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ABSTRACT

This study of the relationship between academic science and the federal government was undertaken at the request of the NAS membership at the annual meeting of 1963. Three main elements were considered: the federal government, institutions of higher education, and the scientific community, most of whom were also members of teaching faculties. Among the major questions considered are: what are the policies by which accountable support can effectively advance scientific inquiry in the common interest; and how can inaccurate conceptions of both necessary freedom for scientific research and the accountability of funds be prevented from stifling the fruits of research? The discussion covers: The Role of Basic Research and the Scientist in Mid-Twentieth Century America; The Heritage Available in 1939; World War II, The OSRD Creates the Interrelated System; The Government-University Alliance, 1945-1950; Maturation of the System, 1950-1957; After Sputnik; Profile of the Government's Present Role in Science; Principles for the Project System; and The Role of the Institutions of Higher Learning in the Operation of the Project System. (JS)

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FEDERAL SUPPORT OF BASIC RESEARCH IN INSTITUTIONS OF HIGHER LEARNING

NATIONAL ACADEMY OF SCIENCES

FEDERAL SUPPORT OF BASIC RESEARCH
IN INSTITUTIONS OF HIGHER LEARNING

FEDERAL SUPPORT OF BASIC RESEARCH IN INSTITUTIONS OF HIGHER LEARNING

Committee on Science and Public Policy
National Academy of Sciences

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The present report, which is addressed to a very basic issue involving the relationship between science and our society, was undertaken by the National Academy of Sciences on the request of its membership at the annual meeting of the Academy in April of 1963. There was an overwhelming opinion among the members not only that the issue was an exceedingly urgent one to study, but also that the Academy's Committee on Science and Public Policy was a most appropriate body to explore the views of the scientific community and to formulate responsible conclusions.

On behalf of the membership of the Academy, I would like to thank the study group, including its consultants, for the high level of dedication it brought to the task.

Frederick Seitz, President
National Academy of Sciences

Washington, D. C.
March 19, 1964

Committee on Science and Public Policy

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Alvin M. Weinberg, *Oak Ridge National Laboratory*
Robert E. Green, *National Academy of Sciences,* Executive Secretary

A. Hunter Dupree, *University of California, Berkeley,* Consultant
Don K. Price, *Harvard University,* Consultant

The Committee wishes to acknowledge its great indebtedness to Professor Dupree and Dean Price for their valuable contributions as active participants in its deliberations and in the preparation of this report. It acknowledges also its appreciation of the financial support of this study by the Ford Foundation.

Preface

This report had its origin in a resolution, passed by the American Society of Biological Chemists in April 1963, urgently requesting the National Academy of Sciences "to enunciate the principles and philosophy which could serve as a basic policy in the future conduct and administration of federal programs in support of fundamental research." The resolution described the situation that impelled the request in the following terms:

"The condition of mutual dependence between the federal government and institutions of higher learning and research is one of the most profound and significant developments of our time. It is abundantly clear that the fate of this nation is now inextricably interwoven with the vigor and vitality of these institutions. In turn, the fate of these institutions is dependent upon the wisdom and enlightenment with which federal funds are made available in support of their activities. It is imperative, therefore, that the conditions governing this mutual interdependence be subject to continuing appraisal and that the policy underlying administration of federal programs in support of research assures that this relationship will continue to be mutually beneficial."

Several other scientific societies passed similar resolutions calling for consideration by the National Academy of Sciences of federal support of basic research in institutions of higher learning.

The Academy voted at its annual meeting of 1963 to undertake an appraisal of the subject as defined in the resolution. In June, the Council of the Academy asked the Academy's Committee on Science and Public Policy to prepare a report. Almost the entire membership of the Committee has participated actively in its preparation. Moreover, in response to announcements in several scientific periodicals and to personal letters soliciting the views of the membership of the National Academy of Sciences, many comments and constructive suggestions were submitted to the Committee. It is against the background of the thoughtful expression of many individual investigators, therefore, that the Committee has prepared this report, taking account of a broad spectrum of opinion among scientists. The Committee accepts full and sole responsibility, however, for its conclusions.

The resolution that called for this report was prompted by an increasing concern, both in the Congress and in the scientific community, about the principles that guide the federal government's system of science support in the universities. The sheer size of the government's financial stake in research and development might alone have triggered this stock-taking. The figure of $14.9 billion, so often heard, is not fiscal year 1964 government investment in *basic* research, but rather in its *total* research and development effort, encompassing many military and space development programs. Nevertheless, a figure of nearly $1.5 billion (this year) for basic research in the United States, of which almost half goes to institutions of higher learning, is sufficient cause for thought and discussion.

More immediately, reports of the Intergovernmental Relations Subcommittee of the House Committee on Government Operations, dealing with grant policy and administrative practices of the National Institutes of Health, have marked the beginning of a period in which government agencies have been revising their policies. Much of the discussion within the scientific community has been closely focused on administrative changes of direct consequence to the individual investigator. Even the original resolution of the American Society of Biological Chemists, however, envisaged not a narrow examination of specific issues but a study covering the general policies of all the government agencies supporting basic research in the universities. The action of the National Academy of Sciences confirmed this concern with principles rather than specific cases. The swift-moving events of the last half of 1963—the period of the deliberations relating to this report—have amply justified the wisdom of emphasizing the fundamental relationships of the government and institutions of higher learning, rather than specific incidents.

Three main elements have entered into the Committee's consideration—the federal government, the institutions of higher learning, and the community of professional scientists in these institutions, most of whom are also members of teaching faculties. These are the same three elements dealt with in the statement of the President's Science Advisory Committee entitled, *Scientific Progress, the Universities, and the Federal Government,* issued in November 1960. That report set forth a rationale for federal support of basic research in institutions of higher learning and reasons why the support of basic research and the support of graduate education must be merged. The present report is a sequel, in that it accepts the major assertions of the report of the President's Committee and moves on to consider how the donors and recipients of government support should manage their interrelationship.

One principle dominates all others in the present report: The government and the universities must work within two noble traditions characteristic of all free societies—the political freedom of a democratic people and the freedom of scientific inquiry. The scientific community, the Congress, and the Executive have long since agreed both that a strong and free development of science is a national necessity and that accountability for the use of government funds is a fundamental part of the exchange by which a people in a democracy entrusts power to its leaders, who are in fact and theory public servants. Can freedom of scientific inquiry and accountability be reconciled? We believe that they can be and must be. We ask in this report: What are the policies by which accountable support can effectively advance scientific inquiry in the common interest? How can inaccurate conceptions of both *the necessary freedom for scientific research* and *the accountability of funds* be prevented from stifling the fruits of research—a potent resource of our society not only for today but for the future?

Many important matters cannot receive full consideration here. Development and applied research claim and will continue to claim a large share of money and talent in both government and industry. In many instances, the scientific community has found the surroundings it needs for outstanding work within the walls of both governmental and industrial laboratories as well as in the universities. Moreover, the universities have essential purposes that transcend basic research, graduate education, and science itself. Nevertheless, we shall give but little attention to these considerations, and will limit our report for the most part to consideration of federal support of basic research in institutions of higher learning. It is at this point, where the universities, the government, and the scientific community come together, that the issue of reconciling scientific freedom with fiscal responsibility appears most clearly and is in greatest need of wise formulation of policy and mutually satisfactory means of implementation.

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CONCLUSIONS

The commitment of large public funds for the support of basic research in universities has led not only to spectacular growth of the scope of scientific effort but also to advances in quality: American science has reached a position of world leadership. We attribute this in no small measure to enlightened policies of several federal agencies committed to furtherance of basic research; specifically to the current emphasis on support by research project grants and by fixed-price research contracts (not too unlike grants), coupled with an extensive use of advisory scientific bodies, such as panels or study sections, to select scientifically meritorious projects for support. We believe that research project grants and contracts should remain the backbone of federal policy in support of basic research in science in universities. The emphasis on large programmatic ventures and laboratories which has been manifest in recent times must not lead to a *1*
loss of emphasis on individual scientists: the individual investigator has been and will remain the source of strength in American science.

Concerning Federal Agencies

1. The criterion of selection for grant or contract support of basic research has been primarily the scientific quality of the work proposed. The selection of projects on this basis has come about in various ways, but particularly as a result of the judgment of scientists well versed in the areas concerned. We believe this merit judgment should be retained as a prime basis for federal support. The methods of obtaining this merit judgment at present vary; the following meas-

ures will strengthen and bring greater effectiveness to the judging process.

(a) Federal agencies not presently using study sections or advisory panels for the merit rating of research proposals would improve the quality of their research programs by the adoption of these or similar devices.

(b) Membership in the panels and sections should be on a relatively short-term rotating basis, and wide circles (in terms of scientific disciplines, geography, and function) of the scientific community should be tapped for this service. This is necessary because conscientious service on such panels is very costly in time to consulting scientific personnel. Moreover, we are convinced that infusion of new blood into the sections and panels is conducive to the maintenance of high scientific standards and helps to induce the selection of the most original and promising research proposals.

(c) When panel, section, or consultant activity has resulted in ordering of proposals by scientific merit, the order suggested should be seriously considered by the federal agency staffs and modified only in special circumstances which are explained to the panel or section members.

(d) Panels and sections should not be involved in detailed evaluation of proposed budgets, although panel judgments on the general reasonableness of proposed budgets should be seriously considered by agency staffs. Detailed budget considerations should be the responsibility of agency staffs alone. However, panel or section judgments as to the proper duration of grants or contracts should be given considerable weight by the agency staffs. While panels and sections must supply the primary judgments regarding scientific merit, questions of administrative responsibility and agency policy must be dealt with by full-time staff members, and the agency itself must assume responsibility for the final decisions with regard to awards of grants and contracts. For this reason, we strongly endorse the efforts of the government to improve the quality of the career
2 service, by providing compensation at levels comparable with private salaries, and by encouraging staff members to continue their scientific and professional advancement.

(e) Consultation with scientific referees by mail is less satisfactory than the panel-section procedures. Where this procedure is used, however, it is essential to keep the referees informed as to the effect of their advice in each case. Failure to do so is bound to lead to less responsible attitudes among referees and in the end to purely administrative choices of projects. We do not believe that personnel whose main functions are administrative can for long retain keen judgment as to what is most promising in science. We believe, therefore, that purely administrative mechanisms for selection of worthy research proposals would lead to inferior programs and thus to a waste of public funds.

2. The advantages of grants generally outweigh those of fixed-price contracts for basic research. However, research contracts have been developed into legal instruments that place few restrictions on the principal investigator beyond those imposed by grant arrangements under present regulations. Unfortunately, there is a current trend toward introducing into grant and contract negotiations and regulations administrative restrictions that are inimical to effective basic research. We believe that this trend should be reversed, with the universities taking increasing responsibility for proper administration of grants and contracts.

3. We recognize and endorse the fundamental legal principle that public funds may be spent by contractors and grantees only for stated purposes, and thus that diversion of funds to other purposes cannot be tolerated. We welcome in principle the issuance of guidelines concerning the expenditure of grant and contract funds. But we discern a recent trend toward unnecessary restriction of scientific freedom and increases in the bookkeeping chores of scientists in both grants and contracts; we believe that this trend will result in lower returns on the investment of public funds in science.

4. The project proposal by an applicant states the purpose of the requested grant. The implications of this are not always understood by applicants. We believe that many difficulties could be avoided if the federal agencies, in their printed instructions for the preparation of research proposals, explained clearly the relation between the contents of a proposal and the purpose of the grant. Scientists should bear in mind in making application for grants that the preambles of their proposals define the purposes for which granted public funds may be spent. We believe that a project proposal should include:

(a) Broad objectives of the proposed research in terms of areas of scientific knowledge to be advanced. 3

(b) Specific early research objectives stated as illustrative of the broader aims.

(c) Scientific tactics (experimental methods) to be employed.

We also hold that the grant or contract instrument should explicitly recognize the broad objectives (a) as its legal purpose. Only a deviation from the broad objectives of a project proposal, thus stated, should be considered as constituting a change in the purpose of the grant, thus calling for special approval from the federal agency.

5. Current regulations concerning the expenditure of grant moneys restrict the transfer of funds from one budgetary item to

another. We believe that these regulations are quite proper insofar as they deal with the compensation of senior personnel, with travel (especially travel abroad), and with improvements in the facilities of the grantee institution. On the other hand, we believe that the principal investigator should be given maximum latitude in spending other grant moneys for the stated purpose of the grant as he sees fit. Ordinarily, so much time passes between the preparation of a proposal and the expenditure of grant funds that preferred tactics change, new equipment becomes available, and so forth. We believe that the principal investigator should be free to shift funds between budget items of equipment and expendable supplies, and that a provision that the principal investigator explain the reasons for substantial shifts, in his application for renewal or continuation of the grant, would provide an adequate safeguard against misuse of grant funds. At the very least we urge that the present limit (usually $500) on purchase of initially unspecified equipment be increased in some proportion to the total value of the grant. Thus principal investigators will be spared a great deal of wasteful paper work to obtain, necessarily, either perfunctory approvals or arbitrary refusals from remote agency staffs.

6. The accounting for part-time service of principal investigators and other academic personnel in projects supported by research grants or contracts, whether or not such service is paid for with grant funds, must be realistically related to the input of professional effort on the project. We believe that accounting for research effort in terms of time input, i.e., in terms of days or hours, is unrealistic and can lead to fiscal policies that fail to make allowances for the nature of scientific research. We recommend that accounting for effort of professional personnel on a grant or contract be expressed in terms of some fraction of the total effort applied by the individual to his university duties.

The full fiscal year of a grant, or the full academic year, is recommended as the minimum period of time for which accounting
4 of service should be made by a university. However, the time periods
in which individual scientists have no university duties, such as summer vacations, may be accounted for separately.

7. We are not competent to enter into a detailed discussion of the problem of appropriate overhead costs. We believe, however, that inadequate provision for such costs is harmful to the universities as communities of scholars dedicated to the balanced education of American youth. We urge that overhead payments be provided for, on grants as well as on contracts, based on application of essentially the same formula in both instruments.

8. While we strongly endorse the project grant/contract system of research support, we believe that three auxiliary types of

support are also necessary for the healthy growth of American science.

(a) The first of these are institutional or general research grants related to existing totals of project grants, now being made on too modest a scale by the National Institutes of Health and the National Science Foundation. These should be strengthened and broadened in purpose to overcome serious imbalances created in the universities by the growth of existing project research support and to meet the need for initial support of new projects.

(b) The second type is necessary to meet the problem of junior faculty members who have difficulties obtaining support for independent research. We believe that a system of *small research grants*—on a modest scale—should be introduced. These would be awarded to junior scientists for individual research on the basis of a very general outline of their research interests, supported by letters of endorsement from senior scientists personally acquainted with the work of applicants. Aside from an agreed sum as reimbursement to the grantee institution for work of the applicant, the budget should provide only for supplies and smaller items of equipment, but should not be broken down into component parts. The grantee investigator should, within the purpose of the grant, be allowed to pursue such researches as appear most fruitful to him in the broad area defined in the application. Some truly original ideas and discoveries have come from young scientists, and we cannot afford to tie them down to narrowly defined research objectives.

(c) The nation faces the problem, in addition to that of rapidly growing population, of an even faster-growing need for highly educated personnel. This, we believe, makes the efforts to increase the number of strong educational institutions a matter of first importance. Therefore, we urge a third type of auxiliary support: a distinct and selective program of research grants to be made available to some weaker institutions on the basis of demonstrated will to utilize new funds to raise the level of research and graduate education.
The number of strong institutions must grow. We recognize 5
that the framing of criteria by which such grants can be awarded is not an easy task, and invite careful study of the problem by a competent task force.

9. We subscribe to the conviction, expressed in the President's Science Advisory Committee 1960 report, *Scientific Progress, the Universities, and the Federal Government,* that research and the graduate education of young scientists are intimately related. Considerable progress has been made in modifying federal agency policies to adapt them to this principle since the issuance of that report. We urge continuing review of such policies in the same direction; only thus can the nation be prepared for the future.

10. In surveying the practices and regulations of the several federal agencies engaged in support of basic research, we find an extraordinary diversity. At the same time we find a growing tendency to provide the same principal investigator with multiple grants and contracts, often from different agencies, to support closely related facets of his work.

We recognize the advantages of some variation in the practices of the several agencies, and of multiple sources of support where a principal investigator is engaged in research toward several objectives. We believe, however, that the present situation forces investigators to devote too much time to detailed accounting and other non-productive administrative matters. We urge that vigorous efforts be undertaken (a) to simplify and align the requirements of the several agencies regarding preparation of research proposals, accounting, progress reporting, and similar matters, and (b) to reduce the need for multiple support by more inter-agency agreements designating a single agency to provide total support of an investigator's work in a given scientific area.

Concerning the Universities

11. A clearer recognition by university administrations of the purpose of federal project grants and contracts for basic research is an essential requirement.

12. In dealing with federal agencies, university administrations should assert more clearly and emphatically the central purpose of American universities: the advanced education of American youth integrated with the scholarly activities of teachers; in the natural sciences these activities take primarily the form of scientific research. This purpose is not inconsistent with the purpose of the federal government in providing grants and contracts for basic research. It should be stated and restated lest both the government's purpose and the purpose of the universities be obscured by the administrative practices of the agencies.

13. University administrations, certainly no less than federal agencies, can defeat the basic purpose of federal grants or contracts for project research by their policies; for instance, by imposition of unnecessary bureaucratic controls and red tape on principal investigators, or by neglect of the investigator's problems in dealing with federal agencies. We urge a more consistent policy of positive cooperation between university administrations and the faculties engaged in research under federal sponsorship. The specific organizational forms such a policy calls for depend upon local circumstances. One form, which we believe could be widely useful, is a joint committee or board, made up of representatives of the administration, the faculty engaged in research, and supporting staff.

Some of the responsibilities that should be assumed, or acted upon more consistently, by university administrations are as follows:

(a) There should be a clear definition of the mutual responsibilities and authority of university administrations and principal investigators under grants and contracts.

(b) There should be a review of research proposals by faculty personnel to ensure only that they are not inconsistent with the concept of the university as a community of scholars engaged in both education of youth and the advancement of knowledge.

(c) There should be assistance to faculty personnel in the preparation of research proposals, to ensure that the wording of the proposals will not place undue restrictions on the scientific freedom of principal investigators.

(d) Principal investigators should be educated in the responsibilities that they assume when using federal funds in support of research.

(e) There should be an explanation to faculty personnel, primarily principal investigators, of the purposes for which overhead funds and institutional grants are being spent. Understanding of this will reduce rather widespread misunderstandings among faculties and assist in developing more harmonious relations between faculties and university administrations.

(f) Principal investigators should be relieved of as much budgetary work as possible, kept informed of the status of and commitments under grants and contracts, alerted to the possibility of disallowance of certain expenditures, and in other ways apprised of essential fiscal requirements.

Concerning the Scientific Community

14. We believe that understanding of the purpose of the federal support of basic research by the project grant/contract system is not sufficiently widespread in the scientific community. Grants and contracts are given as trusts to institutions for a purpose, which is substantially as described by the principal investigator in his proposal. The investigator assumes a major responsibility in accepting federal funds and has an obligation to account for their proper use. Acceptance of a grant commits him to a conscientious effort to achieve its stated purpose; he acquires no other rights to the granted or contracted funds.

15. To make the project grant/contract system consistent with essential freedoms of scientific research, the substance of project proposals must be properly formulated. We have described (conclusion 4) the general form of proposals that should be acceptable to federal agencies and that should minimize the problem of overly restrictive interpretation of the purpose of a grant. We urge the

scientific community to present proposals in accordance with the recommendations contained in conclusion number 4.

16. The quality and effectiveness of the project grant/contract system can be no better than the scientific community makes it, by conscientious and enlightened service on panels, study sections, and other advisory bodies and as consultants in the selection of the best research proposals. We urge the scientific community to see such service in this light and to give time willingly to it.

17. In concluding our findings, we want to remind that part of the total scientific community to which we address ourselves that they, being part of the university community, are part of a society of scholars; that they have an obligation to their society: to share in the education of youth as well as in advancing scientific knowledge.

The federal government, the universities, and the scientific community have entered into an enlightened partnership whose common purpose is the advancement of scientific knowledge and the upbringing of younger cadres to continue this task. This report is but a reminder of this central fact and an attempt to set out a few simple guidelines that should reduce some mutual irritations and help the partnership in its grand purpose of advancing the welfare of our nation and of all mankind.

INTRODUCTION

The Role of Basic Research and of the Scientist in Mid-Twentieth Century America

Characteristics of Basic Research

The objective of basic research is to increase our understanding of nature. The objective of development and of applied research is to apply such understanding to human uses. Because a use for some result of basic research is not immediately apparent, it need not remain useless forever; on the other hand, it is not to be taken as inevitable that it will become useful. Centuries of experience demonstrate the likelihood that some results of basic research will prove useful and that it is often impossible to foresee before the research is carried out which results will be useful and which not. The total cost of all basic research in progress in a given period may be more than repaid by the long-lasting benefits from the uses of even a small part of the result.

By definition, the objectives of basic research, in contrast with the objectives of developmental research, are *exploration of the unknown or little known.* Frequently it becomes apparent in the course of research efforts that a different approach must be taken in order to realize anticipated objectives. It is then folly to insist on proceeding according to the original plan, and so to fail or to delay progress toward meaningful results. An investigator, necessarily being unable to describe in advance the discoveries that will be made in the course of his research, should not be expected to adhere to a course mapped out in advance. Progress is the measure of his success, and progress is initially oriented by a particular question or set of questions, by tentative experimental plans, by tentative indication of usable techniques and methods. As the investigator proceeds from such a starting point, subsequent developments may indicate that the initial plans, experiments, or methods are less promising than anticipated or even that they will not lead to significant results. Responsibility as well as wisdom then dictates that they should be replaced by other questions, experiments, or methods. Retaining the original approach runs the risk of forcing a change in the direction of the research, while a new formulation may actually be required for satisfactory progress of the kind originally anticipated.

The Scientific Community

The community of scientists is not a formal organization limited by any membership list or even by national boundaries. No single leader anywhere has an authorized right to speak for the whole of it. Membership is based on scientific accomplishment. It has been in existence at least since the seventeenth century, and over the years it has gradually developed the means of publication and continuous internal criticism by which the results of research and interpretations of them are checked and winnowed. The various fields of science are "disciplines" in the literal sense of the word, for the scientific community has developed the apparatus by which the results of its activity are continuously subject to scrutiny and criticism of the most searching sort. The great and evolving strength of this disciplinary system stems from the continuous exercise of objective judgment by the scientific community concerning the validity and significance of scientific findings. The expressions "freedom of science" and "freedom of scientific inquiry" refer to the intellectual freedom of the scientist to conduct his research and reach his conclusions in his own way, and then to test them against the judgment of his peers. These often-misunderstood expressions do not refer to special political or economic freedoms but to the reasonable contention that experienced scholars and investigators have the best prepared minds in their own fields for devising pathways to new knowledge and for interpreting what they find as they progress.

World Leadership in Basic Research Has Shifted to the United States

Though no longer a colony of Great Britain, the United States remained colonial in its research institutions long after 1776. Indeed many scientists living today grew up in an atmosphere of awe toward the great European centers of learning. When James B. Conant looked out over the assembled delegates at the Harvard Tercentenary in 1936, he could feel that his university, for all its resources, still had only a modest place among the ancient and illustrious centers of research and education in the western world. At the commencement in 1947, when he and Secretary of State George C. Marshall looked out on the assemblage and contemplated the wreck of western Europe, they both saw that the United States had a new and unique responsibility. It was on this occasion that the Secretary of State made the speech that led to the Marshall Plan. Just as the

American people responded to the call of Marshall for the rehabilitation of Europe, the American university and the American segment of the scientific community had to respond to the clear demand of history that they assume the responsibilities of world leadership.

This fundamental change of position coincides with the rise of federal support for scientific research. World leadership could not possibly have come to the United States if the government had not possessed both the enlightenment and the mechanisms to allow American scientists to take up the challenge. Yet the new leadership was not entirely a matter for self-congratulation, since it was born of the misfortunes of civilization as well as of American action. American leadership in basic research had its roots in the blood shed along the Somme and the Marne and at Verdun. The destruction of the freedom of the German university system by the Nazis played its part. Twice-sacked Louvain served as a symbol for the destruction of institutions of higher learning. One of the more inspiring features of this gloomy scene is the fact that many victims of war and totalitarianism found opportunities in the United States for the brilliant research of which they were capable.

Statistical measures give only a pale indication of the extent of the American assumption of world leadership in basic research. The percentage of Americans among the foreign memberships of the great academies of Europe went up very steeply after 1945. The award of Nobel prizes is another measure of quality in certain fields of science. In the years 1900 to 1930, Americans received only 4 of 92 awards. In the decade 1931 to 1940, the United States was still represented by only 9 of 34 awards. Yet, in the decade 1941 to 1950, the number rose to 15 of 36 awards, and, in the decade 1951 to 1960, to 27 of 52 awards, or about half. In 1933 in key British and German scientific journals, references to American work were a small fraction of all references to foreign sources. In 1963, references to American journals exceed considerably in number those to all other foreign journals. The use of such means of measurement is not necessary, however. Common observation affords massive and persuasive proof that the United States has assumed a large role in basic research since 1945.

Has Federal Support Been a Boon to Science?

The United States has achieved scientific leadership by being willing to invest heavily in science. American leadership and federal support have joined to make the mid-twentieth century a brilliant period in the history of science. The period since 1945 has been amazingly productive of scientific advances.

Physics has moved into one of the great ages of its history as experimentation with ever higher energies has made it possible to get at the particles that make up the nucleus of the atom. Without large accelerators, which cost many millions of dollars provided by federal support, physicists would be shut out from many lines of investigation. Yet these great accomplishments of experimental nuclear physics have been only part of the story. Progress in solid-state physics has been spectacular. Many groups have developed skills in theoretical physics unknown in the United States 30 or 40 years ago. Out of the basic research has come a flood of applications. The fission of uranium and thermonuclear reactions have, of course, been used in the bombs. But nuclear reactors are also used for peaceful purposes, such as the production of electric power. The theory and experiments of solid-state physics lie behind the development of the transistor. Masers and lasers, undreamed of and unnamed a few years ago, now attract both scientific and public attention. The general picture in American physics is one of vigorous activity and significant progress, with no slowing down in sight.

In chemical science, a new and deeper understanding of molecular structure and behavior has come into being, due in large part to American initiative. Skillful use of totally new and costly techniques, such as nuclear magnetic resonance, electron spin resonance, and microwave spectra, for example, has played an important role in this progress. The new understanding is the foundation beneath many of the developments of new materials for agriculture, textiles, structural materials for almost all of modern industry, power production, communications, and biological manipulation of all sorts, particularly chemotherapy. Chemistry has also been stimulated in the post-war period because its lines of research have tended to converge with those of physics and biology. On the one hand, the discovery of the transuranium elements is closely akin to nuclear physics; on the other hand, the discovery of the biological activity of nucleic acids has brought chemistry into central problems of genetics by making possible the study of the gene at the molecular level. All this work requires electron microscopes, ultracentrifuges, mass spectrometers, and similar equipment to proceed at all. No university can hope to acquire much of such equipment without assistance. It also requires many investigators trained to new standards of excellence in chemistry and, at the same time, much more aware than their predecessors of developments in other fields.

Biology has moved into a spectacular new biochemical and biophysical era marked by fruitful concentrated attacks on its simplest and most fundamental phenomena. The genetic material was shown to be nucleic acid. The structure of DNA was discovered, and this led quickly to understanding in molecular terms the reproduction, mutation, and action of the gene, and later to deciphering the genetic code. These are among the greatest scientific advances of all time. They shed a brilliant new light on age-old questions of the origin and nature of life. They have led to new insights into the nature and action of viruses, major agents of disease. Extension of all these revolutionary findings to man is initiating what will surely prove to be a period of great progress in understanding human genetics, physiology, and pathology. Side by side with these biochemical achievements, which include many other things such as deeper and fuller understanding of photosynthesis, upon which our supply of food and energy ultimately depends, have also come biophysical achievements such as those in radiation biology and electron microscopy. The latter, by opening up a new order of visibility, has revealed previously unsuspected similarities of cellular structure in all living creatures and is leading to corresponding advances in understanding cellular functioning.

The shift to biochemical and biophysical molecular biology has not, however, rendered classical fields less fertile. Ecology, animal behavior, and many other older areas have become major objects of investigation in new and promising ways. Genetics has put new life in biological research that many gossips thought moribund—taxonomy, for instance. The new style of work in biology is heavily dependent upon modern physical instruments—such as electron microscopes, ultra-centrifuges, spectrometers, scintillation counters, amino acid analyzers, computers, and the like. Skilled technical assistance is needed in their use. Again, no university is able, unaided, to keep pace with the demands.

Mathematics in the United States has moved from colonial status to a position of pre-eminence. The solution of a famous unsolved problem by George D. Birkhoff in 1913 was an American scientific landmark. Such events have been rare. Since 1959, however, young American mathematicians have contributed to the solutions of at least five problems of comparable importance. In every case, some of the work involved in these solutions was supported by a government agency. Mathematics has also moved into an important auxiliary position in almost every line of research.

The role of science in modern society has recently been described by the President of the National Academy of Sciences, Dr. Frederick Seitz, in the following terms:

"It is important to note that the first support of science in European society was provided by the enlightened aristocracy in a desire to increase that enlightenment. Everyone hoped that the work of the scientists would prove useful, but did not demand it. In this period, well before the Industrial Revolution, it was considered sufficient to get more understanding of the laws of nature relating to matter and energy, to understand more about such things as the shape and size of the earth, the distances to the moon,

the planets and the sun, and to classify the various forms of life which are found on the earth.

"Events proved that the systematic knowledge and general concepts which came out of science were exceedingly valuable in helping man to live more nearly in harmony with nature in countless ways. They lightened his burdens and made him more free. The useful aspects of science were greatly magnified once the Industrial Revolution got under way in the seventeenth and eighteenth centuries. At first, the engineer, who was responsible for the Industrial Revolution, found that only portions of science were useful, and even then, only in a limited way.

"In our century, the discoveries of science have become so complex that the scientist has had to work hand in hand with the engineer in exploiting them for practical purposes. This cooperation between the scientist and the engineer is now so close that the person who is not a professional scientist or engineer is quite apt to think of science almost exclusively in terms of applications. I wish to emphasize, however, that the uses of science for human welfare in areas such as energy conversion, communications, and medicine are always accompanied by contributions to human enlightenment which lift our minds farther and farther from the primitive origins of the past."

We believe that the scene in basic research would be far different if the federal government had not played a positive role. The federal government, the universities, and the scientific community have worked together to make this present age of science possible. Indeed, one of the outstanding accomplishments of the democratic system of government in the United States over the last 25 years had been the forging of a durable and flexible alliance between government and science. In its totality, the system of support of research in the universities by federal funds is a fine example of responsible government in action. The system has been made of different pieces at different times, and only a complicated statistical analysis can define the extent of the relation. However, from the very breadth and complexity of the system stems a lack of public understanding, even among people who have had experience with parts of it.

Clearly the system was not created in secret, as some conclude, without the consultation and support of the people's representatives—the Congress, on the one hand, and the spokesmen for the scientific community on the other. Some of the best legislative talent of a generation laboriously shaped its components, and the procedures have been thoroughly tested at every level of the government. The story of the fashioning of the system is worth the telling in brief form simply because, so well known in its discrete parts, it is so seldom put together for consideration as a whole.

BACKGROUND OF THE ALLIANCE BETWEEN THE FEDERAL GOVERNMENT AND INSTITUTIONS OF HIGHER LEARNING

I

The Heritage Available in 1939

Congress and Science

The Congress has had continuous and fruitful relations with science ever since the early days of the republic. Long before the end of the nineteenth century, it had learned some obvious lessons about the administration of science. For instance, the attempt by the Joint Library Committee to arrange for the publication of the scientific results of the Wilkes Expedition (the first major national effort in the professional use of scientists in exploration, 1838-1842) had demonstrated the inappropriateness of any attempt by Congress to oversee directly a scientific enterprise in every technical detail. Congress had played its part in the creative resolution of the problem of overlapping scientific jurisdictions when the United States Geological Survey was established in 1879. If larger appropriations for the scientific work of the government were not always forthcoming, they were not withheld after 1865 because of any theoretical doubts about the propriety of federal support.[1] The Allison Commission amply aired the whole subject between 1884 and 1886.

One characteristic of the governmental posture toward science in the nineteenth century is worthy of special note: the Congress at no time took a stand against the government's participation in basic research. Through the continuous spectrum of scientific activities, from the pursuit of knowledge for its own sake to the intensive application of the fruits of research, the government was

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[1] A. Hunter Dupree, *Science in the Federal Government: A History of Policies and Activities in 1940* (Cambridge, Massachusetts, 1957), 73, 195-214, 380. Professor Dupree's study was supported by a grant from the National Science Foundation.

naturally at all times concerned with the applications that would further its missions. Yet the rule to which nineteenth-century lawmakers gave allegiance was that the federal government should do "such work as is within neither the province nor the capacity of the individual or of the universities, or of associations and scientific societies." [2] When the ability of private colleges to conduct research was low, the federal government considered it part of its responsibility to help science as such. As Thomas Jefferson said, "a public institution can alone supply those sciences which though rarely called for are yet necessary to complete the circle, all the parts of which contribute to the improvement of the country, and some of them to its preservation."[3] The Smithsonian Institution is the major example of the federal government's commitment to basic research in the nineteenth century, but it is not the only one. In an age particularly conscious of the sphere of action of local institutions, both public and private, Congress saw the need for basic research and attempted to meet it.

The Federal Scientific Establishment before 1939

Congress opened the twentieth century with an increasing awareness of the government's need for research institutions to carry out many of its functions. For instance, in 1901 it met the constitutional demand for standards of weights and measures by changing a modest and administratively orphaned program into the National Bureau of Standards. The charter was broad and flexible enough to give the new institution a place among the national physical laboratories of the world and to enable it to cope successfully with rapidly changing scientific and technological developments.

By 1916 an impressive federal scientific establishment with its own laboratories and highly educated personnel had taken clear shape. It was responsive to the government's need for research in its own operations, such as the Army and Navy, at the same time that it served some large interests of the country that could not provide their own research. American agriculture had at its disposal a unique and flexible research service that had few parallels and was already beginning to affect the welfare of the nation in a broad way. Even so recent a development as the airplane called forth a governmental response in the creation of the National Advisory Committee for Aeronautics in 1915.

[2] [Alexander Agassiz], "The National Government and Science," *Nation*, Vol. 41 (1885), 526.

[3] Thomas Jefferson, in J. D. Richardson, com., *Compilation of the Messages and Papers of the Presidents, 1789-1897* (Nashville. 1905). I. 409.

The Constitutionality of Federal Activity in Science

Congressional enactment of legislation, creating the federal research establishment over a long period of time and in response to many different needs, provides important background for the constitutional position of science within the government. Each piece of legislation stands the test of constitutionality in terms of solving a problem of the government, rather than in terms of specific authorization in the Constitution. Science is specifically mentioned in the Constitution only in connection with patents, but among the founding fathers the advancement of science was generally considered to be closely related to the advance of political freedom and representative government. Patents, weights and measures, and the census were all matters that suggested in 1787 the interest of the federal government in activities that were to grow in range and depth with the increasing development of science and technology. By the twentieth century the growth of the government's scientific establishment was clear evidence that the power to tax for the general welfare, to regulate commerce, to establish post offices and post roads, to raise and support armies, to provide and maintain a navy, involved the power to conduct research in furtherance of government missions.

Public health provides an example of the constitutional basis for government support of research. Not mentioned specifically in the Constitution at all, public health became an object of concern to the federal government as early as 1798, when it undertook the specific task of providing hospitals for merchant seamen. Yet health is a common concern that transcends community, state, and national boundaries. Federal responsibility for public health has followed disease and the conditions that produce disease into areas where no local authority is capable of acting effectively. The commerce clause, the taxing power, the appropriation power, the postal power, the treaty-making power, and the national war power have all contributed to the development of the public health function of the federal government. In 1912, the act creating the Public Health Service stated that the "Public Health Service may study and investigate the diseases of man and conditions influencing the propagation and spread thereof. . . ." This grant of power was recognized even in the 1930's as "broad enough to cover virtually any activity in the field of public health. . . ."[4] Thus Congress has built up through its legislation a many-rooted statutory structure which upholds the government's research operations.

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[4] National Resources Committee, *Research—A National Resource* (Washington, 1938), I, 96-97.

Professional Scientists and the Necessary Conditions for Research in Government Service

In a continuous conversation with Congress over a century and a half, the scientific community also has taken a solicitous interest in the building of the federal research establishment. Those scientists who have undertaken the responsibility of carrying out research for the government and of administering the scientific bureaus have not been backward in stating the special requirements that science demands of its partner—the government. Though varying in intensity as times and issues change, these requirements are so stable that Ferdinand Rudolph Hassler, the first director of the United States Coast Survey, formulated most of them before 1842 in almost their modern form. The major requirements that one generation of scientists after another has urged upon the government may be summarized in the following propositions.

(1) *The need for long-term support.* The scientist cannot fit his experiments or the staffing and equipping of a laboratory into short periods arbitrarily laid down by a budget tied to a calendar.

(2) *The need for flexibility in objectives.* Research, as an exploration of the unknown, by definition precludes rigid projection of the shape of scientific thought and experimentation very far into the future.

(3) *Freedom to publish.* The discovery of knowledge without its communication leaves the process of research incomplete. American scientists have insisted on this point early and late, and they have suffered when it has been breached, as when the brilliant explorations of Lewis and Clark failed to have their full effect because of the lack of machinery for publication of the results.

(4) *Access to the international scientific community.* Government research, like all other research in the United States, grew up under the shadow of European accomplishments. To break communication with Europe meant not only cutting off a source of knowledge of great value but also blocking the avenue for American science to add to its stature by making contributions of its own.

(5) *The need to improve the position of the professional scientist in American society.* The people who represented science in discussions with the government were aware that pay and conditions of work were a reflection of the value that Americans placed on science, and they worked incessantly to raise that value because of their sense of what science could contribute to the national life.

Congressional Friends of Science

As the spokesmen for science urged these five themes before Congress through the years, they had to contend with many difficulties. Scientists could not attract attention by their numbers, and in the earlier periods they had trouble establishing an obvious connection between their research and the practical interests of the common man. The lament of Senator Simon Cameron, as he slashed at a $6,000 appropriation for the Smithsonian Institution in 1861, echoes down through the years. "I am tired of this thing called science here." Yet the Senate voted the $6,000 by twenty-eight to six.[5] Joseph Henry, the secretary of the Smithsonian, had friends in Congress, and scientists have in every generation had effective help from members of both Houses. The two groups—scientists and politicians—built the research establishment together.

The friends of science in Congress may or may not have constituted a majority. They have usually not had a scientific education, and their interest in science has not stemmed from any professional connection with it. Sometimes their attention has been called to the subject by people and institutions within their home districts, but usually they have discovered science as an area of public policy through their specialized work on committees in Congress. The friends of science have usually joined the scientists who appear before them in considering science "non-political" in any narrow sense of the term. As a corollary, they have come from all political parties and have often divided among themselves on other issues. It has been their constant work over the years to hold the hearings, to study the issues, to draft the organic acts, and to defend the appropriations that have made the federal scientific establishment possible.

The Status of the Various Sectors of Science Support

Great as had been the accomplishments of the government in institution-building and precedent-building for science, the years between the onset of the Great Depression and the second World War brought into sharp relief the shortcomings of the American research structure and the need for more and better research. Each of the major sectors of science support had its own tradition and internal coherence, but their greatest limitation was a lack of clear relation, even in some cases a lack of communication, between them. The four major sectors of American society that provided the support of science were: the government; the universities; industry; and the private foundations.

a. *The government:* The government's research establishment had lost some of the lustre of its position relative to other sec-

[5] W. J. Rhees, ed. *The Smithsonian Institution: Documents Relative to its Origin and History, 1835-1899* (Smithsonian Institution, *Miscellaneous Collections,* XLII-XLIII, Washington, 1901), I, 611.

tors of science support by the 1930's. The depression had meant severely cut budgets that did not rebound quickly. The bureaus had trouble holding good scientists and in securing adequate laboratories and equipment. The Department of Agriculture, with its network of experiment stations and land-grant colleges, weathered the storm better than many other agencies. The military departments were able to carry on research only at a very modest level through most of the 1930's. In terms of financial support, national security ranked well below agriculture and only a little above natural resources in the functional categories of government research and development.

b. *The universities:* In contrast, the American university had clearly emerged by the 1930's as the home of basic research. It had also, thanks to federal grant programs to the states beginning with the Morrill Land-Grant Act of 1862, developed a distinctive capability for conducting research in certain broad fields of applied science such as agriculture. Yet the American university was a strikingly recent phenomenon in the nation's experience. It had scarcely begun to take form in 1880, and much of the development of its strong and specialized departments, its laboratories, and its great research libraries came after 1900. The best creative brains of American science found a haven as professors at a small number of universities, where they taught graduate students and performed research supported in part by university funds derived from state or private sources. In part also, university research was supported by the professors themselves, in the sense that they did not render accounting to anyone for their time or for many minor expenditures. They simply did what research their other duties and their own pocketbooks allowed them to do.

c. *Industry:* Industrial research as a distinct sector had crystallized even later than the universities. The spread of the industrial research laboratory among the corporations of the United States had been one of the most striking developments of the years after World War I. And the laboratories had found for themselves an increasingly well-defined and effective place in corporate structure. More and more businesses were finding science not only a useful handmaiden in testing and production but also an organized source of innovation and diversification. In some industries, notably electrical manufacturing and chemicals, research had moved to the center of the stage. In these industries, increasing emphasis on creative thinking and basic research could be noted. By and large, industrial research was tied to corporate organization, and research as an independent business or as the function of industry associations was a minor theme. In only a few instances, where the number of economic units was large, as in the case of the Bureau of Mines, did the federal government play the direct role in industrial research to which it was quite accustomed in agriculture. The morale was high in the industrial sector in the late 1930's, and an air of confidence and self-sufficiency was evident.

d. *Private foundations:* The remaining sector, which held a position almost as a peer of the three already described, was the private foundations. Since early in the twentieth century, when the fortunes of Rockefeller and Carnegie took form as foundations, private wealth in the hands of professional foundation executives had played an important role in science. The foundations pioneered in the art of supporting science both by institutional grants, such as those by the Rockefeller Foundation's General Education Board, and by grants to individual projects—for instance, those that became common with the Rockefeller Foundation after 1928. Some had developed research departments of their own—for instance, the Carnegie Institution of Washington.

So dramatic had been the arrival of the great foundations on the American scene that they were for a time accustomed to function in areas that, in other periods, might be the responsibility of some other sector. The worldwide medical programs against yellow fever and hookworm were on a scale suggestive of government rather than private action. And, between the wars, grants from the foundations had supported such efforts at coordination of the national research structure as were being made by the National Academy of Sciences and the National Research Council. The support of President Franklin Roosevelt's Science Advisory Board by the Rockefeller Foundation, between 1933 and 1935, gave evidence of activity in an area very close to the public purposes of the government itself. The very effective National Research Council fellowships, earmarked for science, came from the private foundations. Yet in the late 1930's the foundations, their own capital funds battered by depression, could see little prospect of rapid expansion of their resources.

Thus the sectors of science support existed alongside one another in the late 1930's, each with a tradition and a self-sufficiency of its own. Each one felt that it had a clear mission independent of the others. The universities did basic research; the government did applied research related to its own missions and served a few special groups such as the farmer; industry applied science in its own laboratories; the foundations alone kept up a slight interchange with the other sectors, but even they thought in terms of special missions peculiarly appropriate to themselves. The interrelated system—the totality of arrangements by which the sectors of science support work together—which has developed since the 1930's consists of a tight interweaving of all the sectors, and the government has taken its place at the center of the system. The key link that will concern us henceforth in this account is that between the government and the institutions of higher learning. It was a weak link in the late 1930's, so weak that many denied its existence at all, and its strengthening was a crucial factor in making the world a different place almost overnight.

Scattered Indications of Impending Change

A few portents in the 1930's foreshadowed the interrelated system as the postwar world has come to know it. In hindsight, one can almost see it coming even before the crisis of World War II, which intervened and hastened it. The establishment of the National Cancer Institute in 1937, as a part of the Public Health Service, brought with it grants-in-aid to private institutions as well as advanced training programs. The National Advisory Committee for Aeronautics had close ties with aeronautical engineering departments in leading universities and made a number of contracts for special investigations. A few scattered advisory committees to government agencies kept open a channel to university scientists. An unsuccessful try at a comprehensive organization was made by Karl T. Compton as chairman of the Science Advisory Board between 1933 and 1935. A new self-consciousness concerning the role of research is reflected in the studies of the National Resources Planning Board, which attempted an analytical and statistical profile of the sectors of science support and their relations. Indeed, the title of those studies, *Research — A National Resource*, was to become the watchword of the new system.

Yet, as warclouds gathered around the world before and after Munich, the critical question for science in the United States stood out starkly clear: Could research affect military events quickly enough to determine the outcome of the war? The modest research programs of the armed services were entirely inadequate in the new situation. There was no time to build new laboratories and train new career scientists to enter government service. The only realistic hope for deploying science lay with the university scientists and laboratories, and the weakness of the existing link between the government and university science made formidable the task of bringing the two together.

II

World War II: The OSRD Creates the Interrelated System

The Wartime Leaders of Science

By creating the National Defense Research Committee (NDRC) in 1940, and by expanding it into the Office of Scientific Research and Development (OSRD) in 1941, President Franklin Roosevelt provided the new framework of government-university relations even before Pearl Harbor. The link between universities and government research for national security had been established in a remarkably complete form. One of the many contributions the scientific community made to the war effort was the leadership that proposed this channel and then made it work. Four men from among a great many deserving scientists may be mentioned as providing this crucial administrative leadership: Vannevar Bush, James B. Conant, Karl T. Compton, and Frank B. Jewett. Chance plays a part in the good fortune of the United States here. The group possessed just the right combination of youth and seasoned experience. Only Jewett had played a role at high levels in World War I, and yet the others had had major administrative experience in the 1930's to season them.

Bush, Conant, Compton, and Jewett had an importance beyond their own personal qualities, impressive as those were. They were, in an unofficial way, representatives of the various sectors of science support. Conant, of course, was a distinguished chemist and president of the oldest and most prestigious private university in the country. Compton had within a few years made the Massachusetts Institute of Technology into the nation's leading scientifically oriented technical institution. Jewett was both a senior leader of industrial research, as president of Bell Telephone Laboratories, and the recently elected president of the National Academy of Sciences. Bush had served as a professor of electrical engineering and as a vice-president of M.I.T., but he was now in the strategic position of president of the Carnegie Institution of Washington. He also was chairman of the National Advisory Committee on Aeronautics. Thus all the sectors of science were handsomely represented by men who commanded major respect, and Bush, an engineer at home in the universities, private foundations, and government research, was the natural spokesman of the movement. These men had an effective knowledge of the whole sweep of American research institutions and their scientists. Their job was to determine the military needs of the country and relate them to the research capability they knew to exist in the universities and industrial research laboratories. The need was so great that considerations of field of science and institutional affiliation made little difference. Nor could long-run effects on the science establishment, such as the supply of scientists for future years or the accumulation of basic knowledge, take precedence over the cardinal requirement of adequate weapons to win the impending war.

Policies of the OSRD

After a year's trial with the NDRC of 1940, an executive order of June 28, 1941, created the more comprehensive OSRD, of which Bush was director. This order set up the Committee on Medical Research as parallel to the weapons-oriented NDRC. Although many of the basic decisions were made between June 1940 and June 1941, we shall for convenience use the designation OSRD in describing the salient characteristics of the system. It operated no laboratories of its own. It did not supplant projects already under way under the Army and Navy. It made contracts with both universities and corporations. It early adopted the principle that the contracting institution should neither make a profit nor suffer a loss as a result of OSRD research. This led immediately to the allowing of a charge for overhead costs not easy to specify in the contracts. Since by definition these costs were hard to determine, the OSRD adopted for educational institutions the formula of 50 per cent of the actual labor payroll involved in a project.

The urgency of war placed its stamp on every OSRD decision. No distinctions were made between private and public universities, or between land-grant and non-land-grant institutions. Where work could be broken down into small lots, investigators were left at their own institutions. When great concentration was necessary, as in the case of the Radiation Laboratory at M.I.T., the institution was chosen purely on the ground of its ability to perform the work. In this case Karl Compton avoided a conflict of interest simply by refraining from taking part in either the discussion or the decision.

The OSRD was early confronted with the problem of delimiting its mission. Because in the twentieth century all parts of the spectrum of activities from basic research to its applications are dependent on one another, the OSRD could have gone off in a number of directions. Most of the key men, both on the panels doing the selecting and among the investigators chosen, were university-connected and had worked on basic research before the war, so that the organization might have been expected to favor basic research at least covertly. Or it might have sought immediate applications from the introducers of new designs and mechanisms, the inventors. Or it might have used its contracts deliberately to change the pattern of research institutions in the country along some preconceived path. It could have taken up the responsibility of providing general research service to industry in such fields as large-scale synthetic rubber production. However, it early set its face against those who wanted any or all of these things. As time went on, the OSRD became less and less concerned with the basic research end of the spectrum and more and more concerned with development, but no diminution in the reliance on university scientists accompanied this shift.

The OSRD Contract

The OSRD contract for research and development deserves special mention. As Irvin Stewart wrote at the end of the war, the "heart of the contract problem was to reconcile the need of the scientist for complete freedom with assurances that government funds would not be improperly expended." [6] The procurement contracts in use by the Army and Navy were not well adapted for research and development, so that the legal division of OSRD set out to provide an instrument of sufficient flexibility to accommodate both the government and the scientist.

The United States of America was one party to the contract, an institution the other. "Whereas, the Government desires that the Contractor conduct studies and experimental investigations

[6] Irvin Stewart, *Organizing Scientific Research for War: The Administrative History of the Office of Scientific Research and Development* (Boston, 1948), p. 19.

as hereinunder specified requiring the services of qualified personnel, and whereas the Contractor is willing to conduct such studies and experimental investigations on an 'actual cost' basis. . . ." described the essential transaction. By 1944, the OSRD made a distinction in function within its own staff by designating in the contract a "Contracting Officer," to be responsible for the business and fiscal aspects of the work, and a "Scientific Officer," usually a chief of division, to direct the scientific aspects. Not specifically mentioned but strongly implied, both by the phrase, "qualified personnel," and by the fact that an object of research was specified, was the existence of a scientist or group of scientists to take over the responsibility for the work at the contracting institution. Indeed, the principal investigator was often already at work gathering a staff and beginning operations, on the basis of a letter of intent, before the contract was signed.[7] Thus the OSRD by its contract assembled the entire cast of the new system of government support: the fiscal officer and the scientific officer on the government side; and the university administrative officer and the principal investigator on the university side.

The contract laid down the rules for cost determination (of salaries and overhead, for example), disposition of property, responsibility of the contractor, and patent and security provisions. In each of these matters the OSRD set important precedents and educated large numbers of people in the government and in the universities in the fundamentals of the new support system for research.

Congress and Science during World War II—the Kilgore Subcommittee

How did Congress and the American people get the opportunity to approve or disapprove the OSRD? Some had thought of asking for legislation in 1941, but the urgency of the times argued that it be done by executive order under temporary war powers. An announcement of the formation of the agency was published, but the need for security so sheltered it that Stewart, as executive secretary, could handle public information and Bush, as director, could handle congressional liaison all by themselves. A tacit agreement between Congress and OSRD tended to give force to Bush's insistence, which went all the way back to the beginnings of the organization, that it was a purely temporary agency. Once the emergency was over—once the narrow objective of weapons for this war had been accomplished—the OSRD had no thought but to place science and the agency before Congress for fundamental decisions about the shape of the future.

[7] Standard form 1001 of the OSRD contract appears in *ibid.*, pp. 339-346.

So great was the obvious relevance of science to the war effort, however, that not everyone was willing to wait until the shooting was over to find out whether the OSRD's strictly delimited program was adequate. Senator Harley Kilgore, Democrat of West Virginia, arranged major hearings before a subcommittee of the Senate Committee on Military Affairs in 1942, 1943, and 1944. Senator Kilgore and his staff came at the whole problem of science and government from the point of view of war industry. Hence they stressed patents, inventions, industrial research for small business, and the imperfect utilization of technical manpower. Since the OSRD started with a problem and tried to find the men best qualified to work on it, it took no responsibility for the scientists, often geologists or biologists whose specialties were not in great demand, who were left outside the war effort. And, since the OSRD had long insisted that it was not working on materials or methods of wide use in industry, it did not concern itself with supplying research support to war industry generally. Hence the Kilgore Subcommittee aimed at an organization to work in such an area. On July 8, 1943, a group of senators, headed by Kilgore and referring directly to his hearings, asked James F. Byrnes, then Director of War Mobilization, to set up a central scientific and technical body. Among the 23 signers, both parties and all major geographical regions were well represented.

Science—the Endless Frontier

Bush, already on record as opposing Kilgore's big agency for scientific and technical mobilization, became increasingly aware, as the successful conclusion of the war in Europe loomed up, that a major reorientation of scientific support was on the way. His oft-reiterated intention of closing down the OSRD at the end of the war had the effect of forcing a full-dress examination of science's role in American life. And that examination would eventually have to be made in the public arena, with fundamental legislation the result. But first the scientific community, if it did not wish to be caught unawares, should examine the postwar support of science and come forward with a program. Although the OSRD could not by itself take up the study of the shape of postwar science, it formed a natural framework. Therefore, President Roosevelt, in a letter dated November 17, 1944, asked Bush for his recommendations. The letter carefully referred to the OSRD as "a unique experiment of team-work and cooperation in coordinating scientific research and in applying existing scientific knowledge to the solution of technical problems paramount in war." The letter asked Bush to give his considered judgment personally, "after such consultation as you may deem advisable with your associates and others." Roosevelt thus empowered Bush to convene an advisory committee-of-the-whole of the scientific community to answer four questions. They were:

"First: What can be done, consistent with military security, and with the prior approval of the military authorities, to make known to the world as soon as possible the contributions which have been made during our war effort to scientific knowledge? . . .

"Second: With particular reference to the war of science against disease, what can be done now to organize a program for continuing in the future the work which has been done in medicine and related sciences? . . .

"Third: What can the Government do now and in the future to aid research activities by public and private organizations? The proper roles of public and of private research, and their interrelation, should be carefully considered.

"Fourth: Can an effective program be proposed for discovering and developing scientific talent in American youth so that the continuing future of scientific research in this country may be assured on a level comparable to what has been done during the war?" [8]

Bush, having made his opportunity, took advantage to the fullest by appointing distinguished committees to study each of the four questions. The committees for questions three and four, headed by Isaiah Bowman and Henry Allen Moe, respectively, were the ones that considered in detail most of the features of the government-university link. A committee representing medical research in the universities had its say on question two. While university men, especially presidents, predominated on all the committees, the other sectors of science were also represented. The only major group not represented as such (although Bush, Conant, I. I. Rabi, and perhaps a few others bridged the gap) were the atomic scientists, still hidden even from the OSRD by compartmentation within the confines of the Manhattan project. As nearly as one could expect the scientific community to have a voice, it had one here.

Bush's report, *Science—the Endless Frontier,* attempted a profile of American science and a prescription for the future. The basic principle of the interrelated system appears in the body of the report.

"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,

[8] Vannevar Bush, *Science—the Endless Frontier: A Report to the President on a Program for Postwar Scientific Research* (Washington, 1945, Reprinted 1960), pp. 3-4.

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. For many years the Government has wisely supported research in the agricultural colleges and the benefits have been great. The time has come when such support should be extended to other fields.

"The effective discharge of these new responsibilities will require the full attention of some over-all agency devoted to that purpose. There is not now in the permanent governmental structure receiving its funds from Congress an agency adapted to supplementing the support of basic research in the colleges, universities, and research institutes, both in medicine and the natural sciences, adapted to supporting research on new weapons for both Services, or adapted to administering a program of science scholarships and fellowships.

"Therefore I recommend that a new agency for these purposes be established. Such an agency should be composed of persons of broad interest and experience, having an understanding of the peculiarities of scientific research and scientific education. It should have stability of funds so that long-range programs may be undertaken. It should be recognized that freedom of inquiry must be preserved and should leave internal control of policy, personnel, and the method and scope of research to the institutions in which it is carried on. It should be fully responsible to the President and through him to the Congress for its program."[9]

The National Research Foundation envisaged in the Bush report had about it a comprehensive nature that matched the situation into which it would move. It would have a Division of Medical Research and a Division of National Defense parallel to its Division of Natural Sciences. The Foundation was to have the power to "make contracts or grants for the conduct of research by negotiation without advertising for bids." [10] Many characteristics of the OSRD were included, such as the principle that the research should be "conducted, in general, on an actual cost basis without profit to the institution receiving the research grant or contract." [11] No geographical or other formula was proposed because the "Foundation must . . . be free to place its research contracts or grants not only with those institutions which have a demonstrated research capacity but also with other institutions whose latent talent or creative atmosphere affords promise of research success." [12] In general it was envisaged that the National Research Foundation would adopt

[9] *Ibid.*, pp. 8-9. [10] *Ibid.*, pp. 36-37.
[11] *Ibid.*, p. 39. [12] *Ibid.*

the historic goals of scientists in their relations with the government and extend them to the contract-grant system of tying the universities to public purposes. At the same time, the Bush report was explicit on the ultimate responsibility of the President and Congress. "Only through such responsibility can we maintain the proper relationship between science and other aspects of a democratic system. The usual controls of audits, reports, budgeting, and the like, should, of course apply to the administrative and fiscal operations of the Foundation, subject, however, to such adjustments in procedure as are necessary to meet the special requirements of research." [13]

The End of the War

Science—the Endless Frontier, which did not mention uranium or fission or nuclear energy, appeared the same month as the Alamagordo test—July, 1945—and only a month before the world learned of the atomic bomb with Hiroshima. Dramatic impact made atomic energy seem like a separate area of science policy to be dealt with as a thing apart. Indeed it proved to be, as the creation of the Atomic Energy Commission in 1946 showed. But meanwhile the problems attacked in *Science—the Endless Frontier* had their day in Congress. Senator Kilgore introduced a bill which represented his long-standing interests, while Senator Warren G. Magnuson introduced a bill embodying Bush's ideas.

On September 6, 1945, President Truman, in a special message to Congress on reconversion, set the keynote of the discussion when he said: "No Nation can maintain a position of leadership in the world of today unless it develops to the full its scientific and technological resources. No government adequately meets its responsibilities unless it generously and intelligently supports and encourages the work of science in university, industry, and in its own laboratories." In calling for a single federal research agency for science, Truman clearly confirmed the concept of an interrelated system of "universities, industry, and Government working together," and promised in unmistakable terms the freedom demanded by the nature of science. "Although science can be coordinated and encouraged, it cannot be dictated to or regimented. Science cannot progress unless founded on the free intelligence of the scientist. I stress the fact the Federal research agency here proposed should in no way impair that freedom." [14]

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[13] *Ibid.*, p. 33.

[14] *Public Papers of the President of the United States, Harry S. Truman, 1946* (Washington, 1962), pp. 292-294.

The Kilgore-Magnuson Hearings

Senators Kilgore and Magnuson arranged jointly for hearings on science legislation which lasted through most of the fall of 1945, and gave the wartime leaders of science and many others a chance to express themselves on the shape of the future for science in the United States. The striking thing about these hearings is that every one of the witnesses except one supported the principle of some sort of science foundation in the government. Senator Kilgore led off by saying: "As the war has so dramatically demonstrated, science is a national resource of the greatest importance for our whole national life. Scientific skills and scientific know-how have enabled us to win rapid and decisive victory on the war fronts. The same skills and know-how must now be converted and expanded to meet the needs of peace- the improvement of our national health, the security of our national defense, the promotion of our prosperity." [15] As one eminent scientist put it, "we require the mass will of the people as expressed by the Government. Science and technology need the direct help of the Government. The Government needs ever more urgently the help of science and technology." [16]

Yet below the level of this large fundamental agreement, tensions predictable in a democracy's first public airing of an unfamiliar concept promptly emerged. *Science—the Endless Frontier* had proposed a part-time board of people otherwise unconnected with the government, not merely as an advisory body but as a responsible head of the agency—appointing the director, formulating over-all policy, and making grants and contracts. Senator Kilgore's bill favored a straight-line organization, with the director appointed by the President. Harold Smith, then director of the Bureau of the Budget, was strongly of the same opinion, equating the responsibility of the director with the control of public funds. "I believe that the most important principle involved in these bills is that an agency which is to control the spending of government funds in a great national program must be a part of the regular machinery of government. If the government is to support scientific research, it should do so through its own responsible agency, not by delegating the control of the programs and turning over the funds to any nongovernmental organization." [17]

President Edmund E. Day of Cornell University, representing the Association of Land-Grant Colleges and Universities, advo-

[15] "Hearings on Science Legislation," Hearings before a Subcommittee of the Committee on Military Affairs, U. S. Senate, on S. Res. 107 and S. Res. 146, 79 Cong., 1 Sess., October and November 1945, p. 1.
[16] Harlow Shapley, *ibid.*, p. 48. [17] *Ibid.*, p. 96.

cated a formula by which a percentage of the foundation's funds would be distributed to the land-grant institutions, making "as a counterweight an independent, Federally financed program administratively directed by the important public institutions in the several States. . . ." [18]

On this issue, Harold Smith and the Bureau of the Budget were on the side of *Science—the Endless Frontier* and geographically unrestricted grants and contracts. The "proposed foundation should be free to support the advancement of knowledge in any institution which, in the judgment of the foundation, is able to do effective and competent research." He went on to link the freedom of the foundation to support excellence, in specific packages wherever found, to the ability of the government to safeguard the use of the taxpayers' money.

"Only by specific contracts, rather than general purpose contracts, can it make sure that it is supporting in each institution only the type of research which that institution is qualified to perform. This is not to say that it will restrict the proper degree of freedom of research, or impose a narrow type of administrative supervision over the institutions with which it deals. But it would obviously be improper and ineffective to give funds to private institutions without some assurance of their ability to further the purpose of the program, and the foundation must have freedom to select the institutions that are able to do so." [19]

The patent problem occupied more hearing time than any other. In general, Bush stood for the OSRD practice of leaving patents in the hands of contractors whenever possible, while Kilgore hoped for government ownership of patents produced in the course of government-supported research. As it became clearer in the course of the hearings that the foundation would support basic research rather than industrial applications, more and more witnesses expressed doubt that science legislation was the place to reform the patent system.

The Failure to Make the National Science Foundation Parallel the Atomic Energy Commission

Despite the broad areas of consensus evident in the fall of 1945, legislation for a foundation did not clear both Houses of Congress until 1947. The seriousness of the organizational issue was demonstrated by the subsequent veto from President Truman.

"Our national security and welfare require that we give direct support to basic scientific research and take steps to increase the number of trained scientists. . . . However, this bill contains

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[18] *Ibid.*, p. 794. [19] *Ibid.*, p. 96.

provisions which represent such a marked departure from sound principles for the administration of public affairs that I cannot give it my approval. It would, in effect, vest the determination of vital national policies, the expenditure of large public funds, and the administration of important government functions in a group of individuals who would be essentially private citizens. The proposed National Science Foundation would be divorced from control by the people to an extent that implies a distinct lack of faith in democratic processes." [20]

The failure of legislation to emerge in 1946, the last session of the Seventy-Ninth Congress, is partially explained by the bitter controversy over atomic-energy legislation. Two of the main issues dividing the May-Johnson bill from the MacMahon bill—organization of the commission, and patents—were parallel to the issues dividing the opposing forces on the science legislation, which reflected the dissension more faithfully than it reflected the urgency of atomic energy as a policy area. The closest students of the legislative history of the Atomic Energy Act of 1946 have noted that "many thousands of Americans had expended millions of words in public debate. . . . The final bill was not what any single one of them would have written. Yet, it was probably better than any individual could have produced. In this fact, perhaps, lay the secret vitality of American democracy." [21]

In the case of the science foundation, the congressional ability to be cautious in the face of conflicting philosophies dominated the result for the time being. But the vitality of American democracy had already been at work to create the interrelated system. The need for it had outrun the ability to create over-all institutions, and even before the war's end practical arrangements were being made by Congress and the Executive to insure the nation against the limitations in the organization of government-supported science that had prevailed in the 1930's. The OSRD would go out of existence, but the system it created had to live on.

[20] *Congressional Record,* Appendix (August 14, 1947), pp. A4442-A4443.

[21] Richard G. Hewlett and Oscar E. Anderson, *The New World, 1939-1946 (A History of the United States Atomic Energy Commission,* Vol. I, University Park, Pennsylvania, 1962), p. 530.

III

The Government–University Alliance, 1945-1950

Postwar Reconversion

The determination not to return to the 1930's, only dimly sensed by scientists who had served in the wartime projects, was explicit in the minds of those responsible for national science policy. Europe, for the first time in American history, could no longer be relied upon to send over a sufficient stream of basic research results relevant to the rapidly changing frontiers of science and technology. The need to revive a free flow of information was acute, but the need to begin new knowledge from the basic end of the scientific spectrum was the only hope for a healthy growth of technology. Because the universities had almost shut down graduate education during the war, a shortage of scientific manpower was also in everyone's mind; fellowships were needed to close the gap in the ranks created by the war's diversions.

Military and civilian leaders in all the services were especially insistent that the partnership with university scientists be continued. James V. Forrestal, Robert P. Patterson, and General H. H. Arnold emphasized it as a necessity when they appeared at the Kilgore-Magnuson hearings. General Eisenhower, as Army Chief of

Staff in 1946, made a particular point of the Army's commitment to basic research. He advocated a separation of "responsibility for research and development from the functions of procurement, purchase, storage, and distribution." [22] In short, the military itself did not wish to lose its new-found partnership with science. Without the OSRD, it had the choice either of building up its intramural laboratories or of maintaining by contract its liaison with the university scientists. And the choice was really not free, for few scientists in 1945 and 1946 were willing to accept civil service careers in the government laboratories. Therefore all the services had ultimately to think in terms not only of keeping as much classified and applied research as possible within their own laboratories, but also of making contracts with the men who, after having performed prodigies in the defense laboratories during the war, were now back on university faculties thirsting to work on basic research problems rather than hardware.

The Office of Naval Research

The Navy, for various reasons, made the clearest and earliest response to the necessity for a contract program after the end of the war. Men at several levels in the Navy had been thinking about the future of science in the Department at least since 1942.[23] As a result, the Office of Research and Inventions was, by September 1945, under way on re-allocated funds and ready with proposed legislation that would give congressional approval to its operations. The Vinson Bill, which became law in August 1946, became the charter of the Office of Naval Research. The act's preamble indicates the comprehensive vision of the founders of ONR:

" . . . to plan, foster, and encourage scientific research in recognition of its paramount importance as related to the maintenance of future naval power, and the preservation of national security; to provide within the Department of the Navy a single office, which, by contract and otherwise, shall be able to obtain, coordinate, and make available to all bureaus . . . world-wide scientific information and the necessary services for conducting specialized and imaginative research. . . ." [24]

The ONR Act provided, in addition to ample authority to make research contracts, for a Naval Research Advisory Committee.

Thus, the ONR possessed all the elements of a model program for the interrelated system. It had a direct administration

[22] Quoted in Don K. Price, *Government and Science* (New York, 1954), p. 57.
[23] The Bird Dogs, "The Evolution of the Office of Naval Research," *Physics Today*, XIV (1961), pp. 30-35.
[24] 60 Stat. 779. 79 Congress, 2 Sess. Ch. 727—August 1, 1946.

with a regular navy officer as director. In practice the chief scientist served as deputy director and headed a staff of program directors knowledgeable in particular fields. The advisory committee and a large number of subsidiary committees and panels brought eminent scientists in from the universities on a part-time basis to help the Navy decide what projects to support. As soon as word got around, ONR did not have to solicit proposals from the scientists; they came in a flood. The ONR officials did, however, have to establish rapport with university administrations to convince them to make the contracts which would allow the scientists to go to work.

In their missionary work with university presidents, the ONR representatives had to convince administrators, already harried by the dislocations of war and the returning flood of G.I.'s, that they should take on navy contracts for research. The document they used was already far from the straight military procurement contract. "Contracts are not new to the Navy, but the idea of conducting contractual relationships in the field of basic research with independent agencies and institutions . . ., using tasks instead of specifications, is a new departure in Government contracting." [25]

The men who made the ONR a success in the eyes of both the Navy and the universities had a driving belief in four major propositions:

"(1) The primary aim of much of the Planning Division's scientific program is free *rather than directed research. Instead of being pointed toward direct solution of some practical problem, its intention is to explore and understand the laws of nature, both animate and inanimate."* [26]

"(2) Practically none of the basic research work conducted by the Navy is in a confidential or secret status." [27]

"(3) We want to have listening posts in various scientific fields and we want to maintain contact with the most imaginative people in science." [28]

"(4) To date, there has not been established a unit similar to the proposed National Science Foundation; nor has any agency, other than the Office of Naval Research, indicated its willingness to accept even pro tempore *some of the associated responsibilities."* [29]

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[25] Office of Research and Inventions, *Annual Report*, 1946, p. 63.

[26] *Ibid.*, p. 108.

[27] Admiral P. F. Lee, "National Science Foundation," Hearings before the Committee on Interstate and Foreign Commerce, U. S. House of Representatives, 80 Congress, 1 Sess., March, 1947, p. 209.

[28] E. R. Piore, "Some Thoughts on Federal Science," *Physics Today*, VII (1954), p. 13. [29] Office of Naval Research, *Annual Report*, 1947, p. 1.

University officials suspicious of military domination eventually came to believe the ONR.

It might be asked how a military agency could achieve rapport with scientists, even while the National Science Foundation legislation was stalled because too many scientists feared a single director appointed by the President, and insisted on a part-time board. The answer lies in the fact that the Navy recognized the level at which the independent advice of scientists was at that time most needed. No general board, or even the Naval Research Advisory Committee of fifteen members, could constitute an adequate representation of all the disciplines and subdisciplines of science. Therefore it set up an extensive network of advisory committees by fields of science to assist in the screening of research proposals. In 1948 the list of fields under consideration included: geophysics, astronomy, mathematics, chemistry, undersea warfare, fluid mechanics, psychophysiology, biochemistry, human ecology, physiology, microbiology, and psychology.

From the point of view of the government, re-establishing scientific merit as the major criterion for spending money, and obtaining the most reliable and experienced university scientists to make the decisions, meant the best available insurance to the taxpayer that there would be no waste. Who, other than a microbiologist, could judge the scientific worth of a proposal in the field of microbiology? From the point of view of the investigator making the proposal, the advisory committee represented one of the most ancient and cherished rights of the Anglo-American legal tradition—the judgment of his peers. From the point of view of the university, even the largest of which did not have enough microbiologists to form a disinterested jury, the national committee relieved the local administration of the necessity of making substantive decisions on individual projects. For the advisory committee members, who were by definition the men with the best reputations for research, life began to include periodic trips to Washington.

Other networks of advisory committees spread over Washington in the postwar years. The four groups brought together by the OSRD contract for weapons research—the scientific program director with his advisory committee in the agency, the agency's contract administrator, the administrative officer in the university, and the principal investigator in the university—were brought together in a close partnership in the name of basic research by ONR. By 1949, the agency had expenditures of the order of $20,000,000 for 1,200 projects in 200 institutions, engaging nearly 3,000 scientists and 2,500 graduate students. It was to that time "the greatest peacetime cooperative undertaking in history between the academic world and the government." [30] If a serious flaw existed in the effective Navy program between 1945 and 1950, it was that the American people did not know that they had a productive partnership between government and their universities.

The National Institutes of Health

In the organization of the government-university partnership, medical research has always been a special problem area. The problems stemmed, on the negative side, from the increasingly heavy costs of both medical care and medical education. The medical schools in universities reflected these problems, and the OSRD was set up in part to give medicine special administrative handling in the Committee on Medical Research. On the positive side, no field offered more promise in the peacetime world envisaged in *Science—the Endless Frontier* than did medical research. A people who had entered the war without penicillin emerged from it with altered expectations. A reproach against the federal research establishment in the early 1900's had been "that more pains are now being taken to protect the health of farm animals than of human beings." [31] Because of the strength of the Department of Agriculture, this taunt was still valid in 1945, though clearly neither the Congress nor the people accepted the situation as an expression of their will. The result was pressure to do something in medical research. The National Research Foundation of *Science—the Endless Frontier* was not ready. The OSRD was closing down. The Public Health Service seized the opportunity, not merely because its leaders were ambitious, but also because the Congress had already prepared them for the task by statute.[32]

Much was made in the 1945 discussion of the inadvisability of a research agency with extramural contracts also operating in its own laboratories. *Science—the Endless Frontier* recommended against it, and the Atomic Energy Commission had only contract laboratories. Many old-line agencies that did not develop significant extramural programs—the National Bureau of Standards and the Geological Survey, for instance—have found the postwar decades a period of trial.

The Public Health Service was unimpressed by this seeming incompatibility. It had an impressive program of intramural research in its Hygienic Laboratory, which after 1930 was called the National

[30] Office of Naval Research, *Annual Report,* 1949, p. 1.

[31] Irving Fisher, *A Report on National Vitality: Its Wastes and Conservation* (Washington, 1909), p. 126.

[32] D. C. Swain, "The Rise of a Research Empire: NIH, 1930 to 1950," *Science,* Vol. 138 (1962), pp. 1233-1237.

Institutes of Health. It had begun making grants-in-aid to medical schools through the National Cancer Institute, established in 1937. Observation of the effectiveness of the Committee on Medical Research led the National Institutes of Health of the war period to become enthusiastic about research in universities as an adjunct to their intramural program. Therefore, in the Public Health Service Act of 1944, Congress conferred upon the Surgeon General of the Public Health Service the power to "make grants-in-aid to universities, hospitals, laboratories, and other public or private institutions, and to individuals for such research projects as are recommended by the National Advisory Health Council, or, with respect to cancer, recommended by the National Advisory Cancer Council." The next year, R. E. Dyer, director of the National Institutes of Health, testified at the Kilgore-Magnuson hearings that the Public Health Service already had "all of the authority in reference to health and medical research that is contemplated for the proposed foundation." [33]

Since authority is one thing, and money is another, the Public Health Service Act of 1944 did not assure the future of the National Institutes of Health as a major source of support of medical research; nor did it assure the future of the grant instrument as the most important means of linking university research to the government. In 1944 and 1945 the Bureau of the Budget withheld permission from the Public Health Service to seek funds for a grant program in general medical research. Only when the OSRD Committee on Medical Research went out of existence, and its contracts were transferred to the National Institutes of Health, did the nucleus of an extramural grant program come into existence. Thus it was the National Institutes of Health that carried on beyond OSRD in medical research. By 1951, when a National Science Foundation came into existence, the National Institutes of Health expenditures for health research were of the order of $30,000,000, more than half of which was spent through extramural grants. The pattern of the congressional appropriation exceeding the budget proposal sent up by the President had already put in an appearance.

The National Institutes of Health system of research support bore striking resemblances to that of the Office of Naval Research. The grant, a simple letter from the agency to the institution stipulating in broad terms the purpose of the research and the financial aspects of the transaction, brought the responsible officer of the government and the responsible administrative officer of the university into essentially the same relationship as that created by the Office of Naval Research contract. The investigator presented his proposal

[33] "Hearings on Science Legislation," p. 514.

describing his research in a similar way. The study sections of the National Institutes of Health, which corresponded to the advisory committees of the Office of Naval Research, were organized by fields of medical research to obtain the part-time advice of leading university research men. Thus the government again gained the assurance of quality and the investigator gained the judgment of his peers.

Some significant differences appear between the two operations, however. In the first place, while medicine depends on basic research in many sciences, it is itself an applied science with a highly specific object, the human being. The National Institutes of Health could argue for broad and fundamental studies, but it could also argue the practicality of its research in a way that the Office of Naval Research could not, at least if it were to maintain its flexibility. In the second place—also related to the nature of medicine—the National Institutes of Health could serve uniquely well in promoting certain lines of research. Diseases made such obvious targets that even the members of the appropriations subcommittees in the House and Senate could see areas such as cancer chemotherapy and virus study as worthy of special emphasis.

In the third place, the Office of Naval Research's Naval Research Advisory Committee, even though set up by law, had less specific authority than the Advisory Councils of the National Institutes of Health, which by statute had to recommend a grant before the Surgeon General could act. Thus the voice of the scientist was more authoritative in the National Institutes of Health than in the Office of Naval Research, however similar the practices of the two agencies. Finally, the grant-in-aid, as applied by the National Institutes of Health, was explicitly and unequivocally a support for research and not a purchase of research. In practice the Office of Naval Research contract also supported research rather than purchasing it, but the government's vast machinery for procurement contracts put the Office of Naval Research at a theoretical disadvantage.

Other Niches Occupied—AEC and Weapons Research

The period 1945 to 1950 saw other agencies profit by the example of OSRD and fill niches left by its demise. The Atomic Energy Commission could and did contract with universities for much research on a project basis. But it also built upon the university-operated laboratories inherited from the Manhattan District to create a system of national laboratories. Oak Ridge provided the site for one, close to operating plants of the Commission. Others, notably Argonne National Laboratory at the University of Chicago and the Lawrence Radiation Laboratory at the University of California, had close physical and intellectual ties with their universities.

In the case of Brookhaven National Laboratory on Long Island, the Atomic Energy Commission made its contract with Associated Universities, Incorporated, set up by several eastern universities for that purpose.

The national laboratories were technically institutions that conducted contract research, and much public commentary concerning the government-university interrelated system actually refers to incidents and arrangements at these famous institutions. Actually their work is not in the same category with project research performed by individual professors on campuses. A single contract may well cover an entire laboratory, with its large scientific and supporting staffs and its huge and costly machines. The laboratories have traditions of free research, and the red tape of administering such large organizations rests but lightly on the investigators. The laboratories play a significant role in graduate education, and they have carried the United States to pre-eminence in many fields of physics which, without large-scale government support for expensive and highly specialized equipment, could not have been entered at all.

The armed services, in the throes of unification and faced with the prospect of the cold war, had to evolve a weapons-research establishment after the end of the war without benefit of OSRD. The Office of Naval Research and contract programs in the other services provided for a continuing link between the military and the universities, but, as the diplomatic stalemate with the Soviet Union set in, and as weapons became so unconventional that research, relative to production, became an ever greater percentage of military expenditures, two major trends became evident. One was the heightened emphasis on intramural research by the military departments. The other was the increasing use of the research contract to purchase development on weapons systems from both profit and non-profit corporations. While not directly related to the government-university thread of this account, the contracts in the weapons area have had the indirect but sometimes almost overpowering effect of adding to the over-all cost figures for research and of increasing the demands on the scarcest commodity of all, brainpower. Moreover, the research and development contracting officers, becoming accustomed to dealing with profit corporations, tended to apply the same procedures to research contracts with universities.

The Steelman Report

In spite of the accomplishments at the working level which put the Office of Naval Research, the National Institutes of Health, and the Atomic Energy Commission laboratories and many university scientists to work, the failure of the immediate postwar reconversion to deal explicitly with the arrival of university science as a major national resource aroused concern. A feeling of unease led President Truman to appoint a President's Scientific Research Board under the chairmanship of John R. Steelman. Urgency and a sense of competition still radiate from the major recommendations of that committee, dated August 27, 1947:

"(1) That, as a Nation, we increase our annual expenditures for research and development as rapidly as we can expand facilities and increase trained manpower. By 1957 we should be devoting at least one per cent of our national income to research and development in the universities, industry, and government.

"(2) That heavier emphasis be placed on basic research and upon medical research in our national research and development budget. Expenditures for basic research should be quadrupled and those for health and medical research tripled in the next decade, while total research and development expenditures should be doubled.

"(3) That the Federal Government support basic research in the universities and nonprofit research institutions at a progressively increasing rate, reaching an annual expenditure of at least $250 million by 1957.

"(4) That a National Science Foundation be established to make grants in support of basic research, with a director appointed by and responsible to the President.

"(5) That a Federal program of assistance to undergraduate and graduate students in the sciences be developed as an integral part of an overall national scholarship and fellowship program.

"(6) That a program of Federal assistance to universities and colleges be developed in the matters of laboratory facilities and scientific equipment as an integral part of a general program of aid to education.

"(7) That a Federal Committee be established, composed of the directors of the principal Federal research establishments, to assist in the coordination and development of the Government's own research and development programs.

"(8) That every effort be made to assist in the reconstruction of European laboratories as a part of aid to peace-loving countries. Such aid should be given on terms which require the maximum contributions toward the restoration of conditions of free international exchange of scientific knowledge."[34]

Any member of the public who wished to could read these recommendations, and, thus having before him the agenda for the next decade, should not have been overly surprised at the devel-

[34] President's Scientific Research Board, *Science and Public Policy* (Washington, 1947), I, pp. 6-7.

opment of federal support for science in the decade 1947-1957. In fact, the Steelman Report's target figures were in every case far under the actual totals for fiscal 1957.[35]

[35] A comparison of the Steelman Report target figures and fiscal 1957 shows:
Expenses Fiscal Year 1957

	Projected in 1947	Actual 1957
I. Percentage of National Income for Science	1%	2.26% (1)
II. 1. Total Research and Development in U.S.	$2,240,000,000	$10,030,000,000(1)
2. *All* Basic Research in U.S.	440,000,000	834,000,000(1)
3. All Medical Research in U.S.	300,000,000	397,000,000(2)
III. Basic Research supported by Federal Government outside its Own Laboratories	250,000,000	311,000,000(1)

(1) National Science Foundation, *Reviews of Data on Research and Development*, No. 33 (NSF62-9) (April 1962) (Tables 1a, 2a, and 7).

(2) U.S. Congress Senate, *Federal Support of Medical Research*. Report to Subcommittee of Committee on Appropriations, United States Senate, 86 Cong. 2 Sess. (May 1960), p. 77, (Table 22).

IV

Maturation of the System, 1950-1957

The Belated Creation of the National Science Foundation

Since the interrelated system developed so vigorously in the late 1940's, the impulse for a National Science Foundation could have been sustained only by people who still felt that important values were involved. The friends of science in Congress never let the idea die even after the veto of 1947. The Senate passed a bill regularly, so that the main discussion shifted to the Interstate and Foreign Commerce Committee of the House, where the late Representative J. Percy Priest carried the main burden in behalf of the 45
legislation.

On the scientists' side, an Inter-Society Committee for a National Science Foundation brought together a group through which the nation's scientific societies could scrutinize the complexities of the legislative process and keep in touch both with congressional staffs and with the Bureau of the Budget, who, of course, handled the examination of the drafts of legislation for the Administration. The patent issue was largely laid aside as the conviction grew that the Foundation would concentrate on basic research. The organization of the National Science Board and its relation to the Foundation gradually yielded to a compromise in which the President appointed the director as well as the board, to whom certain direct powers of approval for grants were reserved.

As applied research dropped out of the concept of the Foundation, the bill became easier to pass because of the disappearance of the patent issue, but harder to pass because basic research was not clearly and obviously related to the missions of government agencies. The major addition to the concept of the Foundation in these years was the coordinating role in the government research establishment. This feature brought in the support both of those who feared inefficiency in government spending and of those who thought of over-all planning as a necessity if science was to be directed to national goals. In 1950, after the sponsors of the bill had accepted a $15,000,000 ceiling on appropriations (less than the Office of Naval Research was using for contracts and the National Institutes of Health for grants), the National Science Foundation Act passed both Houses of Congress and was signed by President Truman.

By 1950, Congress had clearly adopted the attitude that research required broad and flexible legislation. Under the National Science Foundation Act of 1950, the new foundation was authorized and directed:

"(1) to develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences;

"(2) to initiate and support basic scientific research and programs to strengthen scientific research potential in the mathematical, physical, medical, biological, engineering, and other sciences, by making contracts or other arrangements (including grants, loans, and other forms of assistance) to support such scientific activities and appraise the impact of research upon industrial development and upon the general welfare. . . ." [36]

In some respects the Act said even more about government science policy than its substantive provisions stated. Geographical distribution of research funds by formula—the formula of the land-grant college system or other—was rejected. And the National Science Board was not specifically made representative of particular fields of science. But the legal requirements for membership carried with them the implied policies. Members "(1) shall be eminent in the fields of the basic sciences, medical science, engineering, agriculture, education, or public affairs; (2) shall be selected solely on the basis of established records of distinguished service; and (3) shall be so selected as to provide representation of the views of scientific leaders in all areas of the Nation." Implied here was a check on the power

[36] 64 Stat. 149 (1950). (Public Law 507—81 Cong.)

of the government and a safeguard to a free science. Indeed, a minority report by six senators on an earlier version of the bill had put this apprehension concerning too strong a director into words.

"The Administrator . . . will plan and direct a science program with the full force of two hundred or three hundred million dollars per year. He can ignore the Board's advice in any field he chooses regardless of his competence in that field; he can ignore their advice in all fields and dictate his own ideas. . . .

"Today our educational institutions are proud of their independence and freedom. If in a few years they become dependent upon funds from the Federal Government . . . they will not be able to resist the authority for dictation of this Czar of science,—the administrator. Only those schools . . . satisfying one man will receive the Federal money."[37]

If one proposition is fundamental to the whole postwar debate regarding the structure of science and its link to the government, it is that few—either in Congress or in the scientific community—wished a czar of science. The Act of 1950, by its construction of the National Science Board and the Division Committees, expressed the judgment of Congress that the system of advisory scientific panels was a legal and necessary part of the government's machinery.

The Young NSF and the Choice of the Grant Instrument

The first director of the National Science Foundation, Dr. Alan T. Waterman, moved not in the direction of becoming a czar, but to set up a system of support for basic research that would justify its stewardship of the taxpayers' money by careful scrutiny of each project by non-government scientists. As the former chief scientist of the Office of Naval Research, Waterman adopted many of its ground rules and practices.

At the same time, the young National Science Foundation was aware of the precedent in the National Institutes of Health for using grants in the support of research. Because of the breadth of the National Science Foundation Act, the Foundation was in a position to make a choice of the legal instrument best suited to the needs of supporting basic research in the universities. As a working paper used in the Foundation in July, 1951, put it, "recognizing the inherent heterogeneity of basic research and the difficulty of fostering its conduct through a single administrative mechanism, the Congress has provided the Foundation with a sufficiently liberal

[37] Kurt Borchardt, "Congressional Use of Administrative Organization and Procedure for Policy-Making Purposes: Six Case Studies and Some Conclusions," *George Washington Law Review*, XXX (1962), pp. 440-441.

grant of authority to meet almost any conceivable admixture of need."[38] According to the working paper analysis, "unquestionably the arrangement most widely used by governmental agencies for supporting research is the contract. . . . In theory, at least, there is a *quid pro quo* relationship between the parties to the contract; but in practice, through a gradual (evolution) of the contract form in recent years, this relationship tends to become less rigid and to take on some of the attributes of a cooperative or grant arrangement."[39]

A grant, on the other hand, according to the working paper, "is, in a formal sense at least, a unilateral action by one party by which a sum of money, property, or other valuable consideration is given to another party for accomplishment of an agreed-upon purpose."[40] After reviewing the "elaborate overload of financial and property accountability which has often proved excessively burdensome to both contracting parties" in the use of contracts, and pointing to the wide use of grants by private foundations as well as the Public Health Service, the working paper commended the grant to the Foundation's use. "Because of its flexibility, the grant is most appropriate to undertakings in which initiative and freedom of action play a decisive role and in which the production of *some* beneficial result is more to be sought than attainment of a set goal in a prescribed manner."[41] When the National Science Foundation chose the grant, it added a new dimension to the interrelated system. The Office of Naval Research definition of basic research and its organization of advisory committees were wedded to the legal instrument of the National Institutes of Health, creating an organization highly satisfactory for the continued alliance between university scientists and the government. With little money and an excellent system of advice, the National Science Foundation quickly established a reputation for responsibility in the administration of its grants.

Mission-Related Basic Research

A major problem that faced the National Science Foundation in its early years was finding a rationale for basic research independent of any of the particular missions recognized by the government. An assumption that had some currency in the early years was that the National Science Foundation would "take over" in the form of transfers the basic research already being performed by the Atomic Energy Commission, the Department of Defense, and various other agencies of the government. If this happened, one could say that the mission of the National Science Foundation was basic

[38] "Working Paper on Techniques of Fostering Research," dated 7/23/51, NSF Records. [39] *Ibid.*, pp. 3-4. [40] *Ibid.*, p. 5. [41] *Ibid.*, p. 6.

research, especially in the universities, while the Navy would support applied research related to its mission. Although some people took some time to get over this simple notion, it soon became clear that major transfers were impractical and that the well-established agencies could make a strong case for continuing their university contracts. The fundamental reason for this was that basic research activities and applied research activities had become so intertwined that the various agencies of the government felt a need that was no less urgent because it did not fit accepted definitions—the need for "mission-related basic research." If such a category were admitted, was there a real need for a National Science Foundation, after all?

The answer of the Eisenhower Administration to this question was "yes." In Executive Order number 10521, dated March 17, 1954, arrived at after extensive consultation, President Eisenhower said,

"As now or hereafter authorized or permitted by law, the Foundation shall be increasingly responsible for providing support by the Federal Government for general-purpose basic research through contracts and grants. The conduct and support by other Federal agencies of basic research in areas which are closely related to their missions is recognized as important and desirable especially in response to current national needs, and shall continue." [42]

While this did not say anything that the Congress had not already said in a number of organic acts, the reiteration confirmed the Foundation's mission as "general-purpose" basic research. At the same time it gave other agencies grounds to argue that they had full scope to conduct mission-related basic research. Such a plural system made possible the support of basic research in a variety of different ways, and assured those concerned with missions in health and weaponry of vigorous scientific activity in their areas among university scientists. A National Science Foundation that consolidated everything called basic research might have become rich and powerful quickly, but the plural linkage added much to the strength and flexibility of the interrelated system.

The National Science Foundation took the attitude that fostering mission-related basic research in other agencies strengthened science as a whole. To make the plural system described in Executive Order 10521 even more effective, and to make rapport between other government agencies and university scientists easier, the National Science Foundation encouraged the passage of legislation in 1958 by which Congress authorized all federal agencies to use grants

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[42] Executive Order 10521, March 17, 1954, reprinted in National Science Foundation, *Fourth Annual Report, for the Fiscal Year Ending June 30, 1954*, pp. 118-119.

instead of contracts for the support of scientific research. The law, in effect, put both the National Science Foundation and Congress on record as favoring basic research in widely dispersed agencies of the government.

The Strengths and Limitations of a Plural System

The virtues of the plural system of the mid-1950's were many. The investigator had several chances to seek support for his ideas. The steady flow of proposals, the periodic gathering of the panels and study sections, the judgment of peers, the grant letters and contracts which emerged, became a settled and familiar pattern in the government. The interplay of actions that determined the proportion of federal funds allocated to each field tended to produce a kind of balance in which rapid changes of priority assigned to different fields were hard to accomplish. Indeed, no clear mechanism existed for making priority decisions, either among fields or among agencies.

Occasionally a special circumstance could produce some change in priority. The International Geophysical Year, an event that required the contribution of many countries to a coordinated series of experiments probing the entire environment accessible to man or his instruments, was occasion for a deliberate change in priority. Congress fully supported the emphasis by appropriations. But the plural system allowed such a shift to occur only when the most careful, vigorous, and foresighted action joined an especially appealing opportunity. An external event which disturbed the even tenor of the plural system was sure to create a demand for a more vigorous coordination of the government's role in science.

In a system in which a plurality of executive agencies supported science in a plurality of universities, that Congress should make a plural response is not surprising. The Congress, almost by definition, is largely engaged in resolving conflicts among the plural interests of American life as a whole. In addition, the committee system of Congress makes a single response difficult and a plural response the expected thing. Senators and congressmen gain respect and power by concentrating on a few areas which are the particular spheres of the committees on which they serve. In the early 1950's science policy as such did not have a high priority among the general issues on which all members of Congress have to be informed. Hence the number of full-dress debates on the floor concerning science were few, but there were always specialists who were following the development of parts of the interrelated system closely. Scientists were often confused by this combination of poor understanding of science in the Congress and intimate knowledge of the workings of the system on the part of a few congressmen.

Among the well-informed committees on science matters, the standing committees that had substantive cognizance over the great executive agencies naturally took first place, and of these the Joint Atomic Energy Committee is an outstanding example. It took a detailed interest in the affairs of the Atomic Energy Commission, and some of its members gained a high degree of expertise on the administrative side, and even, in a general way, on the scientific side, of the Commission. The committees of both Houses that had cognizance over the armed services became accustomed to the concepts that underlay the extensive research operations of the Department of Defense. And the committees on commerce and agriculture continued and deepened their historic interest in research.

One of the objectives of the scientific community in its dealings with the government had been, as we have already seen, to get away from short-term authorizations. Science sometimes requires abrupt and unforeseen changes in response to a changed research situation, but it equally requires the long-term support that makes sustained effort possible over periods of time up to several years before decisive results can be shown. Thus the provision of financial support for basic research on a year-by-year basis has often been the bane of science in government programs. In recognition of the need for greater stability, Congress has often appropriated funds for research programs on an open-ended basis—that is, to be available until obligated—so that commitments can be made for research extending over several years.

This practice, together with the practice of authorizing research programs with no definite dollar limitation, gives the appropriations committees a major role in the review of research programs. Some of the legislators most actively interested in scientific programs during the 1950's were members of the appropriations committees.

The mistrust that many rank-and-file members of the scientific community feel toward Congress reached a high pitch in the early 1950's because of the investigations by Senator Joseph R. McCarthy for the Senate Committee on Government Operations. The challenges of the loyalty of scientists, and of their ability to serve the government in sensitive areas, made them fear that the investigatory powers of Congress did not serve the government-science alliance well. Some other hearings of the period did nothing to allay the fears that had been aroused, or to make scientists feel that the investigatory powers of congressional committees were constructive forces.

Yet the pluralism of the government-science scene was so complete in the early 1950's that any channel of coordination might serve the potentially useful purpose of offsetting the sometimes conflicting interests and missions of the several science agencies. In the Congress, the impulse toward coordination would not likely come through the standing substantive committees, linked as they were to individual agencies. The investigatory power, then in the hands of members of Congress outside the senior leadership on the standing substantive committees, was the main hope for an over-all look at the interrelated system and for raising questions about the coordination of its components.

The Committees on Government Operations of the House and Senate might not appear to headline readers as likely instruments to create increased coherence in the interrelated system. Yet even while the Army-McCarthy hearings filled the newspapers, a subcommittee of the House Committee on Government Operations raised many fundamental questions about research and development in the Department of Defense which would never have seen the light of day if the hearings had not been held. Furthermore, most of the leaders of the scientific community gained a chance to put their views before the Congress and the public, which they would otherwise not have had.

The Committee asked fifty leading scientists a series of questions; among them were: "To what extent should the Department of Defense contract with non-governmental institutions to carry on military research and development programs? To what extent should private, nonprofit institutions participate? To what extent should private industry participate? How much in-house research is required for the military services to be capable of exercising qualitative control over research and development conducted by outside laboratories?"[43] As research and development became an ever more prominent area of government activity, and its over-all organization became a cause for apprehension, the Committees on Government Operations became a natural focus for interest in science. If a major disturbing factor were to enter the picture, the Committees on Government Operations could be expected to step up their interest in the over-all organization of research and development.

[43] "Organization and Administration of the Military Research and Development Programs," Hearings before a Subcommittee of the Committee on Government Operations. House of Representatives, 83 Cong., 2 Sess., June 8-24, p. 2.

V

After Sputnik

Competition with the Soviet Union was the disturbing factor that put a new series of stresses on the now well-established plural and interrelated system of government-supported university research. Sputnik symbolized the competition and the challenge of the Soviet Union to the whole American people. The National Science Foundation had already discovered that Nicholas DeWitt's book, *Soviet Professional Manpower,* published in 1955, had a marked effect in interesting Congress in support of its program for education in the sciences. But, with Sputnik, millions who had not previously thought about the government's science policy developed a strong feeling that some priorities should at least be re-examined.

Changes in Organization by President and Congress

The Eisenhower Administration responded promptly with the appointment of Dr. James R. Killian, Jr., president of M.I.T., to the newly created post of Special Assistant to the President for Science and Technology. The President's Science Advisory Committee was reorganized to report directly to the President. Soon thereafter, as a result of the report of the President's Science Advisory Committee, *Strengthening American Science,* the President also set up the Federal Council of Science and Technology.

In the wake of Sputnik, the Congress took a lively and concerned interest in the plural interrelated system. It markedly strengthened the National Science Foundation and passed the National Defense Education Act. To a much greater extent than usual, congressional leaders took the lead in shaping the legislation which created the National Aeronautics and Space Administration and the National Aeronautics and Space Council. It also realigned its committee system by creating two new standing committees—Aeronautical and Space Sciences in the Senate, and Science and Astronautics in the House. The Democratic leadership of the Congress had thus worked with the Eisenhower Administration in creating a whole new set of institutions in both the executive and legislative branches. The senate committee limited itself to "Aeronautical and Space Sciences." But the house committee, by adopting the term "Science and Astronautics," projected a broader role than that of a standing committee for the National Aeronautics and Space Administration.

In the stresses of 1958, with Soviet competition foremost in everyone's mind, with searching questions being asked about the whole range of American education, with the Congress and the Executive controlled by different parties, it would have been surprising if members of Congress outside the regular committees had not given close attention to the workings of the interrelated system. It would also have been surprising if the Committees on Government Operations had not come strongly to the fore with questions about over-all coordination. A subcommittee of the Senate Committee on Government Operations held hearings on a whole series of bills to create a Department of Science and Technology and a cabinet post of Secretary of Science and Technology. At the same time, the subcommittee and its staff became particularly interested in the coordination of scientific information. Their efforts helped in the creation of the Office of Science Information Services in the National Science Foundation through a provision in the National Defense Education Act of 1958. But their interest did not stop there. A series of reports on science information has continued to emanate from the subcommittee, a clear example of how sustained congressional interest can provide long-term stimulation to a matter of science policy.

Congressional interest in a Department of Science and Technology was given a particularly sharp edge because the coordinating structure, erected by the Eisenhower Administration around the Special Assistant for Science and Technology, was located within the White House, and thus was not available for questioning by congressional committees. A senator complained that when "a legislative subcommittee has to dig around and do its own investigation and sleuthing, that is when the trouble starts. That is when the half-truths come out. That is when you get the misrepresentation that takes place. . . . It seems to me somewhere, somehow, there ought to be the openness, the frankness of contact and of communication that the present situation requires, because the scientific program of this Government is no better than the knowledge of Congress about it, because we can either make it or break it either through our lack of knowledge or of enlightenment on the problems involved." [44] Although a consensus for a Department of Science and Technology never developed, either within the Congress or within the scientific community, the interest stirred up by the subcommittee had the great merit of indicating the need for coordination both in

[44] "Create a Department of Science and Technology," Hearings before the Subcommittee on Reorganization and International Organizations of the Committee on Government Operations. United States Senate, 86 Cong., 1 Sess., May 28, 1959, p. 129.

the Executive and in Congress, and of pointing up the necessity for good communication between the two branches. The proposal for a commission to study the creation of a department of science stemmed from these hearings and has passed the Senate regularly since then.

Another subcommittee of the Senate Committee on Government Operations also entered the post-Sputnik arena of science policy coordination through an investigation of national security machinery. This subcommittee sought the opinions of many members of the scientific community and included a section on science policy in its final recommendations, which appeared in the first days of the Kennedy Administration. The subcommittee saw the virtues of the science policy machinery set up within the White House, but urged the President to use his reorganization powers to move the structure out of the White House and into the Executive Office of the President, thereby allowing the Special Assistant for Science and Technology to appear before congressional committees. The step recommended by the subcommittee was taken by President Kennedy in Reorganization Plan No. 2 of June, 1962. With this change, the movement for a separate department of science has lost momentum.

Thus the Congress gained a regular channel of communication to the fourfold structure within the Executive which was concerned with over-all science policy. The President's Special Assistant for Science and Technology now serves as an adviser to the Chief Executive. As chairman of the President's Science Advisory Committee, he presides over a group of scientists from private institutions who provide the Executive with advice from the scientific community. As chairman of the Federal Council for Science and Technology, he presides over a group of high-level representatives from government agencies with major research and development programs. And finally, as director of the Office of Science and Technology in the Executive Office of the President, the Special Assistant is available to give information to congressional committees that seek it. Staff work organized through the Office of Science and Technology helps the Special Assistant to coordinate his several roles in the service of the President.

On the House side, the Committee on Government Operations also responded to the post-Sputnik stimulus. As the Senate groups had done, it took a stance outside the regular committees that dealt routinely with the interrelated system. The Subcommittee on Intergovernmental Relations took a rather different tack from that of its Senate counterpart, but at its base was the same concern for an over-all congressional view of research and development. The House subcommittee chose the rapidly expanding health research area for a detailed examination of granting procedures. In 1961, after two years of investigation, it issued a report dealing with the major features of the linkage between the government and universities supplied by the National Institutes of Health. It reviewed the administration of grants and training programs and the always thorny problem of indirect costs. The relation of this subcommittee to the present report is explained in its preface.

In the post-Sputnik era, the alliance between the government and the universities had to acquire new dimensions, yet the basic relationship could not be forgotten in the urgent attempt to meet immediate national needs. Science was now a yardstick of Soviet-American competition, but the historic urge of the scientific community to preserve the conditions necessary for its creativity could not cease. In the fall of 1960, in the midst of a great national election, the President's Science Advisory Committee pointed to the bond that had grown up between the government and the universities.

"The truth is as simple as it is important: *Whether the quantity and quality of basic research and graduate education in the United States will be adequate or inadequate depends primarily upon the government of the United States. From this responsibility the Federal Government has no escape. Either it will find the policies—and the resources—which permit our universities to flourish and their duties to be adequately discharged—or no one will.*" [45]

As scientists, university administrators, government officials, and congressmen struggle to adjust the many strings that bind the interrelated system together, they can at least take comfort in a few generalizations drawn from a glance toward the past.

The interrelated system grew out of the actions of responsible people consciously responding to urgent problems, and responding to get maximum benefit from the most powerful tool available--research.

The plural system has many roots for its authority and many alternative administrative means of solving a given problem.

The scientific community has consistently insisted on the recognition of the principle of scientific freedom, and the American political community has recognized that this freedom is consistent with our form of society and responsible government.

The record shows a continuous regard for the government's responsibility for the money entrusted to it by the people. And the overwhelming majority of the scientific community has throughout the record respected that responsibility.

Freedom and responsibility are the twin necessities of a system that the American people have every reason to approve.

[45] President's Science Advisory Committee, *Scientific Progress, the Universities, and the Federal Government* (Washington, 1960), pp. 10-11.

CONTEMPORARY PROBLEMS IN THE SYSTEM OF GOVERNMENT SUPPORT

VI

Profile of the Government's Present Role in Science

Statistics: Expenditures

A profile of statistics delineating the government's role in science shows a continuation of the system of support already in existence in the 1950's. It also shows a series of new trends whose development has contributed substantially to the present over-all totals. The rise of total expenditures—public and private—for research and development from approximately $5 billion in 1953-54 to nearly $15 billion in 1961-62 (see Chart 1) is certainly striking enough in itself. But one must also note that applied research and development has been consistently the largest part of that total. Thus expenditures for basic research (on the order of $1 billion in 1961-1962) are a relatively minor part of the over-all total. The trends in federal obligations for research, development, and research and development plant, fiscal years 1947-1964 (see Chart 2), show both that the totals have gone up steeply and that a preponderance of applied research and development has characterized the federal government's program, as it has the total national investment.

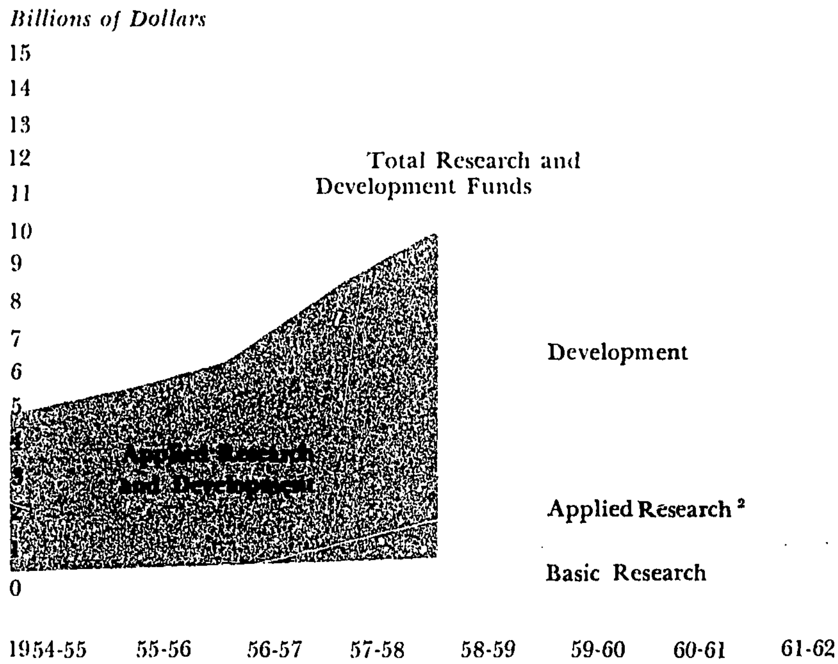
1964 statistics represented on the charts in this section are based upon budgeted figures, and thus do not reflect subsequent modifications resulting from congressional action and administrative decisions (see Table 1). These subsequent modifications do not, however, alter the essential trends of the curves as shown.

If one turns to an analysis of the funds used for research and development in the various sectors, 1953-1962 (see Chart 3), it is clear that industry has remained the major performer of research and development, with intramural research and development by the federal government second, although the latter's relative growth has been less than that of the other sectors. The colleges and universities performed research and development totaling $450 million in 1953-1954, as compared to $1.4 billion in 1961-1962. Federal obligations for performance of research and development, by sector (see Chart 4), reflect the same basic situation, with profit organizations in 1955 performing little more than the federal government in its own laboratories. By fiscal 1957, federal obligations to profit organizations were more than to all other sectors combined. From 1955 to 1961, the percentage of total federal research and development funds used by the colleges and universities remained relatively stable, representing approximately 10 per cent of total federal obligations. This stability lies at the heart of the approach of this report. The government-university partnership was a success at the beginning of the 1950's, and therefore has continued to grow in an orderly manner through the recent past.

The relations among the sectors of science support and the predominance achieved by the federal government as a source of funds are demonstrated by the table of intersectoral transfers for 1961-1962 (see Chart 5). The figure representing the operation of the government-university interrelated system is the $600 million for research and development (including $330 million for basic research) which stems from the federal government as the source of funds, with the colleges and universities proper (as opposed to research centers) as the performers. It is the relative rather than the absolute size of this figure that is a major concern of the scientific community. The graph of research and development performance by sector and type of work, 1962 (see Chart 6), shows the prominence of the universities in the performance of basic research, and the prominence of federally financed basic research in the universities. Thus it is clear that the fate of federal support to the universities and the fate of basic research are closely linked.

Turning to an agency breakdown of research and development (and research and development plant) expenditures for fiscal years 1940-1964 (see Chart 7), one can see the drama of the changing roles of individual agencies. The Department of Defense tops by far all the others in the postwar period, but it shows a decrease in its proportion of total federal research and development expenditures, from 73 per cent in 1960 to an estimated 51 per cent in 1964. The National Aeronautics and Space Administration meanwhile has risen to an estimated 28 per cent. The Atomic Energy Commission, while

CHART 7
TRENDS IN FUNDS FOR BASIC AND APPLIED RESEARCH AND DEVELOPMENT 1953-54—1961-62 [1]



[1] Data are based on reports by the performers.
[2] Data separately identifiable for 1957-58, 1959-60, and 1961-62 only.
Source: National Science Foundation

rising from $1 billion to $1.5 billion from 1960 to 1964, nevertheless declined from 13 per cent to an expected 10 per cent of the total. The expenditures by the Department of Health, Education and Welfare (which, of course, includes the National Institutes of Health) and the National Science Foundation comprise only five per cent and one per cent, respectively, of total federal expenditures for research and development. The declining proportion for the Department of Defense and the rising proportion for the National Aeronautics and Space Administration are reflected on the graph (Chart 8) showing research and development as a percentage of the gross national product.

Federal obligations for research and development by agency for 1962, 1963, and 1964 (see Chart 9) reflect the towering position of the Department of Defense and the growing role of the National Aeronautics and Space Administration. It is notable that basic research is well dispersed through the agencies of the government. The

CHART 2
TRENDS IN FEDERAL OBLIGATIONS FOR RESEARCH, DEVELOPMENT, AND RESEARCH AND DEVELOPMENT PLANT, FISCAL YEARS 1947-1964

[1] Includes pay and allowances of military personnel. [2] To be corrected. See Table 1.

Source: National Science Foundation.

National Science Foundation is neither the sole home of basic research in the government, nor the largest supporter of it. This graph shows statistically what Executive Order 10521 of 1954 stated in administrative language.

That the fields of science have not shared equally in federal funds is shown by the trends in federal obligations for total research by major fields of science, 1956-1964 (see Chart 10). Engineering has been the principal recipient throughout the period, obligations to it reaching an estimated $2.57 billion, or 44 per cent of the total research effort, in 1964. The overwhelming part of this goes into applied work related to large development efforts. The physical sciences accounted for 18 per cent of the total research effort in 1956, but this figure had risen to 26 per cent for 1964. Medicine and biology accounted for 12 per cent each of the total in 1956, but by 1964 medicine was scheduled to rise to 14 per cent while biology dropped to six per cent. The social sciences, at an estimated $352 million in 1964, accounted for two per cent of the total.

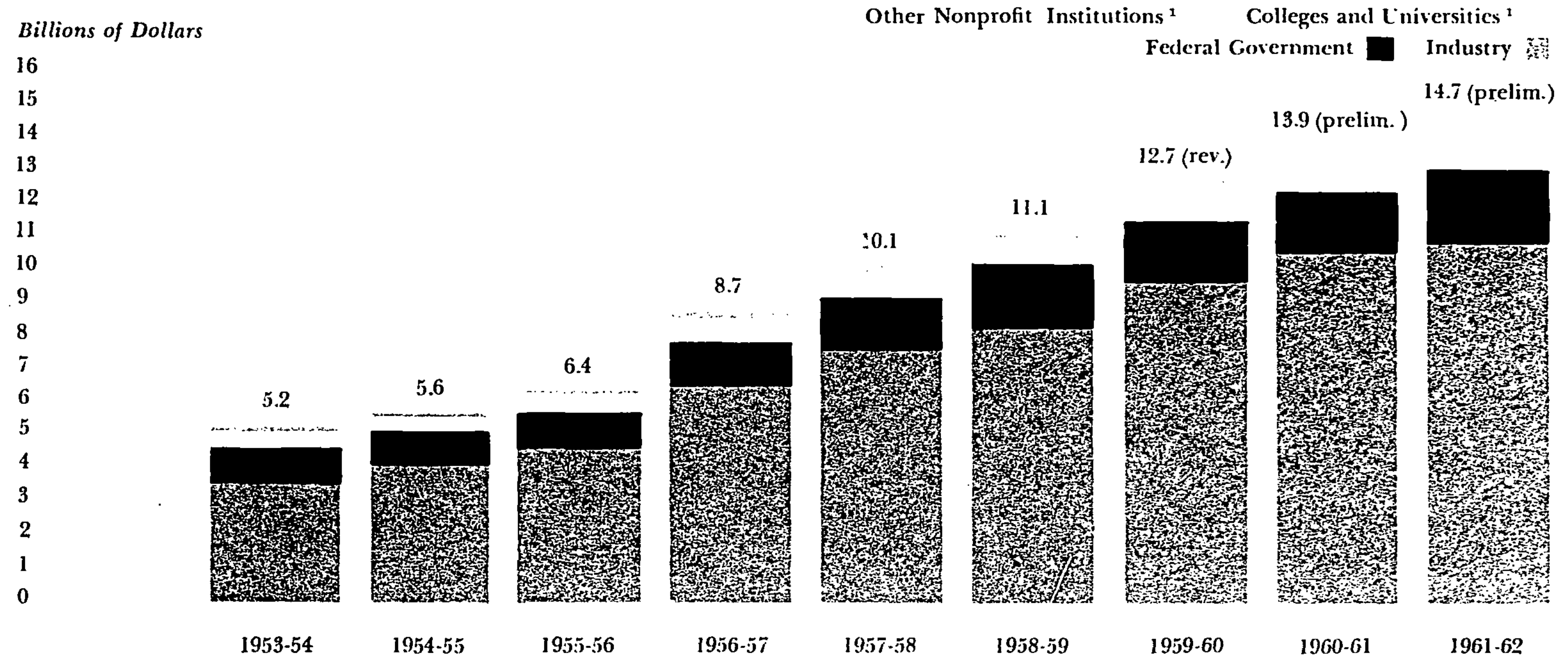
For those genuinely concerned with the critical elements in government spending for research and development, the great lesson of this profile is that the big totals come in parts of the spectrum other than basic research and in sectors other than the universities. The statistics show, however, that the link between the government and the universities does exist, that large funds are involved, and that the funds loom proportionately much larger for the universities than for the government as a whole.

Administrative Practices of Federal Agencies

As already shown, a number of federal agencies participate in the support of basic research, and, as one might expect from the various paths by which they entered the field and the variety of their missions, their administrative practices differ greatly. The agencies in the Department of Defense support basic research to maintain the military strength of the United States. The enabling legislation that paved the way for establishing the Atomic Energy Commission and the Department of Health, Education and Welfare recognizes the need for research in their respective areas. The National Aeronautics and Space Administration is charged with exploring outer space and making the results of this exploration useful. The National Science Foundation has responsibilities for the support of basic research generally.

It is important to note that the established tradition of statutory construction in the United States permits not only activities authorized by the language of the statutes narrowly construed, but also those authorized by reasonable inferences from the statutes. These may be drawn from the records of congressional hearings and reports

CHART 3
FUNDS USED FOR PERFORMANCE OF RESEARCH AND DEVELOPMENT IN THE U.S., BY SECTOR 1953-62

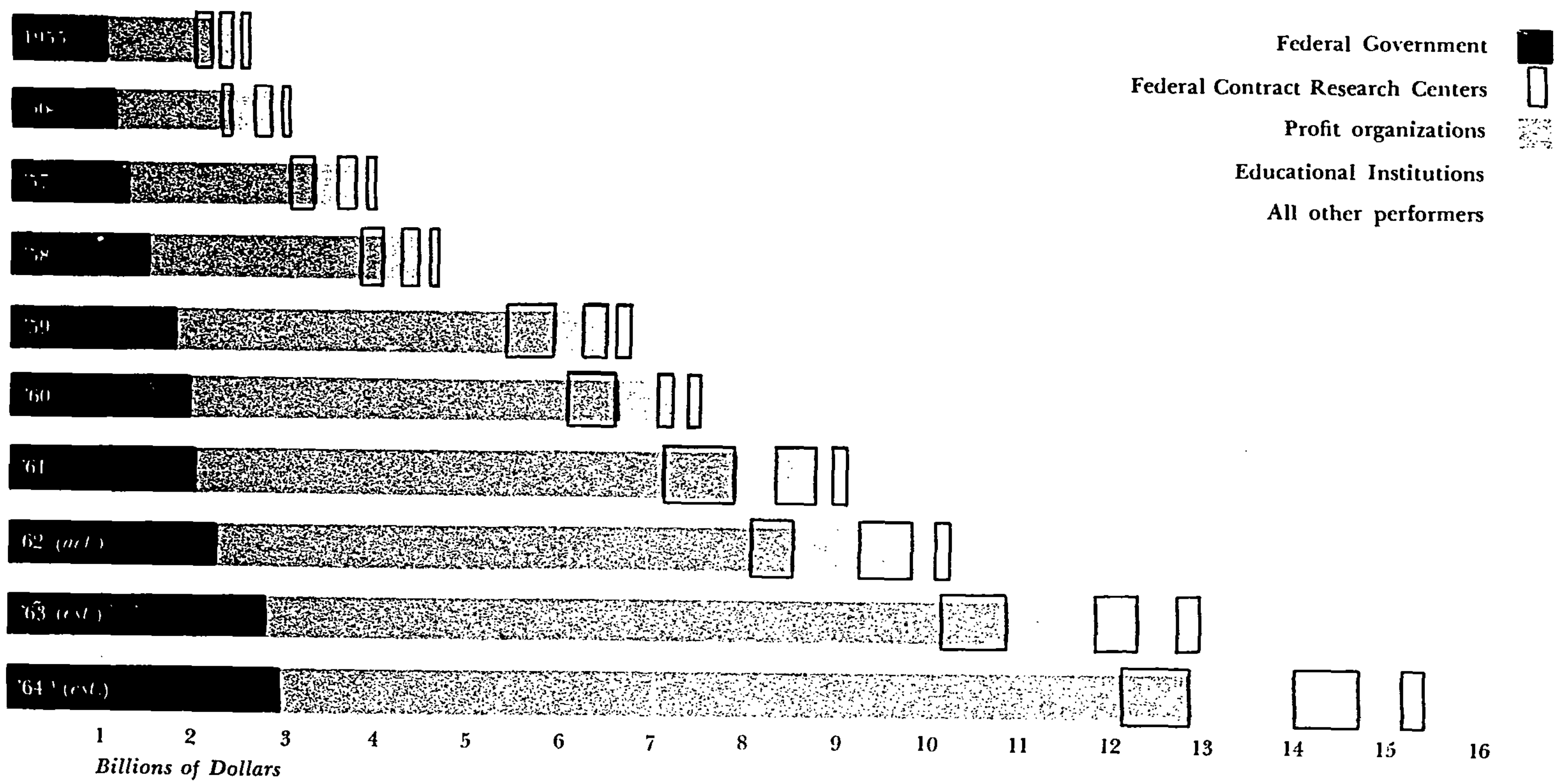


[1] Data include state and local government funds.

Amounts from the federal sector for research centers administered by organizations in the other three sectors are included in totals.

Source: National Science Foundation, 1963 Note: Data are based on reports by performers.

CHART 4 TRENDS IN FEDERAL OBLIGATIONS FOR PERFORMANCE OF RESEARCH AND DEVELOPMENT, BY SECTOR
FISCAL YEARS 1955-1964



[1] To be corrected. See Table 1 Source: National Science Foundation

of congressional committees. They are often drawn from the "common sense" of the situation. Such extended authority has often been sustained by judicial interpretation, by governmental practice in the absence of judicial challenge, and by congressional appropriation of relevant funds. What administrators have long done with government funds is a good index of congressional intent. Thus the nature of the work done by a contractor or a grantee and the degree of freedom of action permitted them do not depend upon the narrowest interpretation of the language of the statutes defining the mission of a granting agency. The basic research contract or grant is within the statutory authority if the agency judges it conducive to the success of its mission as defined by the statute. Thus, agencies with practical missions need not restrict the freedom of action of basic research contractors or grantees because of the practical nature of their missions.

Although all agencies have been authorized since 1958 to use the grant form of support for basic research, the actual practices in support of individual projects differ widely from agency to agency. The National Science Foundation uses grants of up-to-five years duration, the median being approximately two years. In the Department of Defense, the Office of Naval Research continues to use the fixed-price contract form of support, renewable at one-year intervals and sometimes for two or three years ahead. The Army Research Office uses grants or contracts of one-to-five years duration, two years being the median. The Office of Scientific Research of the Air Force uses both grants and contracts of one-year duration, but renewable for two more years. The Advanced Research Projects Agency (ARPA) uses annually renewable contracts. The National Institutes of Health uses annual grants renewable for up-to-seven years, with a median of three years. The Atomic Energy Commission uses contracts, usually of one-year duration and renewable. The National Aeronautics and Space Administration uses grants, mostly funded annually.

Both grantees and contractors are required to report the progress of their work. Implementation of this requirement actually varies greatly from one agency to another, from a simple submission of reprints of published work to frequent and more or less formal progress reports. All agencies use cost-type contracts for large projects and construction of research facilities. Some research contracts (for instance, those of the Office of Naval Research) state explicitly that their purpose is to support the conduct of research (as against purchase of research results). In these contracts, research objectives are described in broad terms only; thus no more restrictions are placed on the research freedom of the investigator than in grants. Other contracts are more restrictive.

All recipients of grants and contracts are required to keep records showing how funds have been spent. These may be inspected

CHART 5

RESEARCH AND DEVELOPMENT, 1961-62 INTERSECTORAL TRANSFERS OF FUNDS USED FOR PERFORMANCE (PRELIMINARY)

Research and Development Performers *(Millions of Dollars)*

Sources of Funds Used	Federal Government	Industry	Colleges & Universities: Proper [1]	Colleges & Universities: Fed'l Contr. Research Centers	Other Nonprofit Institutions	Total	Percent Distribution R & D Sources
Federal Government	$2,090	$6,310 [2]	$600	$450	$200 [2]	$9,650	65
	238	*89*	*330*	*112*	*80*	*849*	*57*
Industry		4,560	55		90	4,705	32
		314	*25*		*12*	*351*	*24*
Colleges and Universities [2]			230			230	2
			180			*180*	*12*
Other Nonprofit Institutions [3]			65		90	155	1
			48		*60*	*108*	*7*
Total	$2,090	$10,870 [2]	$950	$450	$380 [2]	$14,740	100
	238	*403*	*583*	*112*	*152*	*1,488*	
Percent Distribution, R & D Performance	14	74	6	3	3	100	
	16	*27*	*39*	*8*	*10*		

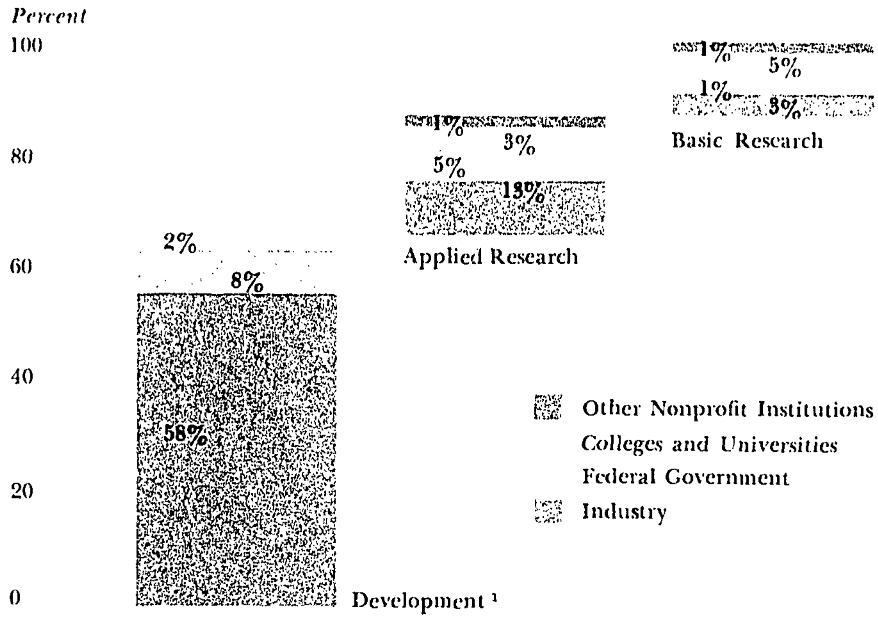
[1] Includes agricultural experiment stations. [2] This amount includes funds from the federal government for research centers administered by organizations under contract with federal agencies. [3] Data include state and local government funds.

Note: All data are based on reports by the performers. Source: National Science Foundation.

Basic Research

CHART 6
RESEARCH AND DEVELOPMENT PERFORMANCE,
BY SECTOR AND TYPE OF WORK, 1962

Total Research and Development Expenditures: $14.7 Billion

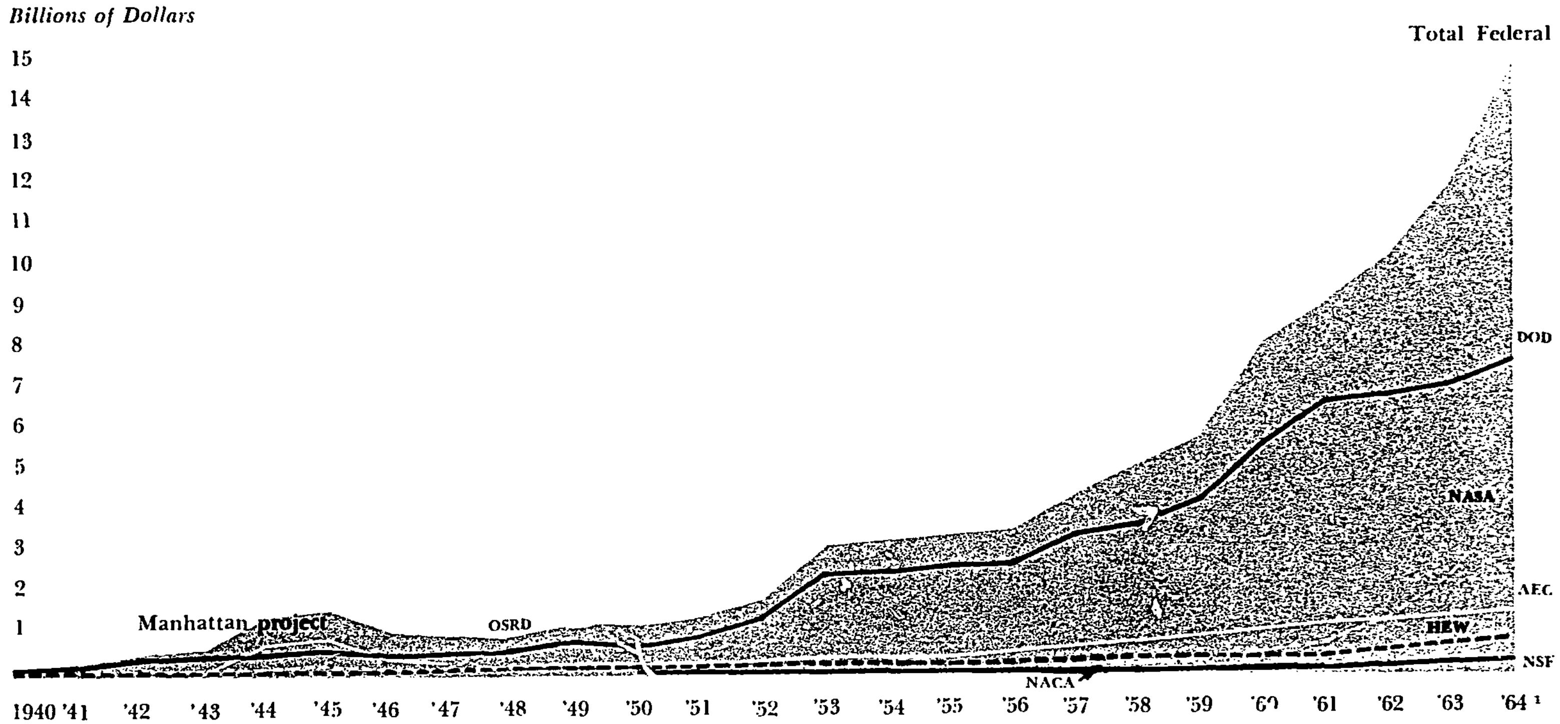


[1] Other nonprofit institutions reported less than 1 percent.
Source: National Science Foundation

by auditors to determine that money has been spent for agreed projects, and, in those cases where a budget has been specified, the auditors may determine that expenditures are consistent with budgets. Contracts usually vest the title to permanent equipment acquired under the contract in the agency rather than the contractor, who is required to keep property records until the agency may decide to turn the property over to him. Grants generally vest the ownership in the grantee institution but, in the case of National Institutes of Health grants, the equipment must be used for health-related research after the expiration of the grant.

Most agencies make extensive use of scientists outside the agency staffs for advisory services in the selection of research projects. Except for a few with a statutory basis, such as the National Advisory Councils in the National Institutes of Health and the National Science Board, the roles of advisory committees, panels, and individual

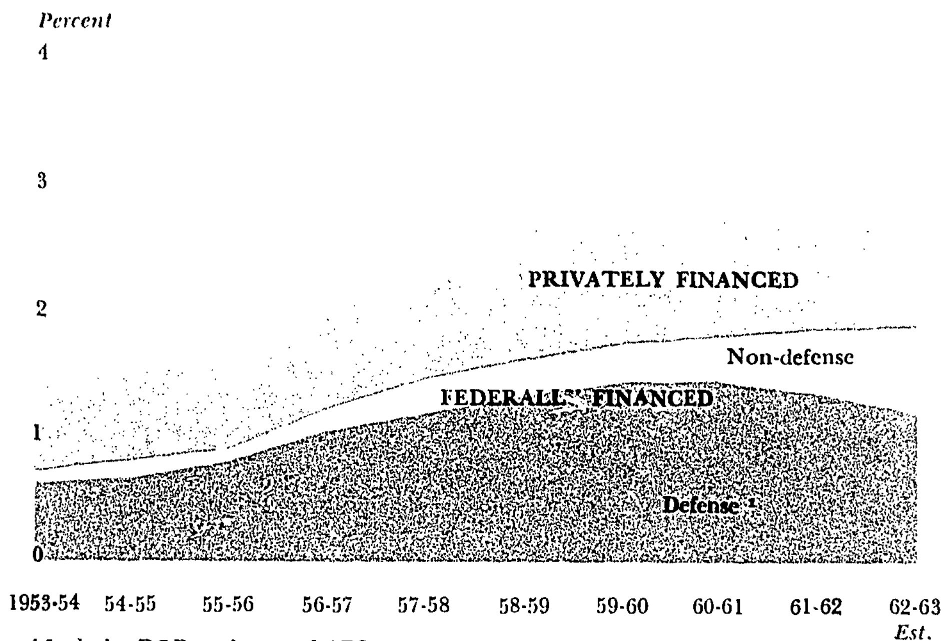
CHART 7
FEDERAL RESEARCH AND DEVELOPMENT AND RESEARCH AND DEVELOPMENT PLANT EXPENDITURES, BY SELECTED AGENCY, FISCAL YEARS 1940-1964



[1] To be corrected. See Table 1.

Source: National Science Foundation

CHART 8
RESEARCH AND DEVELOPMENT AS A PERCENTAGE OF THE GROSS NATIONAL PRODUCT, 1953-54—1962-63

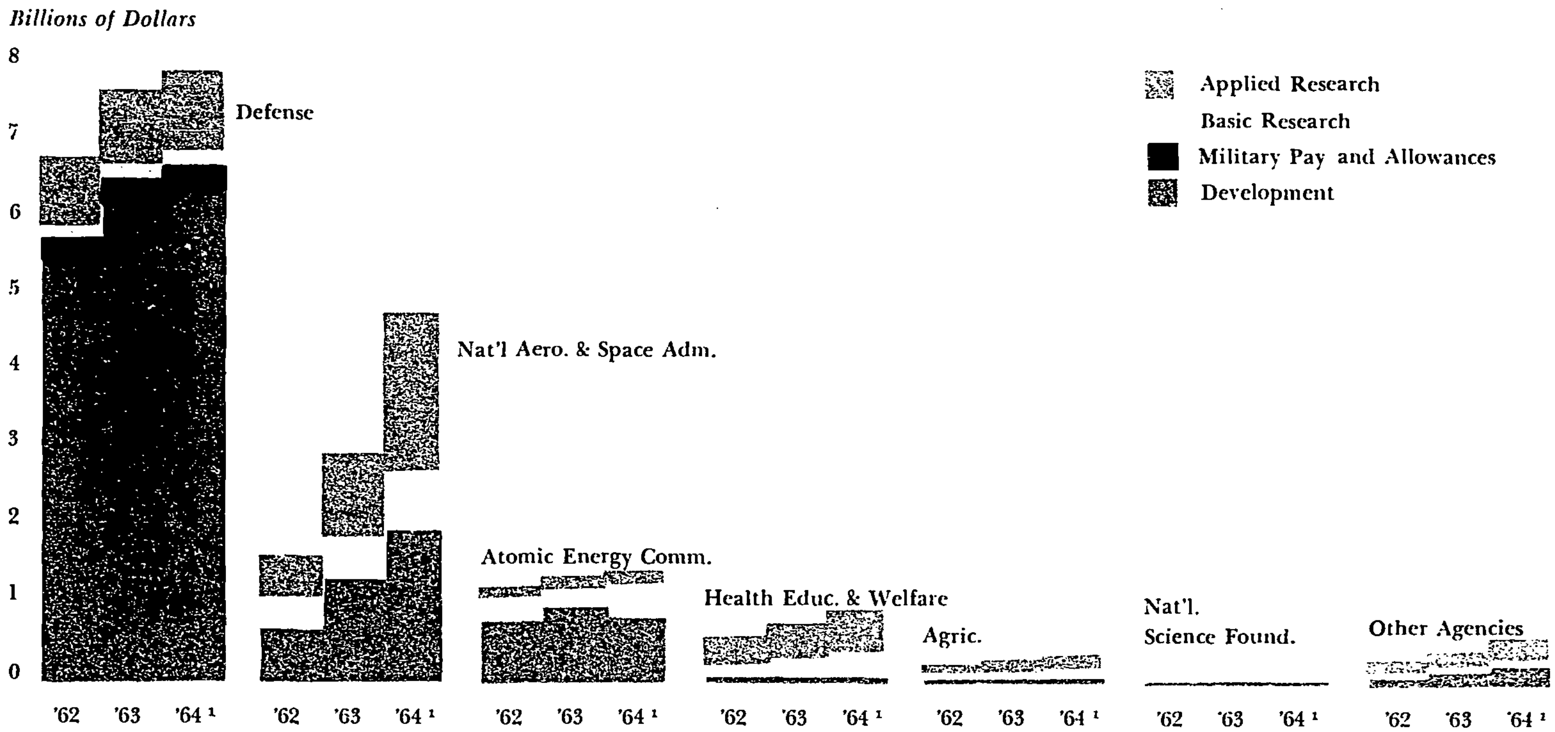


[1] Includes DOD and part of AEC.

Note: Data for the GNP refer to the earlier calendar year. Source: R. & D. data, National Science Foundation. GNP data, U.S. Department of Commerce.

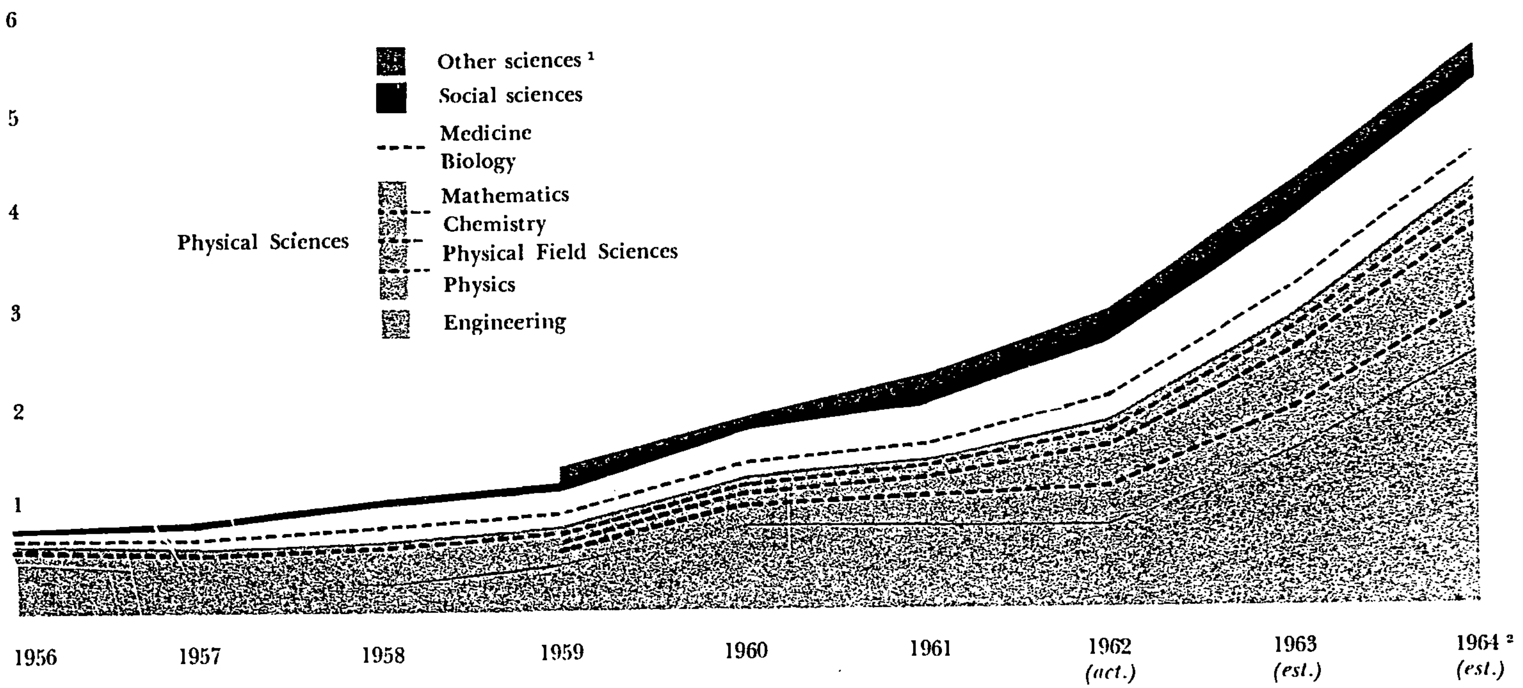
referees are set by administrative decisions. The extent and form of practices differ greatly from one agency to another. Thus the National Science Foundation uses referees to evaluate proposals, and advisory panels usually arrange the proposals in an order of excellence. However, the practice varies from one division to another. In the National Institutes of Health the study sections evaluate proposals for scientific competence and arrange them in corresponding order. The Advisory Councils then make final recommendations based on relevance to the National Institutes of Health program. The Atomic Energy Commission uses only individual referees, while the National Aeronautics and Space Administration relies largely on advice from scientists in the centers it operates. In the Department of Defense, the Office of Naval Research uses some advisory committees and individual referees. The Office of Scientific Research of the Air Force uses panels of referees appointed by the National Academy of Sciences. The

CHART 9
FEDERAL OBLIGATIONS FOR RESEARCH AND DEVELOPMENT, BY SELECTED AGENCY
FISCAL YEARS 1962, 1963 AND 1964



[1] To be corrected. See Table 1. Source: National Science Foundation.

CHART 10
TRENDS IN FEDERAL OBLIGATIONS FOR TOTAL RESEARCH, BY MAJOR FIELDS OF SCIENCE
FISCAL YEARS 1956-1964



[1] Includes psychology [2] To be corrected. See Table 1.

Note: pay and allowance of military personnel not included

Army Research Office uses individual consultants in a manner differing from one discipline to another. The Advanced Research Projects Agency uses advisory committees and individual referees.

Problem Areas Surrounding the Interrelated System

In the changes of scale and emphasis in federal programs for research and development over the last five years, new strains have become evident. Some of these strains are in the government-university partnership itself. Many others, however, have developed elsewhere in the interrelated system. In some cases extension of the project system is clearly required. In others the indiscriminate extension of the project-grant system is an inferior solution to problems that should be faced directly and forthrightly by the makers of policy. We can only list some of the problem areas that we see developing adjacent to our subject, and emphasize that we consider them worthy of separate examination in their own right.

The object of federal support is not only increasing scientific knowledge but also strengthening of the universities themselves. The trained men and strong institutions produced by federal support are in themselves a major national resource in peace or war. Thus, the production of future scientists and strong, independent universities broadens both the opportunities and the problems of federal support beyond the bounds of basic research and related graduate education.

Construction and major facilities. Since the institution of the interrelated system during World War II, the government has increasingly felt the necessity of providing support for research by major plant investment. Chart 2 reflects this federal interest, and the 1963 legislation for college aid will doubtless accentuate the trend. When institutions of higher learning accept support for large buildings and other facilities, the uses to which the buildings are put are often related to other missions of the institutions as well as to federally supported research, and the formulae and legal instruments by which the arrangements are made must take these complexities into account.

Programs in science education. Always present as a direct adjunct to research at the graduate level, programs in science education have developed greatly since Sputnik. They have followed the quest for new scientific talent down into the grade schools, in recognition of the fact that the beginnings of scientific careers are made early. Indeed, the important decisions regulating the supply of scientific manpower are often made by boys and girls in school. Institutes for teachers and programs for improving courses of instruction have gained wide support in Congress, in the universities, and in elementary and secondary education. These educational improvements not only assist the training of future scientists, but also have the effect of bettering the quality of the education of all.

TABLE 1
RELATION OF FEDERAL OBLIGATIONS FOR RESEARCH AND DEVELOPMENT AND R&D PLANT, BASED ON *THE BUDGET, 1964*, TO THOSE BASED ON SUBSEQUENT CONGRESSIONAL ACTION AND ADMINISTRATIVE DECISIONS, BY SELECTED AGENCY, FISCAL YEAR 1964 (ESTIMATED)[1]

(Millions of dollars)

Agency	The Budget 1964			Subsequent Congressional and administrative decisions			Actual change		
	R&D	R&D Plant	Total	R&D	R&D Plant	Total	R&D	R&D Plant	Total
TOTAL, ALL AGENCIES	15,329	1,672	17,001	14,566	1,763	16,329	−763	+90	−672
Department of Agriculture	184	2	186	184	2	186			
Department of Commerce	69	58	127	56	56	112	−13	−2	−15
Department of Defense	7,868	97	7,965	7,636	96	7,732	−231	−1	−232
Department of Health, Education, and Welfare	842	77	919	791	85	876	−51	+8	−43
Department of the Interior	125	10	135	120	9	129	−5	−1	−6
Atomic Energy Commission	1,195	299	1,494	1,237	407	1,643	+42	+107	+149
Federal Aviation Agency	60	17	77	109	19	128	+50	+2	+52
National Aeronautics and Space Administration	4,672	976	5,648	4,175	1,027	5,202	−497	+51	−446
National Science Foundation	211	130	341	166	59	225	−45	−71	−116
Veterans Administration	33	7	40	34	3	37	+1	−4	−3
All Others	70	[2]	70	57	[2]	57	−13		−13

[1] In a few instances, R&D and R&D Plant do not add up precisely to the totals shown. due to rounding of figures.
[2] Less than $500,000
Source: National Science Foundation.

Science information. Unless the results of research reach the people who need to know about them promptly and efficiently, the best of research projects will not be effective. The responsibility for science information is shared by the government, the universities, and the scientific community. A report of the President's Science Advisory Committee, issued January 10, 1963, and entitled *Science, Government, and Information: The Responsibility of the Technical Community and the Government in the Transfer of Information,* deals with this responsibility comprehensively.

The humanities and the social sciences. Healthy universities are more than just collections of departments of mathematics, physics, chemistry, and biology. Their programs in the humanities and the social sciences must also develop their full potentials in the interest of scholarship as a whole. Even the education of scientists cannot neglect other fields of learning, if the scientists of the future are to contribute fully both in their professional capacities and as citizens.

Civilian industrial technology. Means by which the results of research may be brought to bear on the everyday needs of the civilian economy, as they have been on the requirements of military and space programs, should be given careful consideration.

National facilities. In some fields of science, the trend toward national facilities instead of installations at individual universities has been apparent. Special area requirements, expensive equipment, and inter-disciplinary approaches often make the creation of such facilities desirable. They pose special problems, however, for the government agencies and the universities that participate in them.

Experiments requiring large outlay for supporting technology. The cost in dollars per scientist engaged in research has been rising astronomically in some areas. Actually included in the total costs are necessary large outlays—often totaling many millions of dollars—for supporting technology. Some projects involve military personnel and large labor forces. For lack of explicit classification of costs, however, these massive totals are charged entirely to basic research.

Basic research in governmental laboratories. Our general belief that basic research is most often at home in a university setting should not obscure the fact that it also is done in government laboratories and that, in certain fields, the government laboratory has both special equipment and skilled investigators. Also, applied research, which is the usual activity of many government laboratories, may gain significantly in range and effectiveness if some basic research projects are also conducted in those laboratories.

Basic research in industrial laboratories. Like government laboratories, industrial research organizations need basic research results and the breadth of vision created by basic research work.

Patents appear to concern only a small fraction of investigators involved in basic research in universities. This is a very complex problem that cannot be resolved without involving questions of patent rights arising out of applied research in industrial laboratories and universities. We note that on October 10, 1963, President Kennedy issued a memorandum announcing liberalized policies for all federal agencies insofar as existing statutes allow changes in current policies. We believe that discussion of the patents situation as it affects basic research should await changes in agency procedures.

Having taken cognizance of these problem areas, however (and others could be added), we have no hesitation in focusing our attention squarely on the mechanism by which the investigator in the university and the federal government are bound together, because the individual investigator remains, as he has been for decades, the most important person in the interrelated system. In his hands remains most of the research at the farthest edge of the frontier. As a teacher and leader of graduate students, the future is also in his hands.

VII

Principles for the Project System

The Project and the Judgment of Merit

The project system refers to the unit of organization—the project—which defines a particular research activity's size, shape, duration, and personnel as a rational basis for support. Projects may exist in laboratories and research establishments in every sector, and they draw the support of funds from every sector. The experience of two decades has given the project a definite status and fixed it firmly in the rules and customs that govern the interrelated system. The use of the project is consistent with our belief that the investigator's ability and creativity is the crucial ingredient in all research. The project proposal is an important index of the investigator's ability and creativity. Since there is never a sufficient amount of support available for all conceivable research, the evaluation of the project proposal nearly always becomes the basis for judgment in the situation we are considering here—support of the university investigator by a federal agency.

The use of project support as the principal means of aiding basic research has advantages of great practical importance. Through the project system the federal government can finance research in institutions of higher learning in the way that relates the award of funds as closely as possible to scientific merit and minimizes the effects of political pressure. There is no way for the federal government to make general grants to universities with unspecified purpose, on the basis of merit, without undertaking to rate or accredit the universities, either as a whole or with respect to the quality of their scientific programs, and, when large sums of money are granted, the problem becomes particularly acute. The federal government (like the great private foundations) has always sought to avoid this kind of judgment, having no desire to come into conflict with the independence of the national associations through which the colleges and universities maintain and defend their own academic standards.

Through the project system, the federal government can, after the general purposes of research funds have been defined, decide to award funds on the basis of the scientific merit of investigators and their proposals. The ultimate responsibility remains with the duly constituted authorities—the Congress, the President, and the heads of departments and agencies—who decide on the purposes, procedures, and dollar volumes of the several programs. None of these decisions directly determines the distribution of funds among institutions, or infringes upon their independence. The decisions on individual awards can be made with the advice of professionally qualified specialists in the various disciplines, so that each scientist's application is judged by a panel of his peers; and thus no one, in the name of the government, makes an administrative or political decision on the fate of a college or university as a whole. Thus, this competition avoids the perils of overcentralization of planning and management, which are particularly dangerous where the freedom of inquiry inherent in the nature of science is involved.

The decision to ask for and accept a grant in aid of his research can pose a complex problem to the scholar-scientist who values the full freedom of inquiry traditionally fostered by universities. If the grant, from federal or private sources, is made under rules that tend to hamper his wide-ranging studies of natural phenomena, or to curtail his need to teach and work with graduate students, then he sacrifices valuable ingredients that characterize effective research. On the other hand, unless he finds a source of funds, his work is seriously hampered. At present, the project system is the most flexible of fiscal arrangements permitting the federal government to utilize the talents of scientists in our universities. It permits each scientist to decide on the extent of his commitment to governmental support by balancing his scholarly duties to the university with his need for financial support of his research.

We are therefore convinced that, for the foreseeable future, the major emphasis in the federal government's support of basic research in science in institutions of higher learning should continue to be given to the project system.

Grant and Contract

The grant, as the instrument for government support of research in the universities, has continued in favor since 1958. The Bell Report to the President, on government contracting for research and development, concluded that "in our judgment the grant has proved to be a simpler and more desirable device for federal financing of fundamental research, where it is in the interest of the government not to exercise close control over the objectives and direction of research." The arm's length between the government and the scientist, praised in this quotation, has to do with objectives and direction of research rather than with fiscal accountability. A contract can provide—and in many cases has—the same freedom for science, coupled with fiscal responsibility, that the grant does. Long-standing contract procedures, such as those of the Office of Naval Research, use the contract in the freest possible way for the support of research. Yet wide use of the contract in procurement of goods and services by the government has made it a more usual instrument for the purchase of research results than for support of research. Therefore we favor the more widespread use of the grant made possible by the legislation of 1958, so that the increase in its use as the principal instrument for federal support of basic research in the universities will be continued.

The grant-in-aid is traditionally and symbolically different from a contract. It is the basis for a cooperative relationship under which the grantor and the grantee share a common purpose of public service. This is not a relationship between buyer and seller, and not a hierarchical relationship between superior and subordinate, but a relationship between agencies that, differing in financial resources, are equally concerned with serving a public purpose. For instance, the federal government makes grants to states for public welfare programs, and states make grants to local school districts for the support of education. The recipient of funds is indeed expected to account for their use by proving that the funds have been spent for the intended public purpose—and not as if reporting to an administrative superior. Because the contract has most frequently been used for the purchase of commodities from businesses operating for profit, the habits of contract administrators in government agencies sometimes tend to a more detailed and restrictive type of direction and accountability than is appropriate for the support of basic research.

Whether the grant or contract is used in the project system, the same principle should obtain: the terms should never be such as to make it impossible to deliver the goods. The worst way to waste federal money in this system is to give funds to support basic research with conditions attached that handicap the performance of the research, or that reduce the ability of institutions to encourage the utmost scientific imagination and inventiveness.

It is fundamental to both a grant and a contract that the agency and the university enter into the agreement only for some agreed purpose. The only question that can arise concerning the purpose is with regard to its breadth. No agency of government can or should make a grant or otherwise disburse public funds without some definition of the reason for their expenditure. The practical problem is the expression of governmental purpose in such terms as will produce the optimum scientific result. We cannot emphasize too strongly that every grant or contract has a purpose, and that the fulfillment of that purpose is the responsibility of the government, the university, and the scientist. The scientist participates actively in the definition of the purpose in the preparation of his research proposal. In the remainder of this chapter we shall trace the life cycle of a grant, giving special attention to the way in which the purpose is unfolded.

Grant Negotiations

An accepted pattern of negotiation should precede the approval of a grant. For simplicity in describing the process, we shall adopt a single set of terms that are not to apply to any specific agency but rather to an idealized situation. We shall speak of the instrument as a grant, even though much of what we say applies equally well to fixed-price contracts. We shall speak of the university, even though other institutions of higher learning do participate in the system. The four essential officers involved in the negotiation we shall call: (1) the principal investigator, the scientist whose ideas are both the origin and the end-product of the whole process; (2) the administrative officer of the university, the president or his deputy, sharing responsibility with his governing board; (3) the program director, an officer of the government agency with scientific knowledge and standing in the scientific community; and (4) the grants administrator, an officer of the government agency responsible for handling government funds in accordance with the rules laid down by the President and Congress.

Each of the four officers plays a vital role in the negotiation, and each performs a function that none of the others can perform. We believe that each needs a better understanding than he now shows of the roles played by all the others. The grants administrator should be uncompromising on the fiscal responsibility of government, but respectful of the scientific purposes of the agency, mindful of the fiscal procedures and broader responsibilities of the administrative officer of the university, and sensitive to the uncertainties that face the principal investigator in the laboratory. The program director, representing the general scientific purposes of his agency, should use the services of the grants administrator as a fellow officer of the government, join the administrative officer in an understanding of the nature of the university, and work with the principal investigator as a fellow scientist.

The administrative officer of the university, when he accepts a grant, places his university in a position of direct legal responsibility for government funds, for their care and proper disbursement. At the same time he bears a direct responsibility for the institution. One of the proper missions of the university is the research for which the grant was made. It also has other proper missions—the education that is a part of federally supported research, the education that lies beyond the federal support, and many kinds of public service.

The principal investigator is in the most complex position of all. He is at the center of a network of obligations. He (as well as the administrative officer) takes responsibility for the proper use of federal funds when the grant is accepted. He has a responsibility toward the graduate students, postdoctoral fellows, and other staff who work with him on the project. He is a professor of the university, with duties as a teacher both to those graduate students who work with him on the grant and to many students, both graduate and undergraduate, who do not. He is a member of a faculty and may have faculty committee assignments. He may have administrative duties in the university, such as the chairmanship of a department. He is a member of the scientific community, with offices or duties in a variety of learned societies, including such posts as advisory editor on one or more journals. Yet, in the midst of this maze of duties, one thing is clear: the principal investigator's work *as a scientist* is the determining factor in achieving the national purposes envisaged in the grant.

The negotiation of a project grant begins and ends with the principal investigator. He starts with an idea for research and ends with the support that allows him to go ahead with it. If the process were frictionless, negotiation would not be the right word for it. The administrative officer of the university may be faced with severe decisions as to the use of space and facilities for a federally financed project rather than for competing functions. He must guard against derogation of the teaching mission of the university. He must be sure that nothing in a grant agreement frustrates the university's own fiscal procedures (themselves sometimes determined by state law). The program director, who can arrange the support of only a fraction of the proposals that come to him, faces such severe choices that, in our opinion, he always needs help, as the following discussion of panels will show. The grants administrator must be aware of special legal provisions that must appear in grant letters.

The principal investigator may have a friendly relationship with the program director of the federal agency. He may be in a position to exchange views with the administrative officer of his university and his staff, but as a faculty member he is not likely completely to share the administrative point of view or be aware of all the competing considerations. He is least likely to know personally or negotiate informally with the grants administrator. Thus the participants in grant negotiations come to their task with divergent attitudes and responsibilities, often leading to frictions in the negotiation process. A campaign of education for all four groups of officials would pay beneficial dividends.

We believe that the health of the project system requires that three principles remain inviolate, *never* becoming subjects of negotiation or giving rise to restrictive clauses in grants. They are: (1) the responsibility of the government for the expenditure of public funds; (2) the independence of the universities; and (3) the freedom of the scientist to conduct his research, reach his conclusions in his own way, and make them public.

The Proposal

The purpose of a project, which provides the test of the propriety of the use of federal funds throughout the life of the grant, is first defined by the principal investigator himself in the body of a proposal. Too often this fundamental fact is not well enough understood by the scientist seeking support. He may avoid later difficulties in making his budget conform to the scientific realities of his research by his own action in broad, yet careful, description of his project. Federal granting agencies should make it plain in their instructions that the content of the project proposal is the basis of the purpose of the research as it will be stated in the grant letter. Approval of the proposal by the university and by the agency means that the investigator will be expected conscientiously to try to reach the scientific objective defined in his proposal. If the proposal sets out a highly specific method of investigating a scientific problem, rather than the fundamental nature of the problem itself, even small changes in tactics may cause trouble. Thus, investigators can do themselves a major service in the very beginning by presenting carefully conceived proposals, or they can lose the opportunity and bind themselves in ways that will prove unfortunate later on.

We believe that the impact of administrative restrictions can be minimized if project proposals consist of the following elements:

(1) Broad objectives of the proposed research in terms of areas of scientific knowledge to be advanced.
(2) Specific early research objectives stated as illustrative of the broader aims.
(3) Scientific tactics (experimental methods) to be employed.

With such a proposal, only a deviation from the broad objectives of the project proposal should be considered the kind of change requiring special approval from the federal agency.

The Panel and the Consultant

When a proposal comes to the desk of the program director in a federal agency, he must take action to determine whether the proposed project should be supported by the government. Each program director is knowledgeable in a particular field of science, and previous budgetary decisions by the administration, the Congress, and the agency have determined that his particular field has only a finite sum at its disposal, usually only a fraction of the total budgets of all the proposals in hand. A decision must be made, in the interest of both the taxpayer and the investigator, on the *scientific* quality of the proposal. We believe that no agency has or should have sufficient funds to avoid making this decision. We also believe that, in general, program directors can seldom make the required judgment of scientific quality without assistance. That assistance must come from the scientific community itself.

Agencies have usually recognized, some more formally than others, that a judgment of scientific quality can be adequately defended only when the scientific community has participated. Selection of advisers from the national pool of scientists in a particular discipline, avoiding undue regional or institutional concentration, is the best means of securing competent judgments and freedom from irrelevant considerations. We use the word "panel" to mean a group of scientists qualified in a particular field, who hold appointments to regular terms and meet periodically to pass on the merit of proposals. Their names should be well known to the scientific community, and they should have all pending proposals in a given field before them for comparative ranking. Some agencies informally use consultants with special competence to pass on particular proposals. Consultants usually render judgments of proposals by mail, without knowledge of other referees or of other proposals. We believe that consultants can usefully supplement the information otherwise available for the judgment of proposals, and that agencies that do not use the panel system would benefit by calling upon them.

While we can see certain difficulties in the present functioning of the panel system of review, we feel strongly that it should be retained and also improved and expanded. The overwhelming majority of scientists who have commented to us on the evaluation methods of federal agencies have praised their fairness, wisdom, and success. Among the difficulties we see in the functioning of the system, however, we especially note the following:

(1) It makes a heavy additional demand on the time and energy of the very scientists who have the most to contribute as investigators.

(2) It tends to be cumbersome and to increase the period of waiting from the time of an original proposal until work can begin.

(3) When some individuals serve too continuously on the panels of one or several agencies, and when a few universities are regularly over-represented, the burden is too concentrated on the individuals involved and the system is open to the charge of favoritism in judgment.

(4) With the constant shifts in the boundaries of disciplines and the interdisciplinary nature of much current research, panels may not always reflect the current frontiers of research, and proposals may be sent to the wrong panels for judgment.

We believe that the shortcomings of panels can be corrected if the federal agencies are alert to the fundamental reasons for consulting the scientific community, and if they take steps along the following lines:

(1) The burdens on individual advisers must be kept to a minimum, by using more advisers and rotating them often. The pool of competent scientists from which panels can be drawn is not only large but expanding.

(2) Every effort should be made to give younger scientists their turns on panels, both to spread the work and to infuse new points of view.

(3) The constitution of panels should represent perspective as well as specialty. Panels in given fields of science should include some members from allied fields.

(4) While the final responsibility for action rests with the federal agency, the advice of the panels must be consistently taken seriously to maintain the conviction among advisers that their services, even though part-time, are important.

(5) The judgment of panels as to the general reasonableness of proposed budgets is a part of their judgment of proposals, but the talents of panelists are not being properly utilized when they are requested to make detailed decisions on fiscal matters properly an agency responsibility.

(6) The plural system, in which several agencies support basic research in the same broad scientific areas, should be continued because, in addition to its other advantages, it permits individual investigators to appeal to more than one panel. This

multiplicity of opportunity is worth more than its increased cost in money and in scientist-man-hours served on panels. It tends to reduce charges of personal or institutional bias on particular panels. Moreover, in the face of different approaches of different agencies, dictated by their missions, new ideas that may be at variance with a current consensus have several chances for appreciative examination.

Agency Staff

The program directors, while in general avoiding judgments of scientific quality without the advice of the scientific community, have a crucial role to play in the project system. Every agency has an important and delicate task in building its program staff. Program directors must be sufficiently knowledgeable about their fields to command the respect of the scientists with whom they deal. At the same time, their full-time presence as agency employees means that they are withdrawn from the ranks of active investigators even more completely than panel members. Extended service away from direct contact with research problems eventually impairs the program director's essential grasp of the state of the frontier in his area. Agencies can minimize this problem by utilizing scientists on leave from university positions; the rotation from campus to agency has done much over the last few years to broaden understanding of the complexities of the project system. Yet the agencies must beware of filling key positions continuously with temporary and partially committed people, thus impairing continuity of policy. To maintain the quality of agency staffs, the career service should be improved by providing compensation at satisfactory levels, and staff members should be encouraged to continue their scientific and professional advancement.

The decisions leading to the granting of funds already allocated to a field are only half of the essential duties of the program director. He must also closely observe research trends within his area and form judgments on proper levels for the future allocation of funds to the field. With the frontiers of research always changing, and with the fission and recombination of disciplines always going on, continuous review of trends is necessary if the agency director, the Bureau of the Budget, and the Congress are to have a rational basis on which to make support allocations in budgets for future years. Program directors, with their intimate links with the scientific community, are in the best position to provide the data necessary for sound program planning.

The administrative staff of an agency—including the grants administrators, the comptrollers, and the counsels—has an important role to play in the processing of proposals. It deals with proposals at the point at which they are brought into detailed agreement with the fiscal practices of the government. We believe that a completely strict and proper fiscal administration of federal funds under the project system is entirely compatible with the scientific flexibility so often emphasized in this report. Detailed, repetitive reporting and requirements of advance specifications are familiar administrative devices to ensure responsible performance in many procurement activities of the government, but their application, even occasionally, in the project system is a violation of proven management practices in the support of basic research.

Duration, Size, and Multiplicity of Grants

Since the duration and size of grants vary not only with agency policy but with field of science, we can set forth here only general principles. The durations of projects range from one to seven or more years. The money involved in single grants ranges from a few thousand to millions of dollars. Since the time and effort required in the preparation of proposals, panel consideration, and agency work tend to be the same regardless of the amounts of money and time specified in grants, it is natural to regard larger and longer grants as preferable.

We believe that important economies can be achieved by using grants of longer term than a single year, and by refraining from calling for reports and reviews at too-frequent intervals, especially early in the life of a project. The necessary periods of uncertainty that immobilize investigators waiting to know whether staffs can be engaged and orders placed for equipment can be minimized if new proposals are not required at frequent intervals.

We have already stated our approval of the plural sources of federal support as represented by the several agencies. However, the multiple accounting and reporting required by multiple grants for closely related facets of an investigator's program are wasteful, and this system has, in our opinion, gone well past the optimum point for best results. We believe that vigorous efforts should be made to reduce the need for multiple-agency support by inter-agency agreements, with a single agency providing total support of that portion of an investigator's work that has a single, broad, scientific objective.

While we recognize that fewer, longer, more stable grants save the investigator's time and reduce the high cost of administration in both university and government agency, we are convinced that the health of the national research effort requires availability of small grants. By means of such grants, the project system must provide support for young, relatively untried principal investigators. It must also provide for continuous entry into the system of untried ideas that lie outside the current consensus as to where the frontier in a given area lies.

Therefore we suggest a program of special, small research grants for individual independent research, with preference given to junior scientists. These grants should be awarded on the basis of outlines of research interests, supported by letters of endorsement from senior scientists personally acquainted with the work of applicants. Aside from reimbursement for the time of the investigator and indirect payment to his institution, the budget should provide only for supplies, travel, and smaller items of equipment as a single budget item. The investigator should be allowed to pursue whatever lines of research appear most fruitful to him within the broadly described field. Such a program would be based on the recognition that many original ideas and discoveries in science have come from very young investigators, and we as a nation cannot afford to tie all our well-trained young people to narrowly defined objectives or to routine work in subordinate positions on big projects.

Termination of awards by an agency should be given as careful and serious consideration as approval of applications. Abrupt termination can thoroughly disrupt a research organization and scatter valuable personnel. Such devices as notice of the beginning of a terminal year and tapering off of grants over reasonable periods of time give opportunity to conclude the current stages of projects, to develop new proposals for further work, or for skilled personnel to find other places of employment.

Changes in Budget Items

Two types of projects run no risk of having to suffer changes in budget items during the life of a grant. In one of these the investigator is so completely unimaginative that he can foresee and describe in detail both his results and his methods before he begins. This kind of "efficiency" we do not recommend. The other type of project that runs no risk of change is that of a creative investigator who describes his project strictly according to the rules we have discussed; whose proposal moves through its review by both university and agency in zero time; and who executes the research so fast or works in a field of such gradual change that the state of knowledge and technique does not change while he is at work. In actual practice, however, some risk of changes in budgets is inherent in every project, no matter how well conceived and executed.

Often an interval of nine months or more elapses from the time an investigator writes his proposal until support is assured and the research can begin. During this time the state of knowledge may have changed in unanticipated ways. Scientific papers are published; new instruments become available. The personnel available for assistance may shift. New ideas emerge that require modification in the direction and emphasis of the project. The original design of the project no longer quite fits the state of knowledge or the tactical position in the field.

After the grant is awarded, external factors continue to change the configuration of the field. In addition, the investigator's own understanding of related problems should begin to sharpen rapidly. Even if the larger generalizations with which the investigator began are confirmed, many details will appear in different lights as he progresses. Even tactical decisions to change a method may affect the budget. And changes stemming from changed university regulations and the uncertainties that go with employing several people may affect the precise sums spent in particular categories.

The granting agency has the responsibility of assuring itself that inevitable changes made in budget items during the life of a grant do not constitute a change in purpose as originally described in the proposal and approved by the agency. Some regulation of the transfer of funds from one budgetary item to another is necessary if the agency is to have this assurance. We believe that the regulations limiting changes in the compensation of senior personnel, in travel (especially abroad), and in improvements in the facilities of grantee institutions are quite proper. On the other hand, we believe that principal investigators should be given maximum latitude in modification of other items in their budgets. We also believe that any limit on the purchase of initially unspecified equipment should be proportional to the total values of a grant.

If the principal investigator, in his application for renewal or continuation of a grant, explains substantial shifts in the specific budget items of his project, and thus justifies them on scientific grounds, adequate safeguards will be provided against diversion of funds. (We believe that a requirement for such explanations would be appropriate and sufficient.) Thus, projects will not be delayed pending approvals from federal agencies, and agency staffs will be spared the dilemma of making either perfunctory approvals or arbitrary refusals.

Total Professional Effort

Nearly every project grant provides for the payment of federal funds for the compensation of professional and technical personnel. Since these people are all employees of the university that receives the grant, the rules of the university rather than the rules of the government (through civil service regulations or otherwise) govern the rates of pay and conditions of employment. This fact is a cornerstone of the whole project system.

Accounting for the time or effort of technical and supporting personnel who carry out assigned work on a single grant is quite clear-cut. The supporting personnel can be hired in a nonacademic status on the basis of a standard work week—for instance, forty hours. The personnel supported by funds provided by a federal grant should be subject to the same regulations, salary scales, and working conditions as those that apply to employees in comparable positions with salaries paid from university funds. For both types of employees, the university must require the same adherence to standards of attendance and quality of performance. The university should keep, and make available to officers of the granting agency, appropriate records of the working time and salaries of all technical and supporting personnel working on a grant. This accounting should be annual rather than for briefer periods.

For principal investigators and other scientists with academic appointments, the problem of time-accounting is more delicate, whether they are reimbursed from government funds or not. The results in research for which they are paid cannot be measured in days or hours, or in percentages of them. Scientists do not "put in" a specific number of hours per week on a project. Insights and ideas do not "come in on schedule." They come to scientists, just as they come to politicians and poets, while driving to work, while discussing unrelated problems with colleagues at a convention, or even while attending committee meetings. Thanks to long-established scholarly traditions, most universities have met the demands of free inquiry by establishing an atmosphere free from restraint and regulation, with no percentage time assignments and with research work freed from administrative direction. It is the total professional effort that counts, and, in the last analysis, the progress achieved by an investigator over a three- to five-year period is the most reliable measure of his effort.

Under some circumstances a simple fraction of total professional effort in university duties can be assigned to a grant. Three cases will illustrate a range of possibilities for a professor who is a principal investigator.

Case 1. During the summer, the professor is not being paid by the university and has no formal teaching or administrative duties. He can be paid a salary from his research grant based on a fraction of his regular salary for that portion of the year for which the extra (grant) salary was drawn.

Case 2. During the regular university year, the professor finds his research project so demanding that he requests the administration of the university to lighten his teaching responsibility and other duties by a definite proportion, and to reduce his salary from local funds by the same proportion. The university then is obliged to seek replacement personnel. The funds of the research grant having been budgeted to pay the corresponding portion of the investigator's salary, he is then properly committed to the government to spend a commensurate portion of his total professional effort for that year on the project for which the grant was made.

Case 3. During the regular university year, the investigator undertakes his full teaching responsibility and his full range of duties as a professor, for which he is paid full salary from local funds. Among the duties for which he is being paid by the university is research. It may be an active year for the experiments in process under his grant, and he may spend what time he can working on it himself. He has full-time responsibility for the supervision of supporting personnel, who will continue to work through this period. Because of the fluctuations of activities geared to the academic calendar, the professor may be completely engaged in teaching duties and examinations one week, and then, because of a laboratory emergency, spend 80 hours on his research project the next. Because some of his research assistants are probably also his graduate students, much of the time he spends with them cannot be assignable separately to teaching or research. The two are intimately intermingled. Under case 3, any effort at time-accounting, even in terms of a fraction of total effort, is unrealistic, and should not be demanded by the agency.

We recognize that many variations in the patterns of compensation described in the three cases can be produced by multiple grants, each claiming their fraction. We also recognize that professional schools and large facilities, with many non-teaching appointments for senior scientists, produce difficult problems of application. However, we believe that the concept of total professional effort, when properly defined by academic institutions, contains within it not only a realistic measure for the scientist but an adequate safeguard for the government.

This tracing of the grant through its life cycle has enabled us to illustrate the principles that should govern every federal agency in supporting basic research in institutions of higher learning. The plural system of support, which we have praised and which we wish to see continued, precludes a government-wide uniformity in every detail of policy and procedure. Nevertheless, uniformity in the *principles* of support will foster the diversity of research patterns which contributes to the strength and glory of contemporary American science.

VIII

The Role of the Institutions of Higher Learning in the Operation of the Project System

Improving the Administration of Grants in the Universities

Because the grant is a cooperative arrangement of trust between the government and the university, the health of the project system and the achievement of national purposes through it depends upon enlightened policies both within the universities and among the government agencies. We believe in the importance of the universities' traditional self-disciplined freedom and in federal support on terms that will protect this freedom, because this combination has proved to be the most productive of increasing effectiveness in basic research which, in turn, is absolutely essential to the well-being of the nation and of civilization.

It is desirable to protect the freedom of a university scientist to choose a subject of research according to his own interests, because it will let science deploy more rapidly and effectively along the new and moving frontiers of knowledge. This freedom is not inconsistent with continuing federal government plans for a total national research program involving the selection of particular fields for special financial support. Moreover, this freedom of the investigator does not relieve the university administration of making responsible and discriminating judgments in deciding which projects or types of research to approve. Administrative officers should consider the relationship of proposals to the development of long-range university interests.

Weak university administration is no more in the interest of the government than it is of the universities themselves. Nor is it desirable to develop grant-supported university programs so heavily specialized in a few fields that the universities fail to fulfill their traditional function of providing an environment for education and free inquiry in all fields of knowledge. But the administrations of universities, both in the way in which they get their funds and by the nature of their faculty appointments, are, to a much greater extent than business corporations, or some private foundations, limited in the freedom with which they can commit their resources. A large part of their money comes (from the states and private sources as well as from the federal research programs) for particular purposes which cannot be changed by administrative decisions. The general structure of expenditure is set by the appointment of professors on permanent tenure, whose independence is the basic guarantee of academic freedom.

A university can make a major contribution to the cause of fiscal responsibility by maintaining a business and accounting staff with both high professional standards and knowledge of the granting procedures of the various federal agencies. The touchstone of the university stewardship of government funds is the rule that federal grant money should be expended with the same prudence, economy, and probity that governs the expenditure of university funds from other sources. This rule works well only to the extent that the university has clear policies for the expenditure of large sums. Unfortunately, while federal research money now equals the entire university budget of a few years ago, adequate mechanisms for supervising its proper, productive use are sometimes lacking.

An able business staff can do much to relieve principal investigators of the detailed bookkeeping and financial reporting required by grants. It can also keep abreast of the latest interpretations of grant requirements by the various agencies. It can advise the investigator, when he draws up his proposal, as to the provisions in the grant that will ensue from the content of his application. It can serve as a watchdog to be sure that the investigator, unaware of the niceties of legal phraseology, does not give away some essential freedom of action to a government agency in the course of negotiation. It should educate the investigator in the legal responsibilities he assumes when his university accepts a grant. It can direct the investigator to the agency whose program is most relevant to the project proposed.

Even with punctilious attention to the fiscal side of the federal grants on his campus, the administrative officer has not exercised his full responsibility if he does not give some kind of academic review to project proposals. He cannot, however, give direct orders to faculty members about the substance of their research, any more than a government agency can. The national panels are in a much better position than are administrative officers to rank proposals by scientific quality. The university has, of course, reviewed a professor's general capability as a scholar and teacher when it bestowed a tenure appointment on him. The academic review of project proposals addresses itself to the question whether a grant is consistent with the concept of the university as a community of scholars engaged in the education of youth and in public service, as well as in the advancement of knowledge.

We believe that all universities will do well to examine their mechanisms for the review of grant proposals, and that nearly all these mechanisms require drastic improvements. While specific measures to be taken depend upon previous accomplishments and local circumstances, we believe that some form of research board, representing both administration and research faculty, might be found widely useful. No university that does not now have a large program of federally supported research projects can realistically hope to gain one if it tries to manage its research grants by haphazard and outmoded policies.

Graduate Education and Basic Research

The 1960 report of the President's Science Advisory Committee, *Scientific Progress, the Universities, and the Federal Government*, examined carefully the connection between basic research and graduate education. We believe that this connection requires re-emphasis, because its relevance to the health of the project system is just as great today as it was in 1960.

Graduate education can be of highest quality only if it is conducted as a part of the research process itself. The research must not be in the form of mock problems; it must be a part of the exploration of the unknown, with all the uncertainties and challenges that go with it. By the same token, research can remain truly a quest, with freedom to follow unexpected lines, if the tentative conclusions of recent scientific research are tested in the interplay of advanced teaching.

Two trends are discernible which, if extended far enough, would lead to the impairment of the fruitful combination of research with graduate education. In some fields, basic research has moved into laboratories that have lost close touch with university teaching departments. Special conditions of geography or size sometimes dictate that a basic research facility be located away from a university center. Some of these facilities have done distinguished work in basic research. Nevertheless, we do not believe that the pattern of the intellectually isolated research facility should be encouraged without compelling reason. We agree with the President's Science Advisory Committee Report in its call for invention of ways to bring about further interpenetration of these institutions with the universities.

The other trend that may impair the fruitful combination of research and graduate education stems from a lack of strong policy within the universities themselves. Administrations, under pressure to retain distinguished scientists who are tempted by the simplicities of life in non-teaching laboratories in government, research institute, or industry, find that the easiest counter-offer is a promise of reduction in teaching. Some scientists retire from virtually all contact with students, while others only a little less distinguished are so overloaded with teaching that they are forced out of research. Administrations, hoping to add to the prestige of their universities by encouraging large-scale research projects of high visibility, may expect faculty members to buy large amounts of released time from the university. If the administration then allows a professor buying released time to use grant money to run up his salary far above the regular university scale, the stage is set for teaching of all kinds—graduate and undergraduate—to become a "poor relation" to research in the university.

University administrations need courage to be far-sighted in maintaining a balance between teaching and research. They also need the active help of enlightened policies in the federal agencies, for these agencies affect both basic research and graduate education by their fellowships and grants. Research professorships and postdoctoral fellowships that specifically exclude teaching should be carefully weighed for possible schismatic effects on research and education in the universities.

Indirect Costs

One of the most serious fiscal problems to develop in the operation of the project system has grown up around the payment of indirect costs to universities. The roots of the overhead payment or indirect cost problem go all the way back to the OSRD. Because it conducted federally supported research, a university clearly incurred some expense that could not easily be separated from other institutional expenses. Thus, the difficulty of description in accounting terms is precisely what made indirect costs indirect. The no-gain-no-loss principle for research contracts indicated that the government should defray these costs, which, as the amount of federal support grew, became a real drain on the institution. Clearly, the vastly expanded research program owed some share to the universities for administration buildings, maintenance services, accounting systems, libraries, and dormitories, in a way that the finest distinctions of the accountant could never quite pinpoint. The realization gradually dawned that no absolute difference exists between direct and indirect costs, and, as accounting procedures have developed, some items, retirement benefits for instance, have moved from one category to another. As different agencies developed different patterns of reimbursement, comparability became ever harder to achieve.

The introduction of the grant instrument for the support of research initiated a different pattern for the reimbursement of indirect costs. Ideally, the grant makes only a partial contribution toward a purpose to which the grantee institution is already fully committed, and on which it is willing to spend some of its own funds. We believe that this principle is correct, and, as we noted earlier, the institution often does make a sizable investment of its own funds in the form of the investigator's salary. But indirect costs have become so large that the universities cannot easily assume these costs on every research project that a faculty member arranges. A generation ago, when outside funds provided only a few minor supplementary research expenses, an administrative officer could quite properly encourage every professor to seek funds from any possible source and in any amount that he could get. But when federal research expenditures reach many millions of dollars per year on a single campus, the administrative officer can no longer afford to take the old approach. The university must be maintained as a community of scholars dealing with all aspects of knowledge, and there are not enough unrestricted funds from non-federal sources to provide for that and also for the management of massive new programs.

The administrative officer with a large federal grant program is tempted to do several dangerous things if indirect costs are not adequately covered: (1) He may divert funds from work in other branches of knowledge. (2) He may divert funds from the teaching function of the university. (3) He may neglect the proper administration of federal funds. (4) He may divert federal funds to questionable uses. In partial recognition of these dangers, the government agencies that use grants have been allowed to pay a flat rate, a percentage of the direct costs of the grant. In recent years, the percentage paid by the National Institutes of Health and the National Science Foundation, for instance, has ranged from 15 per cent to 25 per cent. Since actual overhead on individual projects varies, and the costs at different institutions vary, the flat rate can easily produce individual instances of overpayment and underpayment.

The contract pattern of reimbursement, developed by the Department of Defense and adopted in Circular A-21 of the Bureau of the Budget, is a negotiated rate based on an audit of the expenditures of the institution. Hence the administrative officer of the university, in general preferring the flexibility of the grant, looks wistfully at the contract when he thinks of indirect costs. Most universities have felt that on grants with a flat rate they have been undercompensated, and thus forced into cost-sharing for government-financed research, in a way not chosen by themselves and not advantageous to the over-all health of their institutions. A report to Harvard University comments, "Research can be carried on effectively in the long run only if a university maintains its overhead in an intellectual and academic, as well as an administrative, sense . . . . It is not a question of asking the government for more money, but rather, of asking it to give its funds with a proper regard for the total function of the university."

The indirect cost issue unfortunately has become a wedge not only between the government and the universities but also between investigators and administrators on university campuses. The investigator can see where direct costs go in his project, and he realizes that the national panel in his discipline has only a finite number of dollars to grant, so that, the more money paid into indirect costs by the government, the less remains available for research. All that goes to the university in indirect costs simply disappears, as far as the investigator is concerned. The administrative officer, on the other hand, concerned with institutional balance and with those parts of the university that would be deprived of funds from other sources if the federal projects drain off local funds, is likely to be quite as emphatic as the investigator, but in the other direction. We suggest that university administrations should make special efforts to explain their use of funds from indirect cost payments to their faculty members.

We believe that federal agencies should pay for indirect costs, on grants as well as contracts, at a rate substantially equivalent to audited costs. We also believe that an institution that accepts payments for indirect costs should accept the obligation for those institutional functions that, in fact, give support to the research activity, thus supporting the investigator and his department adequately.

Institutional and General Research Grants Tied to the Project System

Almost from the beginning of the project system, it became obvious that, while the independence of the universities was being reasonably preserved, the effects on the institutions that received the grants were great simply because the research was done there. Often these effects were of greater significance than the results of research, which in a given case might not be decisive. The effects showed up where the institutions, with the help of project funds, were able to build up a "capability" for the future with the faculty personnel they had attracted and facilities they had established. The kind of grant that, as its main object, would build up an institution's capability has therefore seemed attractive to some universities during the last two decades. Yet institutional and general research grants have always entailed the judgment of scientific excellence on an institutional basis. The project system has brought satisfactory resolution of the problem of judging scientific quality. The advocates of institutional grants have always to meet the charge that they will depart from the highest standards of excellence, and hence waste the taxpayer's money. Yet every institution, no matter how many projects its faculty members attract, could increase its capability if it had free funds with which to supplement project grants.

The National Science Foundation and the National Institutes of Health have, in a modest way, recognized the need for supplementary grants somewhat similar to institutional grants. We believe that an extension of this type of grant is desirable and that, if the purpose is broadly enough defined, it would enable a university to support many types of activities that do not fit neatly into the project system. The fact that institutional grants of this type are awarded in direct proportion to the volume of project grants received by an institution means that the judgment of scientific quality supplied by the scientific community carries over indirectly to provide a standard of quality.

Development Grants to Alter
the Geographical Distribution of Federal Funds

Supplementary institutional grants do nothing to protect the project system from the charge that it makes the rich richer and the poor poorer. We consider it a most unfortunate effect of the application of the interrelated system that it historically has led to concentration of federal support funds at relatively few institutions. The country would be stronger and national purposes more nearly fulfilled if there were many more good investigators at many more institutions. If there were no place in the country from which an institution of higher learning of great distinction was inaccessible, the general welfare of every citizen would be vastly increased. As John Wesley Powell told the Congress nearly a century ago, "The learning of one man does not subtract from the learning of another, as if there were a limited quantity of unknown truth. Intellectual activity does not compete with other intellectual activity for exclusive possession of truth; scholarship breeds scholarship, wisdom breeds wisdom, discovery breeds discovery."

We are convinced, however, that a desirable pattern of distribution of research capability cannot be achieved by wholesale redistribution of the federal funds which the Congress, for important national purposes, has made available through the project system. To deprive investigators who have proved themselves worthy of support, in order that those who have not proved themselves may have a share of support, would mean a lowering of national capability in science. And even if large amounts of federal money were available for the purpose, support to institutions that do not have sound policies to foster research would be wasteful. The local university must provide academic freedom, proper salaries, and reasonable work loads before federal support, either in projects or institutional grants, will work in the direction of excellence.

Therefore, we believe that a program of development grants should be launched in support of research and graduate education in institutions with potentiality for becoming strong in the future. We recognize that the framing of criteria by which these grants should be awarded is not an easy task. We suggest that development grants should not be extensively used until principles and the criteria for such awards have been carefully studied by a competent special task force. Since controversial questions are at issue, the membership of this task force should be drawn primarily from two groups: scientists from leading academic institutions not eligible for such development grants, and lay citizens of broad national interests, representative of various geographical areas and of various economic interests. The criteria should be kept distinct from those used by the selection panels in the present project system. Judgment of quality by established standards of excellence gives the project system its present integrity, and the loss of those standards would not help emergent institutions at all, in the long run. Judgment of potentiality and the stimulation of excellence can succeed only if the development grant is awarded for its proper purpose.

The Permanent Interrelated System

When development grants have done their work and increased the number of strong universities in every region of the nation, they should be phased out to let the project system, modified by supplementary institutional grants, take over. Thus we are advocating here, as we have throughout this report, a strengthening of the partnership that has served the nation well for two decades. The achievements of the investigators who perform research will be greater if the institutions in which they work are stronger. If the government's ability to ensure fiscal responsibility is secure, its ability to assist both the investigator and his institution will be increased. The system will be stronger if not one but several agencies have strong policies in support of basic research. And the system will be strengthened with the solution of other pressing problems which the Congress, the Executive, and the universities must meet forthrightly. The one feature of the partnership of the federal government and the institutions of higher learning that dominates the future, as well as the past, is the immense productivity in scientific discovery and the great strength that the presence of science brings to our national life. The federal government, the universities, and the scientific community still have far to go together.

Clearly the government and the universities have essential responsibilities—both separate and joint—for the success of the system. So, too, the scientific community has an essential role to play. That part of the total scientific community with which we are concerned in this report—the scientists in the institutions of higher learning—are a part of a larger society of scholars. As such, their responsibilities are multiple. They have obligations to advance scientific knowledge, but also for the education of youth. They must give conscientious and enlightened service on panels and other advisory bodies, and as individuals they must often give advice on the selection of research proposals. We urge that the members of the scientific community look upon this service as advancing science as significantly as if they had spent the same time in their laboratories. By defining the purpose of the grant or contract in his proposal, the scientist participates in the process that brings him support. When he accepts support funds, he accepts a trust to render conscientious effort to achieve the purpose of the grant or contract. He acquires no other rights to the funds. The responsibility of the scientist as a member of the scientific community works in the direction of harmony with the responsibilities of the government and the universities. To reduce the incidental mutual irritations of the system, the simple guidelines of this report have been put forward. We hope that they will help the partnership of the federal government, the universities, and the scientific community in the grand purpose of advancing the welfare of the nation, and with it the welfare of all mankind. ■