system, the internal control function, and get out of the business of trying to put a stopwatch on a professor's time.

J. ROBERT R. HARRISON:

. . . the Council on Governmental Relations (COGR) has been told by the Department of Health and Human Services (HHS) (the cognizant agency for more than 95 percent of colleges and universities) that it wishes to withdraw its auditors from the campuses of colleges and universities and shift the responsibility for audits to such institutions. The Department of Health and Human Services has proposed an Audit Guide that is considered reasonable by some, but most individuals that have reviewed it believe extensive revisions are necessary. Notwithstanding the relative merits of the proposed Guide, the scope of auditing (and thus its cost) will be increased substantially if the Guide is adopted. Let me explain. Previously, HHS audited institutions with average research approximately every four or five years. A few major research universities have never had a comprehensive audit by HHS. Many small institutions have never received comprehensive audits. The Audit Guide requires an audit every two years for the two-year period by every college and university receiving federal funds. Thus, even if the audit work in the Audit Guide is the same as previously performed by HHS auditors, there is a quantum increase in scope due to this fact. Meanwhile, the Audit

Guide is believed to include more audit work than HHS auditors normally performed during their engagements of colleges and universities. How will the cost of this increase be borne? It will either be charged to indirect costs, which the federal government believes are too high already, or institutional funds will have to be used.

RICHARD L. PESKIN:

The university, and in particular the Principal Investigators, should be totally financially accountable. I do not believe in the arguments recently put forth . . . that somehow our status as university scholars exempts us from accounting for our expenditure of someone else's dollars, whether it be for equipment, supplies, or time. We desperately need federal money to support ongoing research. The least we can do is be accountable.

DAVID V. RAGONE:

Concerning financial accountability, I don't see any reason why a faculty member shouldn't state the hours worked on a research contract. Most professional people are used to keeping track of time and acounting for it. A faculty member can record the time spent on a contract without impairing academic freedom.

WILLIAM M. TOLLES:

A suitable balance must be met between the accountability required by any sponsor interested in the appropriate management of his resources, and a faculty member who must seize opportunities when possible and where appropriate. Academic research funded by one or several sponsors is supported by an uncertain stochastic process. Although the net sum of efforts in an organization may appear to undergo small statistical deviations from a norm, the effort pursued by a single faculty member is subject to large changes by the action of a single funding agency. Such large changes require some degree of flexibility in the manner of utilizing funds. Recognition of this by allowing some degree of flexibility within either a single investigator's purview or within an organized academic unit (e.g., an academic department) is essential in order to allow necessary deviations from a strict interpretation of rigid guidelines.

4. The appropriate role of the government in the support of graduate training of scientists and engineers.

SYLVIA BARUCH:

Another faculty member (a physicist) made an interesting connection between the predictability of federal funding . . . and government support of graduate students: "Unpredictability is one of the greatest weaknesses of federal funding. Several of the physical sciences suffered greatly from the sudden, dramatic decrease in funding at the end of the 1960s. This left many graduate students high and dry. The consequence was not only a decline by as much as 50% in numbers but also a substantial decline in quality. In physics, the numbers have stabilized at that level, but we have seen a marked decline in quality that is more disturbing. . . . It is not clear whether this sad condition can be reversed. In any event, the federal government must learn that the time constant for a science education is at least six years, and that adjustments in funding should be made slowly (up or down!) so as to allow students and faculty to adjust rationally to the coming change."

LEWIS M. BRANSCOMB, JOHN B. SLAUGHTER, AND DONALD N. LANGENBERG:

. . . given the fact that many, if not most, future areas of significance in science and technology are unknowable, maintenance of U.S. leadership in science and technology requires recognition and encouragement of the best-available talent across the entire range of science and engineering fields. Such potentially talented young people should, therefore, be encouraged irrespective of their association with specific ongoing research projects. It follows that the federal government has a legitimate role in providing graduate fellowship support to individuals in addition to the support provided to increase supplies of personnel in critical skills areas and in addition to assistantship support provided as a means for furthering specific research programs.

DAVID R. CHALLONER:

My personal view regarding government intervention in human capital markets is conservative. While realizing that the market perspective is particularly imperfect for individuals who require long and specialized training, I still believe that significant reliance can be placed on rate of return analyses to justify federal intervention or lack thereof to accomplish public goods.

LATTIE F. COOR:

The U.S. government must continue to assume a major role in the support of graduate training of scientists and engineers. We suggest that fellowships from government funds be available for three-year award periods with the university required to assure funding during the fourth year. This matching requirement would assure careful attention by the university to the quality of the recipient of the fellowship.

We suggest further that a block fellowship awards program to an institution be implemented, with renewal after a three-year period contingent on the number of fellows who complete training and secure employment within one year of graduation. We suggest that such a fellowship program be administered within a university and that awards be made only to senior graduate students in their final two years of study, so that they may focus their energies on completion of their degrees.

ADRIAN H. DAANE:

Graduate education has been particularly out of balance because of the availability of attractive jobs for the B.S. graduates, and, as a consequence, we are seeing the number of foreign students in our graduate programs rising with 40 percent on this campus at the present time. It is good to be able to bring in these bright students from other countries, but there is a real shadow hanging over higher education in that we are not able to provide the numbers of B.S. students from our own country that are needed for our graduate programs.

JAMES W. FRAZER:

Scientists and engineers are like fishes in the sea, to be caught, used, and thrown back. Students of high caliber are very perceptive of this attitude and either direct their careers elsewhere or seek alternative means of supporting themselves if their interests are in basic sciences or in teaching. One would have to be completely ignorant of recent history to allow oneself to be isolated in any single federal program of training. The needs of the government, and certainly of the universities, are better served by intensive fundamental training, with specialization reserved for postgraduate work.

CLIFTON R. WHARTON, JR.:

The current federal withdrawal from support for graduate students is very discouraging. Without that support, what can universities do about the critical shortage of qualified graduate students and faculty in science, technology, and engineering? In recent years, even fresh baccalaureates in chemistry, computer science, electrical engineering, biophysics, geology, and other high-technology fields command salaries in private industry that often go beyond what their professors are earning on university salaries. The federal government must resume its support of graduate students by expanding and enriching student financial support programs that can realistically compete with the draw of industry. Universities need additional resources to supplement faculty salaries in all disciplines, but especially in these high-demand fields. A program in capitation aid earmarked for faculty support would be an effective measure.

5. The adequacy of support to assure up-to-date research facilities and equipment in light of the apparent limitations of the project grant system.

ANSON R. BERTRAND:

There is a critical need to upgrade major scientific equipment utilized for research at all universities. Equipping our scientists to work at the cutting edge of science now requires an array of sophisticated instrumentation. The majority of federal research grants provide relatively low levels of funding and may provide for purchase of some small equipment. Institutions usually are expected to provide major scientific equipment such as electron microscope, spectrophotometers, chromophotographs, etc., but inflation has restricted their ability to do this. It is estimated that over 45 percent of the present scientific equipment is over 10 years old and obsolete: the Internal Revenue Service places the life expectancy of laboratory equipment at 10 years. However, some instruments become technically obsolete in 5 years or less. Replacement parts are not always available for old scientific equipment so that continued operation of old equipment often depends on cannibalization of other similar units. Old equipment generally does not have the sensitivity of newer advanced models and therefore limits research that can be undertaken. Many graduate students in science find that after they complete their advanced degree and take a job with industry they are not up to speed on the new equipment advances. The federal government and private industry should investigate ways to help universities modernize their equipment.

CHARLES A. BOWSHER:

Existing studies provide little guidance to policy makers trying to respond to a perceived laboratory equipment deficiency. There is inadequate analysis of the problem's importance to the nation's basic research effort--whether any alternatives to federal funding increases exist; and, perhaps most important, why the problem exists when tens of billions of dollars have been spent on university research in the past few decades.

For about 15 years, U.S. scientists have claimed, in studies and congressional testimony, that instrumentation available to academic researchers was inadequate, due primarily to insufficient funding. In recent testimony, various leaders of the scientific community have estimated the cost of updating university research equipment to lie between $1 billion and $4 billion. A more precise total does not exist. The variation reflects the lack of consensus on what a well equipped scientist ought to have and on the number of scientists that should be well equipped.

CHRISTOPHER C. FORDHAM III:

I would suggest that the federal government initiate an incentive program with the states, offering to provide equipment support and physical plant support, where it can be matched by state, local, and private sources. This places a burden on those constituencies, as well as the institutions themselves, gives the federal government the opportunity to be the catalyst without assuming full responsibility, and has some prospect of getting the job done.

EDWIN R. LEWIS:

Here we have a two-edged sword. Facilities and equipment are important to research, but they are not substitutes for ingenuity and diligence. If the question is whether I am in favor of federal support of a smaller number of excellent research facilities with up-to-date equipment or support of a larger number of first-rate scientists in more modest facilities, I opt for the latter. For those classes of projects deemed important by the scientific community yet requiring extraordinarily large and expensive facilities, the regional-facilities and national-laboratories concepts seem most appropriate.

IRVING F. MILLER:

It is clear to us that the project grant system for the purchase of equipment is very limited in terms of its long-run usefulness to universities. Although we can buy specialized research equipment via the project system, we cannot buy equipment that is suitable for teaching. It seems to us that we have a crisis in the univeristy, not so much in research as in science education. The facilities available for science education are currently not adequate by any criterion.

W. C. ROYSTER:

Without a major retooling of U.S. university laboratories, the next generation of American scientists may have to be trained abroad. The deteriorating state of academic laboratories makes it difficult to retain top scientists and engineers in academic institutions and forces the training of graduate students on old manual equipment that has long been replaced in American industry and research laboratories overseas. Universities are now "abnormally" far behind the cutting edge of science and engineering.

The federal government must be asked to play a part in rehabilitating university research facilities, if for no other reason than to enhance the nation's responsiveness to national security requirements. The present federal grant and contract system is inadequate to provide for the new construction and equipment costs incurred for graduate education in the sciences and engineering.

In times of financial stringency it is inevitable that not all universities can be supported by the federal government in all areas. However, federal funds for research equipment and facilities must be maintained for those universities who have demonstrated the capability to make significant contributions in research and development.

6. The extent to which stability, continuity, and predictability of funding can or should be assured.

JAMES E. BAKER:

From the point of view of both the university research community and the government, an environment of stability, continuity, and predictability of research funding is highly desirable. From the government's point of view, incremental funding arrangements, periodic renegotiation and renewal of contracts or grants, complex option arrangements, and advanced payment agreements add up to additional administrative overhead, often with questionable value accruing to the government, both in terms of fiscal control and recipient accountability. From the research university's point of view, such an unstable, unpredictable environment is costly due to delays in project renewals, funding gaps with resultant disruption of work and personnel dismissal, and unreasonable paperwork burdens. It also runs against the grain of university tradition and philosophy, which sees research and scholarship as important ends in themselves.

However, three basic differences exist between the government's and the research university's points of view that bring the universal desire for stability, continuity, and predictability into question. First, the nature of basic research itself is highly unstable and unpredictable. Long-term funding arrangements are impossible when requirements are undefineable and costs are unpredictable. Second, the requirements of the government may be unstable and unpredictable. They vary with the electorate, the administration in office, internal and external forces affecting national security and well being, and the course of science and technology. Last, since the funding of research is actually a diminutive portion of government acquisitions in total, it is often subject to the laws and regulations covering systems acquisitions.

IRWIN FRIDOVICH:

We really cannot have both the fairness and the stimulus of free competition for available funds and the comforts of stability, continuity, and predictability of funding. We could go to more five-year grants and fewer three-year grants, but any more drastic changes would be counterproductive. Over the long haul a given scientist may grow stale. It would be a mistake to provide some kind of tenured funding for research.

DAVID V. HEEBINK:

I doubt that present uncertainties can be significantly reduced. They result, I believe, from the interplay between the project grant system and our form of government. Experiments with step funding and research block grants have been tried by various agencies during the last 20 years. While such devices have helped to reduce uncertainty, at least for a time, they have themselves often become victims of budget reduction or reprogramming. Nonproject funding, such as that provided by the Biomedical Research Support Program at NIH, is invaluable in coping with the vicissitudes of the federal budget as well as more mundane matters, such as purchasing shared equipment. Indeed, formula grants of this kind can contribute significantly to research productivity; in recent years, however, their effectiveness has been seriously impaired by inadequate funding.

GEORGE W. KEULKS:

Research is not a discrete activity bounded by the temporal periods of grant funding. Most major research laboratories take years to develop, to equip, and to staff. Once in full operation, the creative process evolves and knowledge is advanced. Continuity of funding is essential to success. Budgets must be assembled and employees and students must be hired well in advance. Researchers must have some confidence of continued funding to plan their complex schedules of research, teaching, and service.

Without the assurances of some level of stability and continuity in research funding, the research agenda is severely damaged. We can see this today at national research centers where projects are being shut down and researchers are being furloughed. These activities cannot be turned on and off at will.

For many research universities, the signals from the federal government that funding will not be stable and will not be continuous is the signal to eliminate certain research activities. Many areas of knowledge will stagnate as a result.

FRANCES G. STEHLI:

Given a reliable investigator, it is obviously desirable to provide stability of funding so that the research proceeds as smoothly as possible without interruptions due to failure in funds or the need to write repeated proposals for continuation. On the other hand, not all investigators are reliable producers, and new investigators still unproven may represent a significant risk. A possible approach might be similar to the scheme now used by the National Science Foundation in funding its Materials Research Laboratories. Under this scheme a block grant would be made to an investigator or group of investigators to conduct a piece of research, and the work would be reviewed every two years. At each review period, depending on accomplishments, the grant could be terminated, held constant, or increased. The period between reviews could reflect the experience with the particular investigator or group of investigators. Consistent good productive work would be rewarded by less frequent reviews and longer grant periods. Such a scheme would test young investigators and stimulate those that were demonstrably productive and reward proven investigators with stable funding.

LUTHER S. WILLIAMS:

Stability and continuity of funding have simply fallen apart. The system, which worked 10 or 15 years ago, is functioning miserably today. . . . It is easy to decide on the top 1 or 2 percent who automatically should get continued funding. It makes sense to give some of these individuals long-term predictable funding. . . . It is not too difficult to deal with the sizeable number of requests from people who are not really doing well. . . . The problem seems to come mainly with the large group of sound productive first-class scientists who just are not famous enough or whose work is not eye-catching enough to be assured support. These individuals provide the backbone of the scientific enterprise. It is easy to demonstrate that it is not the few stars that make for the success of American science, but rather it is the sizeable number of very competent, highly functional scientists. These people are now caught in a situation where funding cannot be reasonably assured or planned upon. The number of proposals written per person has increased dramatically. The length of the proposals has in many cases increased as well. Clearly, efforts must be given to exploration of mechanisms that assure reasonable continuity in funding for a larger number of highly competent and productive scientists.

7. The problems and benefits that result from our pluralistic system for support of science.

ANSON R. BERTRAND

In general, pluralistic support of science is a form of insurance against knowledge gaps and has nurtured innovation in many disciplinary areas. In this regard, a judicious amount of replication is preferable to an unacceptable gap that could retard progress in critical and fundamental areas of national importance. Improved communication among government agencies and private sector foundations concerning plans for support of science could reduce duplication of effort and help optimize use of resources.

D. K. HESS:

Pluralistic support of university research is practical and salutary. The attainment of such support is time-consuming, difficult and demands compromises of all parties participating in the support, including the university. The federal government benefits by having others share in the costs and risks of the research. Industry benefits for the same reason as government, but in addition it can obtain a window on advance technology, which helps facilitate and speed the transfer of basic research results to the applied and developmental opportunities which are typically industry responsibility. Beyond this the partnership among industry, government, and universities develops stronger understandings and bases for science and technology. Universities benefit in many ways, including funding support, better opportunities for graduate students' employment, and exposure of faculty and students to the realistic problems of industry.

JULIUS R. KREVANS:

The pluralistic support now available for science is of great benefit in providing many points of view and funding for promising and unconventional research approaches. It is imperative, however, that the federal government as the largest partner make a more sustained commitment to those fields that are in the national interest.

E. J. MCDONALD

Our pluralistic system imposes certain burdens. The numerous sponsoring agencies . . . impose varying criteria on certain aspects of the research process. For example, FDA and HHS have issued differing regulations for the protection of human subjects. In the past, HHS issued its own interpretations of the accountability requirements of A-21, varying from those in OMB's text. OMB's proposed revisions to A-21 would permit each cognizant agency to determine whether to allow interest associated with capital equipment purchases. Differing cost reimbursement formulas exist for differing agencies. In the circumstances where research is contracted for over a certain dollar amount, additional requirements to effectuate social policy are imposed (for example, requirements that the institution utilize small and minority-owned business in its subcontracting effort) with differing reporting and compliance requirements among agencies. Such variations lead inevitably to increased administrative effort and costs for universities. Ways must be found to make more uniform those overarching regulatory requirements so as to minimize their administrative cost burdens.

DAVID MINTZER:

There is no question in my mind that the pluralistic system for the support of science is one of the great strengths of science in this country. By having a number of different possible sources of support for research, we prevent from taking hold a single point of view as to what is good research. I believe the present system, based upon a variety of criteria (using, in various cases, internal and external advisory committees), prevents the establishment of an "official view" of "good science." It is for this reason that I am, as well, against the establishment of more explicit national science policy. I believe that such things as annual reports from the National Academy of Sciences, reports from special committees and commissions, advisory groups, and so forth give sufficient direction and priorities for science and yet do not do it so rigidly that novel approaches are stifled.

8. The advisability of establishing a more explicit national science policy, including systematic criteria for setting priorities for science and for allocating resources for scientific research.

HARVEY BROOKS:

The U.S. scientific research system has become the best in the world in the absence of any systematic "rational" criteria for priority setting, and we should move very cautiously in trying to set up such criteria. The primary difficulty comes in how to apply criteria, who applies them, and what the process is. Science is too complex and dynamic in its development to be masterminded by any single group of "wise men" or "elder statesmen of science." This is not to say, however, that there shouldn't be much more discussion, both in public and among scientists, about priority questions. The danger would come only if a single school of thought were to gain control of the system. I think we do need a better system for priority setting for that part of applied research that is a responsibility of the federal government, particularly applied research that relates or potentially relates to technology assessment and to health, safety, and environmental regulation.

WILLIAM T. BUTLER:

An explicit national science policy systematically setting scientific priorities and their funding allocations would not be in the best interest of basic research or of academic institutions. It runs counter to the evolvement process of research ideas and to academic values and peer review.

LEO M. HENIKOFF:

Despite this substantial level of federal support, the government does not prepare a coordinated annual budget for R&D and issues no long-range plan for future programs and expenditures. In place of a single comprehensive policy, one can find a number of individual science policies. Increased federal obligations for academic R&D in recent years, for example, reflect an effort by federal policy makers to raise the level of support for basic research. The absence of a single codification is not an oversight. It has failed to materialize even in the face of an early legislative mandate to the National Science Foundation and numerous recommendations subsequently for development of a national policy for science. The fact that neither the federal government nor the universities have made progress in this direction suggests a preference for continuing to operate without one. Given a congressional reluctance to restrict its options and powers and an underlying fear in some university quarters that "policy" could mean "control," there is little reason to expect formulation of a policy in the near future. Instead, there is an urgent need for the Office of Management and Budget to publish annual five-year projections of scientific and technologic trends, estimated national needs for scientific resources, expected levels of federal support in various areas, and the relations of these projections to social and other factors that may affect the trend. Such projections and information would materially assist universities in their planning. They would undoubtedly enhance the effectiveness, relevance, and efficiency of the research financed by the government.

JOHN I. SANDSON:

It is true that a more explicit national science policy would probably give scientists a clearer indication of what fields of study would most likely be funded and would, therefore, provide some additional stability. Such a policy would establish goals and priorities for the nation's research and development. There are, however, some inherent dangers in such policy. Areas where promising work is being conducted but which have not been designated priorities might not receive adequate attention and funding to allow the work to properly develop. The setting of priorities is itself subjective and will change frequently--again raising problems of lack of continuity and stability. In the area of training, the setting of priorities could mean that the appropriate number of young scientists are trained in some areas but not others, some of which may well become areas of national concern.

The most desirable form a national science policy could take would be to support the recommendation of scientists for more emphasis on basic research and training so that the country can retain its leadership in the world scientific community. While government should be protecting human research subjects, using research funds efficiently, and encouraging research in the most-needed areas, it should avoid policies or regulations that stifle creativity and innovation.

HENRY R. WINKLER:

If this nation is to have the capability to remain great into the twenty-first century, we must establish an explicit national science policy and provide the necessary national resources to accomplish the goals and objectives of that policy. This policy must recognize that science is a national responsibility, and the results of accepting and satisfying this responsibility will affect every region of the country. It must also recognize that the nation's universities are the key resource in this effort, as they will train the technological experts we need and the teachers to impart scientific literacy at all levels of the educational system.

If we are to achieve these objectives, the nation must invest a larger share of its gross national product in scientific research and development. . . . Our investment in research and development has decreased 20 percent since 1965, while the Soviet Union, Japan, and West Germany have increased investment by 21, 27, and 41 percent, respectively.

9. The proper balance between considerations of scientific freedom and government regulation of research.

BARRY S. COOPERMAN:

We contacted a number of concerned faculty members at the university and asked them to comment on their experience with government regulations. On the whole, all were worried about what they perceive as a growing tendency on the part of federal agencies to haphazardly interfere with currently satisfactory policies concerning the free and open exchange of unclassified scientific information. Most of the faculty members polled agreed that if changes are felt to be necessary, clear regulations should be adopted that explicitly define the limitations to be imposed. Attempts to encourage a system of self-censorship could, because of differences of interpretation, put faculty, their institutions, and their research at risk. We would expect that any new or changed regulations would be formulated with the assistance of leaders from the academic community and would be presented to the community for comment before being adopted. Our faculty is most supportive of the concept of scientists and engineers working closely with government agencies, not only to establish needed classification criteria, but also to broaden the understanding of those outside the scientific community concerning the prerequisites that enable research to flourish.

In both areas, accountability and security controls, it would appear that any improvement in understanding the nature of the academic environment would lessen the need for regulatory measures. I would like to emphasize the strong belief of our faculty and administration that restrictions upon scientific research should be resorted to only after the most careful consideration. Only rarely will security or economic issues be at risk, while science will always be harmed, often severely. Overregulation, whether it involves cost principles or scientific exchanges, will cause us to lose more than is gained.

PAUL E. GRAY:

Another concern is that a reasonable and workable resolution of the issue often referred to as "commingling" be found. The legislation provides for federal rights in inventions resulting from research supported in any amount with federal funds. This has caused uncertainty on the part of industrial companies supporting research at universities, since they may not know in advance whether or not federal rights will be asserted. This could, although less so at MIT, be a major disincentive to increased university-industry research interaction.

EAMON M. KELLY:

Recent initiatives on the part of many universities towards acquisition of increased industrial and defense dollars have one characteristic in common--the opportunity to enter into grants and contracts that increasingly restrict publication of the results of research. There are few characteristics of universities that better define their *raison d'être* than that of academic freedom. The emphasis on tenure and faculty governance, unique among organizations internationally, results from the belief that freedom to pursue ideas without restriction is essential to academic life. Clearly, a necessary condition for the growth of knowledge is the freedom to pursue a wide variety of modes of inquiry and to continuously subject the results of this inquiry to public criticism. While increasing research involvement with industry and defense will not necessarily lead to a curtailment of free inquiry, the potential for this occurring is increasingly present.

ROGER P. MAICKEL:

I will only briefly touch on what is obviously a tender spot in the academic community. As a member of that community for 17 years, I am disenchanted by the inconsistency of many of my peers who are blatantly guilty of the following contradictory stands:

- To argue on the one hand that they must have academic freedom to do what they please, while denying the freedom of their colleagues to choose to work on projects of classified or Department of Defense research.
- To argue against policies regarding confidentiality agreements between individual faculty members and commercial organizations, while demanding personal anonymity in their peer review processes for grants and publications.

RAJAN SURI:

In recent months we have witnessed an alarming trend towards secrecy in many areas of government-sponsored scientific research, including areas quite unrelated to national security. Several of my colleagues, and I, feel quite strongly that any attempts to inhibit dissemination of results (in technical seminars, or in technical journals) will only be counterproductive, for the following simple reasons. On the one hand, it is doubtful that these measures could be enforced stringently enough to prevent any determined party from discovering the findings. On the other hand, the measures would certainly inhibit constructive scientific interaction and thus slow down the advances in U.S. science and technology.

GERALD W. THOMAS:

There are segments within the university that absolutely must have complete scientific freedom. A university must exchange ideas and publish in the open literature and have its research tested by peers. In the research area, government regulation should be as minimal as possible. There are, however, areas of vital interest to the government in which universities have great capability requiring some regulation. Since World War II a large scientific and engineering cadre, working within classified areas, has been developed that is quite able to give peer review and watch on the quality of work within that closed community equivalent to that which occurs in the open literature. It is in the interest of the U.S. government to see this aspect is also protected. The proper balance will be difficult to establish but should be considered.

JOHN S. TOLL:

The prohibition that most campuses have against secret research is not so much a protest against classified research per se as an expression of the purposes of institutions of higher education. One purpose is to provide a milieu for the pursuit and free exchange of knowledge.

We do not question the need for classification when security risks are truly involved. We are anxious, however, to be assured that classification process does not become too encompassing or that the process err on the side of classification.

10. The effects of government policies on university-industry relationships.

GEORGE M. BECKMANN:

Universities are properly sensitized to the potential hazards to open communications, to unfettered choice of research topics, to unhurried preparation of deeply grounded graduate students, etc., but these need not necessarily preclude closer relationships between industry and universities. Each institution must think through its traditions, its opportunities, its risks, and its strengths and weaknesses and relate these to potential collaborations with industry.

The government is more than an innocent bystander in all these relationships. However, the primary responsibilities lie with the university and industry partners. Government agencies must find ways to continue peer review of grants at a time when applicants may refuse to show all relevant data (claiming trade secrets potential) or when potential peer reviewers may have conflicts of interest with commercial firms.

CHARLES A. BOWSHER:

We have reviewed many facets of federal support of university research, including the processes of awarding basic research grants and ensuring accountability. Based on our work, we have concluded that the federal government must continue to provide most of the support for basic research in the United States. Despite an increasing willingness by some large technology-intensive industrial firms to enter into long-term agreements to support selected research at a few universities, private-sector support for basic research continues to be small compared to federal support. Basic research is inherently long-term and exploratory, with little or no assurance of positive results. Therefore, it is unlikely that private sources will ever replace the substantial commitments of the federal government.

JAMES O. FREEDMAN:

Greater cooperation between industry and the academic community could have a profound and positive affect on technological advancement in this country. It will not occur, however, unless appropriate tax incentives are provided to encourage industry to invest in university relations. Recent changes in tax laws regarding industrial research and development do not significantly advance this goal, and certain proposed measures for a minimum corporate tax could actually reduce some current incentives. I would certainly welcome [an] . . . effort that could fashion and promote an effective legislative plan of action to encourage greater ties between industry and the academic world.

ARTHUR G. HANSEN:

In U.S. government-industry-university interactions there appears to be an undesirable adversarial component. By contrast, such interactions in Europe and Japan appear to be symbiotic. We feel that it is important that successful interactions and cooperations should be the prime national goal. Regulations should be secondary, designed to ensure that these activities are generally benign socially, not to insist that they are conformist in managerial detail.

RALPH F. HIRSCHMANN:

Perhaps foremost among the concerns of industry in determining whether to enter into . . . a collaborative effort with a university is the limited period of exclusivity that would be available to the company for inventions and discoveries resulting from the program. An enormous investment on the part of a company in terms of money and scientific personnel is required in order to make a product available to the public. Too often, companies are unwilling to collaborate on university projects that have been "tainted" by the receipt of government money. The government, and universities, should realize that permitting an exclusive license for the life of a patent, rather than merely for a limited period of time, would more often than not result in a benefit to society rather than an unjustified windfall to a company. Government regulations and university policies should reflect that recognition.

H. E. SIMMONS:

We believe that the body of quality scientists and engineers is a national resource, the maintenance of which should have a top priority in government deliberations. Despite the support, . . . that many private-sector organizations give to education, a major portion of the basic research needed for training scientists and engineers will have to be supported by government. Private-sector support--quite properly, we believe--is provided in areas of potential commercial interest. To the extent that this is inadequate, and in other areas, the government must provide support.

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Appendix B
History of Indirect Costs and Cost Sharing

During World War II	Principle of no gain, no loss used; translated into a uniform indirect cost rate of 50 percent of salaries and wages except in large university-administered laboratories where the primary purpose was government research (e.g., Massachusetts Institute of Technology's Radiation Laboratory). In these labs the determination and reimbursement of actual costs was initiated.[1]
1947	The Office of Naval Research, then the primary supporter of university research, and the universities negotiated the first formal set of principles for determining applicable research costs.[2] These principles relied on the actual institutional costs reflected in the institution's annual financial report and introduced the use of a campuswide average rate to be applied in proportion to the size of the project. The principles accepted for the sake of simplicity a series of trade-offs that provided equitable treatment even though they were not rigorous from a cost-accounting standpoint. For example, the universities did not recover the costs of faculty effort in departmental administration (since those costs were not explicitly identified in the financial accounting systems of most universities), but costs of student administration and services were allowed instead.
1956-1958	Government Interagency Committee and representatives of universities revised the principles and

established their applicability on a government-wide basis. These were issued in 1958 as Bureau of the Budget Circular A-21.[3] They allowed for the varying circumstances of institutions, but required that methods used be consistent with sound accounting principles. In particular, costs must be justified, methods must be developed for distributing the costs to sponsored projects, and adequate documentation must be provided for the costs and the basis for cost distribution. Certain costs were declared unallowable in the determination of indirect costs and rates. A simplified approach was provided for institutions whose federal research funds totaled less than $1 million per year. In exchange for the availability of a government-wide approach, the universities had to provide more detail and documentation. The methods required more than reference to the financial report, and institutions were required to accumulate much more precise pools of indirect costs and to develop better methods for allocating these pools among the benefiting projects.

1958-1973 Five different revisions of the cost principles to respond to various needs of government and universities.

1950-1965 Department of Health, Education, and Welfare (DHEW) restricted indirect cost recovery by setting a fixed upper limit for grants. Full reimbursement was provided for contracts. The limit on grants was first set at 8 percent and then at 15 percent. In 1958 it was fixed by law at 15 percent, then raised to 20 percent in 1963 and extended to grants awarded by all other agencies.[4]

1963 Beginning of slowdown in growth of federal research and development budget.[5]

1966 Indirect cost ceiling was removed, but mandatory cost sharing on grants was instituted by language in DHEW appropriations act.

1969 General Accounting Office issued report in response to congressional request for recommendations on how to achieve a realistic and uniform formula for ascertaining indirect costs of research in educational institutions. Report reaffirmed: (1) need for flexible principles rather than uniform formula; (2) need for clarification of nature and extent of cost sharing and need for more consistency in application of cost sharing among agencies; and (3) need for more specific accounting standards in cost determination in universities.

1969 Mansfield Amendment to DOD appropriations act, requiring agency review of relevance of university proposals to agency missions.

Late 1960s and 1970s Recurring disagreements over how much of costs of sponsored projects should be recovered from the government. Increasing concern among investigators that the amount of indirect costs reimbursed to the institution reduces the amount in the agency's pool of funds for payment of costs under investigator's direct control.

1970 Department of Housing and Urban Development and Independent Agencies Appropriations Act introduces new cost-sharing criteria: (1) mutuality of interest and (2) exemption for proposals solicited by the government.

1972 Government Procurement Commission recommends elimination of cost sharing on R&D projects except for those in which performer benefits, through economic benefits or commercial sales.[6]

1976 Congressional concern about continuing increase in indirect cost payments but acknowledgement that principle of no gain, no loss was still intended.[7]

1976 Federal Paperwork Commission recommends removal of cost-sharing requirement to eliminate costly and unproductive paperwork.[8]

1975-1979 Protracted negotiations among OMB, agencies, and universities led to sixth revision of Circular A-21, which increased requirements and somewhat reduced flexibility of methods. Introduced revised requirement for effort reporting but decreased required frequency of reports. Set standard basis for distributing costs among projects (modified total direct costs).[9]

1980 National Commission on Research recommends (1) simpler mechanism for documenting salaries charged to sponsored agreements, (2) elimination of cost-sharing documentation requirement, (3) reevaluation of rationale for cost sharing, and (4) improved communications concerning indirect costs.[10]

1979-1982 Continuing efforts to adjust Circular A-21, principally with regard to effort-reporting requirements, culminating in a joint proposal for revision submitted by Association of American Universities and Council of Scientific Society Presidents.

1982 OMB revised Circular A-21 to ease effort-reporting requirements and to make the cost of interest allowable in certain circumstances.[9]

1982 DHHS proposed fiscal 1983 budget limited reimbursement of indirect costs to 90 percent of negotiated rate for extramural research grants of NIH and the Alcohol, Drug Abuse, and Mental Health Administration. Congress rejected the limit and instructed the Secretary of DHHS to undertake a careful review of the matter in consultation with universities and other agencies.

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Appendix C
History of Effort Reporting

A continuing source of friction in federal-academic relationships is fiscal accountability. Effort reporting has been a particularly contentious subsididiary issue. For many in both government agencies and universities the major concern has been the 1979 revision of the Office of Management and Budget's Circular A-21--"Cost Principles for Educational Institutions." The revised version required a report of all salaried activities for those whose salaries were charged in any degree as direct or indirect costs on a federal agreement. For such people, the 1979 revision of A-21 required in particular an accounting "for 100 percent of the activity for which the employee is compensated and which is required in fulfillment of the employee's obligations to the institution."[1] The reporting system must "reflect the ratio of each of the activities which comprise the total workload of the individual . . . and must use workload categories reflecting activity which is applicable to each sponsored agreement,* each indirect cost activity, and each major function of the university."†

The required accounting for 100 percent of workload in specific categories was particularly objectionable to many in universities, on the grounds that:

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*In Circular A-21 the term <u>sponsored agreement</u> is defined as any grant, contract, or other agreement between the institution and the federal government.

†Circular A-21 defines major functions of the institution as (1) instruction and departmental research; (2) organized research (i.e., separately budgeted research); (3) other sponsored activities; and (4) other institutional activities.

- It seemed to imply that the government fully owns a principal investigator and has a right to documentation of his or her workload even when some of it is unconnected with federally sponsored research.
- It ignored the impossibility of segregating teaching, research, and administration, especially in basic research.
- Such requirements create false categories and inevitably result in meaningless reports that may bury, not reveal, instances of improper use of federal money.[2]

Another frequent objection to the revised effort-reporting procedure was that it required the assignment of precise percentages to the workload categories. This objection was expressed repeatedly despite the revised A-21's explicit recognition that:[1]

> . . . because of the nature of the work involved in academic institutions, the various and often interrelated activities of professorial and professional employees cannot be measured with a high degree of precision, that reliance must be placed on reasonably accurate approximations, and that acceptance of a degree of tolerance in measurement is appropriate.

Many people apparently are unaware of this caveat, find it inadequate, have little confidence in its effectiveness, or are concerned about its interpretation in future audits.

The requirement for effort reporting and the objections to it are not new. Circular A-21, issued September 10, 1958, by the Bureau of the Budget, was revised in summer 1967, when the bureau introduced amendments that would have required detailed documentation of faculty effort. The intensity of the reaction against these regulations led to the formation of a task force, chaired by Cecil Goode of the Bureau of the Budget, to examine the issue. After extensive interviews involving 22 universities and more than 350 individuals, most of them faculty, the Goode report, "Time and Effort Reporting by Colleges and Universities in Support of Research Grants and Contracts," was published in February 1968. The first of its five recommendations began: "For professorial staff, drop the requirement for effort reports contained in the present A-21." The first two of the report's conclusions read as follows:[2]

1. Time or effort reports now required of faculty members are meaningless and a waste of time. They have engendered an emotional reaction in the academic community that will endanger university-federal relations if relief is not provided. They foster a cynical attitude toward the requirements of government and take valuable effort away from more important activities, not the least of which is the research involved.
2. We need to go to a system that does not require documentary support of faculty time devoted to government-sponsored research. No real evidence of faculty effort is provided anyway under the present system, and there is no way to prove how much effort was in fact expended.

As a result of the Goode report, Circular A-21 was revised but requirements for documentation of salary distribution were not eliminated. The revised A-21 required the institution to use one of two prescribed methods for reporting direct costs and gave a separate requirement for reporting indirect costs. The methods for reporting direct costs were:

• The stipulated salary support method, a new method derived from the Goode committee's efforts. It was available only for professorial and certain professional staff. The government and the universities determined stipulated salary support for each individual, on the basis of their judgment of the monetary value of the contribution he or she was expected to make to the research project. This judgment had to take into account any cost sharing by the institution, the extent of the investigator's planned participation in the project, and his or her ability to perform as planned in light of other commitments. In particular, information was required on total salary for the academic year, other research projects or proposals for which salary was allocated, other duties, such as teaching and administration, the number of graduate students for which the individual was responsible, or other institutional activities. Also stipulated were several requirements about payment methods, provision for isolation of summer salaries, handling of changes, and nature of audit.

• The payroll distribution method, in which direct costs for personal services were based on the institution's payroll system supported by either: (1) an adequate appointment and workload distribution system accompanied by monthly reviews by responsible officials and reporting of significant changes in workload of each professor or professional staff member or (2) a monthly after-the-fact certification system that required individual investigators, deans, departmental chairmen, or supervisors having firsthand knowledge of the services performed on each agreement to report the distribution of effort. Changes had to be incorporated during the accounting period and entered into the payroll distribution system. Direct charges for salaries and wages of nonprofessionals had to be supported by records of time, attendance, and payroll distribution.

Indirect costs for personal services were to be supported by the institution's accounting system, if it was comprehensive. If it was not, periodic surveys, made at least annually, were required.

The stipulated salary support method was rarely used. It was cumbersome in requiring explicit negotiation for each individual and renegotiation if additional sponsored research was awarded for the same individual. It was ambiguous about incorporating salary increases in a period in which faculty salaries were rising and about documentation and audit requirements.

Until the early 1970s, the effort-reporting requirements of Circular A-21 caused little attention, although many features were the same as those that today raise objections. At that time, federal auditors, particularly DHEW auditors, began to question the adequacy of universities' compliance with Circular A-21. Systems previously approved by federal auditors were found by new auditors to fall short of meeting requirements. Particular concerns were the absence of documentation of monthly reviews, review by nonprofessional staff rather than by individuals with firsthand knowledge of the work performed, absence of controls to prevent overlap of charges for the same activity as both direct and indirect costs, and absence of controls to prevent charging for more than 100 percent of effort.

These concerns coincided with and were influenced by growth of the federal research budget and uneasiness about rising indirect costs. The indirect costs were rising in part because of the universities' adjustment to the removal of the statutory limit on indirect costs in 1966 and the allowability of recovery of indirect costs on the basis of actual costs. By 1975, congressional concern, aimed particularly at the DHEW budget, stimulated the agency to propose revisions in Circular A-21 designed to tighten procedures for determining indirect costs and to reduce reimbursement of them.

Among the revisions proposed by DHEW was the requirement for accounting for 100 percent of employees' workload, whether charged directly or indirectly to sponsored agreements, and more stringent requirements for review of salary distributions by persons with firsthand knowledge. There ensued protracted efforts by educational institutions to mitigate the effects of these and other proposed revisions in A-21. The institutions submitted alternative proposals, including a new salary documentation system--the monitored workload system--better suited to the academic environment. Most universities recognized that the existing effort-reporting requirements were intrusive and unsatisfactory. They wanted to meet federal demands for time-and-effort accounting in the way they account for their own funds--by prospective planning and subsequent revision if changes are warranted.

The discussions among DHEW, universities, and OMB continued during 1976 and 1977. In March 1978, OMB published in the Federal Register its proposed revision of Circular A-21.

The OMB proposal caused considerable concern to universities and to DHEW. Effort reporting was one of several issues in the long negotiations that followed. OMB officials met extensively with university groups, university officials, agency representatives, and other interested parties. The Association of American Universities (AAU) and the Council on Governmental Relations (COGR), both university associations, were particularly active in these discussions. Although some universities involved faculty in discussion of the proposed revisions, faculty did not participate in the formal negotiating sessions, and the professional societies played little or no role in the discussion. However, a number of individuals as well as institutions and federal agencies submitted extensive comments on the revision proposed by OMB.

Although the objections to 100 percent reporting and the importance of the intertwining of research, teaching, and service in academic institutions were repeatedly raised by university representatives in these discussions, federal officials were not persuaded. The position of OMB was that the university by federal agreement is entitled only to reimbursement of actual costs, up to the amount awarded, and must document that the costs were indeed incurred. Furthermore, some documentation of adherence to intended purposes is required. The government officials insisted that unless 100 percent of the workload were documented, the reasonableness of an allocation of part of the workload could not be assessed reliably. They argued that assurance that the government was paying only its fair share required documentary evidence that the percentage of effort charged to a federal agreement corresponded to the effort actually expended under it.

The revision of Circular A-21 involved issues in addition to effort reporting. Some had potential for substantial impact both financially and in terms of intrusion into the prerogatives traditionally reserved to the universities. Finally, in March 1979, OMB issued the final revision of Circular A-21. Despite the extensive efforts to reconcile differences, neither DHEW nor the universities found the revisions fully satisfactory.

The OMB revision of Circular A-21 replaced the previously approved methods for salary documentation with two others: the monitored workload method (MWL) and the personnel activity reports method (PAR). The MWL method was patterned after a proposal by COGR, but the OMB version differed from the universities' proposals in six ways, three of them major. First, the revision required that every change in the distribution of effort during the year be identified, reviewed, and, if significant, documented into the system. Second, OMB restricted the monitored workload method to professorial and professional staff; the PAR method had to be used for nonprofessional staff. Third, OMB eliminated a special feature of the university proposal--that activities treated as indirect costs could be documented on the basis of an after-the-fact annual survey. Because of these modifications, very few universities elected to use the monitored workload method. The PAR system is quite similar to the after-the-fact reporting system in the previous version of A-21, although the frequency of reporting was reduced for professorial and professional staff.

As both DHEW and the universities developed materials to help implement the A-21 revision, differences in interpretation emerged. A number of universities engaged consultants to help them design systems to meet the requirements. Intermittent reports by the press of inadequate accountability in universities and audit reports setting aside as unauditable* large sums of salary charges led some institutions to be especially cautious in their response to A-21.

The full requirements of revised Circular A-21 came into effect for most universities with the fall semester or quarter of 1980. As implementation proceeded, faculty at some universities, particularly but by no means exclusively private institutions, began to object. Somewhat less concern emerged at state universities, long subject to state requirements for effort reporting. Similarly, universities, that previously had acquiesced to the demands of DHEW auditors for tighter effort reporting did not find the new effort-reporting requirements a source of major concern.

Much depended on the extent of faculty involvement in the process. To meet the A-21 requirement for review by persons with firsthand knowledge, many universities, some on the advice of consultants, required faculty to complete and sign their effort reports. Some faculty members who recalled the furor over effort reporting in the mid-1960s were deeply concerned, even outraged, that the requirement had reemerged.[3] It is not clear whether they realized the extent of the effort reporting required between 1967 and 1979. A few faculty members declined to sign the PAR reports. Many others regarded them as a nuisance and meaningless, but completed them anyway. More than 20 faculty senates passed resolutions opposing the requirements.

In 1978, the severity of the problems between the government and universities led to the creation of an independent National Commission on Research (NCR), which included representatives from universities, research institutes, foundations, and private corporations. Among other issues, the commission carefully considered effort reporting. In March 1980, in the first of five reports,[4] Accountability: Restoring the Quality of the Partnership, NCR recommended that effort reporting be eliminated as a measure of performance in federally sponsored research. In its place, NCR recommended adoption of a simpler, less costly method:

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*These audit reports did not indicate that the expenditures were illegal or improper but simply that they could not be audited under existing regulations and must be adjudicated.

- the institution would provide a report of salaries charged to research;
- the investigator would certify the charges as fair; and
- federal program officers would review the charges in light of the work performed.[4]

Many urged these recommendations on OMB, but they were not accepted.

In response to faculty concerns, university representatives together with some faculty members reopened discussions with OMB and developed suggestions for further revisions of Circular A-21. The summer and fall of 1981 saw extensive negotiations between a government task force headed by Glenn R. Schleede, then Associate Executive Director of OMB, and a university task force headed by Harold Shapiro, President of the University of Michigan. The university task force was organized by the AAU and included representatives of the Council of Scientific Society Presidents (CSSP) and members of COGR. The result was a proposal by AAU and CSSP for modification of A-21, coupled with a "Comment from a Faculty Perspective on Behalf of Effective Work." A dozen other faculty members, not part of the task force, submitted a more vigorous document, "Some Faculty Perspectives on Circular A-21."[5]

On January 7, 1982, OMB published for comment in the Federal Register (vol. 47, pp. 932-934) a proposed revision of the sections of Circular A-21 on salary documentation requirements. This proposal closely followed the AAU-CSSP proposal, but also included changes resulting from OMB's discussion of the AAU-CSSP proposal with federal agencies. OMB's final version, issued August 3, 1982, differs slightly from the proposed version. The most significant improvements are summarized below.

1. The rules adopt language recommended by university representatives with respect to the intermingling of instruction, research, service, and departmental administration. In addition, the revision states that precise assessment of factors contributing to costs is not always feasible or expected.
2. Employees are not required to confirm distribution of their activity. University officials can confirm the distribution using "suitable means of verification that the work was performed." The term "firsthand knowledge" was removed.

3. Removal of language stating that "accounting for 100% of activity for which the employee is compensated. . . ."

4. Universities may treat all activities not directly charged to sponsored agreements in a residual category; its components do not initially require separate documentation.

5. Universities subsequently may take indirect departmental expenses from the residual category by means of statistical sampling, suitably conducted surveys, negotiated fixed rates, or other reasonable methods mutually agreed to.

6. OMB prescribes no best method for documenting the distribution of personal services. Instead it offers principles and criteria and includes examples of acceptable methods for payroll distribution.

7. Where criteria for acceptable methods are met, no additional documentation is required.

8. The definition of organized research was changed to eliminate language viewed as having required reporting of voluntary cost sharing except where cost sharing is volunteered in anticipation of an award.

9. The costs of interest associated with buildings and capital equipment used in support of sponsored agreements is allowable under certain circumstances.

10. Modifications giving flexibility in handling various major functions and other changes in language provide latitude in treatment of certain costs.[6]

The revised A-21 gives universities some flexibility in designing reporting methods to fit their individual situations. Concern about substantial disallowances resulting from audit undoubtedly will stimulate university officials to design these systems with care. Universities have the opportunity to involve interested faculty in modification of current systems.

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