# THE DIRECTOR'S STATEMENT

This annual report covers my first year as Director of the National Science Foundation. It may be appropriate, therefore, to begin by introducing some of my own views concerning the role of science and technology in the life and progress of our country, the responsibilities of the Federal Government for promoting science, technology, and education in the public interest, and, in particular, the role that should be played by the National Science Foundation.

In the span of less than a single lifetime, virtually every aspect of our society and our personal lives has been vitally affected by the tremendous new impact of science and technology. The posture and composition of our military defense forces are determined by this partnership of scientific knowledge. The space program, with implications stretching far beyond the limits of imagination, is wholly a product of this generation. Our position among the nations of the world depends on our scientific and technological accomplishments—as well as on our cultural attainments, which, in turn, are nourished by science and technology.

We have witnessed radical improvements in medical care, nutrition, and in our standard of living generally. Even our entertainments—the arts and recreation—have benefited from this transformation of our society, an event that is difficult to compare with anything heretofore witnessed in human history.

My comments will elaborate on some of the things that I believe are of importance to the scientific community and the Nation at this time in our history. They stem from the following basic convictions:

- Science and its applications have become such an important part of our culture that they deserve more attention (critical as well as supportive) from the American public and its leadership.
- The interrelationships between science and education and between both of these and government (at all levels) must be healthy if our scientific advance is to be continued.
- A central government is quite properly the creature and servant of the people; hence it can and should do those things for which the people see—or are brought by leadership to perceive—a significant need.
- Support of the scientific enterprise can and should be provided from many sources, including—but *not* especially—the Federal Government.
- All those professionally concerned with scientific and technological activity bear a responsibility for making clear these facts: that *re-*

*search* and *development* are separable and separate entities, and that they interact one with the other in ways which are mutually helpful; that science is closer to research, and engineering is closer to development, but that there is much overlap on all sides.

- Expenditures for development can and should be justified on grounds which relate to end purpose, goal, or mission—and should not be made competitive with expenditures for basic or broadly based applied research.
- Broad progress, in science and science administration as elsewhere, usually results from the establishment and gradual expansion of particular salients rather than through inch-by-inch advance across a wide front; "imbalances" are therefore inevitable, and even have a certain value as goads to further action.
- As one increasingly important contributor to the Federal effort directed toward keeping U.S. science strong and progressive, the National Science Foundation must continue to provide support for academic science; the Foundation must, therefore, remain throughly informed concerning the problems of colleges and universities, as well as the problems of the science faculty members at these institutions, and should try to invent mechanisms which will as nearly as possible solve the problems both of investigators and of institutions.

The complexity of modern technology in our society—to which Government programs in space, defense, and elsewhere are contributors—places a heavy burden on the country's educational facilities. In order to keep pace with developments, our schools must conduct elaborate and costly efforts to update their capabilities as they prepare scientists to cope with the technology of the 1970's and later. At the same time, the quantitative workload of our universities has mushroomed as they educate increasing numbers of scientists and engineers to meet current needs of industry and Government. Now we have reached the point where Government must be prepared to shoulder an even greater share of responsibility for education in the sciences, first on the basis of traditional concern for national welfare and progress, and secondly because Government requirements themselves constitute one of the factors that are taxing the educational structure to capacity.

To summarize, continuing progress in science and technology is essential to the public welfare and, hence, is a matter of concern to all the people. To assure this progress is clearly a concern of the Federal Government.

## The Federal Government's Responsibility

American science was developing along sound and promising lines when the Great Depression struck. For a while, along with many other areas of intellectual activity, it faltered. It had already begun its own recovery when the urgencies of World War II quickly pushed it forward at an ever-faster pace. Progress during those years, and in the span of time to the present, has brought us face to face with challenges and opportunities even greater than those posed for our forebears by the Industrial Revolution. The traditional role of the Federal Government has changed as the scope of its responsibilities has been raised to new heights. Our national destiny quite literally depends on how well we meet these responsibilities.

A primary objective of the Federal Government should be and is to make sure that our capabilities in the areas of science and technology are the very best the social structure can produce. This means that leadership must see to it that we have a vigorous and healthy scientific and technological base which will lead to continued social and economic advance. Scientific and technological progress must be viewed as dependent, in the long run, on two factors:

1. The need to maintain and constantly augment a fund of scientific knowledge derived through research, particularly basic research.
2. The need to strengthen science education, especially higher education, to be sure that we produce adequate numbers of young scientists and engineers qualified to do the things our national goals require.

A second Government objective is to develop—or have developed—the hardware, materials, and processes required for national programs conducted by the Government itself, such as those in military defense and space.

A third Federal objective is to foster and encourage developments that will react to the direct benefit of the people. Here, the distinction lies in the fact that the public rather than the Government is the "customer." Improvements in public health; better practices in agriculture; improved transportation; development of energy, water and other resources; and conservation: these and many other applications of the sciences are properly the concern of the Federal Government since private elements of our society cannot be expected to assume sole or even primary responsibility.

Both the Congress and the public have recently focused interest on the rapid increase in expenditures for research and development by the Federal Government. The concern is understandable since the increase over recent years is substantial. Federal expenditures for research and development have increased from $74 million in 1940 to about $12 billion in 1963. The amount cited for 1940 was only one percent of total Federal expenditures; the 1963 figure accounted for 13 percent.

It is possible for misunderstanding to arise if these totals are scrutinized without considering what they represent. This is one of the problems noted by the Select Committee on Government Research of the House of Representatives, which said in its first report: ". . . the most significant thing that can be said about these figures is that, isolated, they are misleading."

What, then, are the facts? How can the figures be presented in their proper perspective?

To begin with, the familiar term "research and development" does not refer to a single entity. On the contrary, it covers a very broad range of scientific and technological activities. These activities range from the most fundamental basic research to the development of highly complex devices. The convenient abbreviation R&D can be dangerous in that it can lead to confusion and misunderstanding.

The obvious questions arise occasionally: "How much can we afford for research and development? What percentage of the Federal budget or of the Gross National Product should be allotted to research and development?" In my judgment, this approach to the problem is fallacious. To reach the perspective we are seeking, research and development should be considered in terms of the component parts.

All development and much of applied research are directed toward specific national goals. These may be in defense, space, agriculture, public health, or elsewhere. A more meaningful question would be: "How necessary is this particular undertaking to achievement of a national goal?" Developments for military defense should be thought of in the context of military defense. The cost of developing a particular defense item should not be considered in competition with research for public health or basic research in general, but in the overall context of defense expenditure. The same reasoning should apply to developmental projects in space exploration, atomic energy applications, and other national programs. In this approach, only expenditures for basic research—and certain components of applied research—should be regarded as the national investment in science.

Scientific and technological activities included in gross expenditures for research and development are usually divided into three categories: basic research, applied research, and development. The boundaries between them are not sharply defined. They cannot be compartmented neatly, however convenient such a procedure might be for the administrator or the budget officer. For example, what the university scientist may regard as "applied" research may seem very basic to the engineer looking for immediately applicable results.

All research is, of course, the quest for knowledge, and knowledge implies understanding as well as information. Basic research seeks an understanding of the laws of nature without regard for specific utilitarian value. The real objective of basic research is not merely to discover a collection of separate facts by weighing this and measuring that—but to develop an understanding of nature by seeking out the *why* and *how* of nature's behavior.

The fact of understanding is singularly important in science and its applications. It is not sufficient for a scientist to have an inventory of isolated facts; he needs to understand them well enough to be able to move on from them to new areas.

Applied research is carried out with practical and usually, but not necessarily, specific objectives in mind. Such research may involve special measurements to yield data needed for some engineering purposes. It could be a broad study of high-temperature materials for application to many purposes. Much applied research seeks detailed information regarding a specific situation for which the general laws are known from basic research. Obviously applied research pursues courses of action deemed most promising in terms of practical results. Increasing our understanding of natural laws, although important, is not the primary objective.

Now let us look at development, the offspring of research. Development is the systematic use of knowledge directed toward the design and production of useful prototypes, materials, devices, systems, methods, or processes. This includes the construction and testing of "hardware," including military weapons systems, space vehicles, nuclear reactors, and many other items great and small. This is the costliest aspect of the research and development spectrum, both in Government and in private industry. It is distinct and separate from research in that it applies the results of research to the production of end products. Much and often most of what we call development is not "science" in the real sense; rather, it is akin to fabrication, construction, and testing, and it often involves large and expensive programs.

All three areas of activity are important. Applied research builds on the results of basic research. Development builds on both. The more complete our basic knowledge, the easier the task of applied research and of development. The debt owed by technology to science is paid back, however, for many fields of basic and applied research are made possible or more fruitful through new technological developments. For example, much of modern research is made possible by electronic devices originally developed for radio, television, and radar. Special materials, such as metallic alloys, plastics, and ceramics, as well as countless industrial devices and other things of practical importance serve as important tools for research. The range of possible research is broadened and the cost is often greatly lessened by these contributions.

Perhaps scientists have been remiss in not explaining the nature of basic research more clearly. We have also made the mistake of trying to illustrate the ultimate utilitarian value of basic research by examples in which we try to show that a single fundamental experiment has had important practical impact. Nuclear fission has been used as such an example for years. Even in this case, a whole series of experiments preceded and followed the discovery of fission. Without them the fission experiment could not have accomplished what it did, even though it was a rare and outstanding scientific-technological breakthrough.

In the broad sense, basic research is the foundation upon which rests all technological development. The technological fruits of research are harvested from a mosaic of knowledge made up of a great many experiments and the understanding derived from them—just as a tree springs from no single root but from many rootlets reaching deep down to the source of nourishment. Thus it is not appropriate to ask: "How can this particular piece of basic research ever possibly have practical application?" The proper question is: "How much might this contribute to total understanding?"

Transistors provide a good example of the process by which basic research eventually reaches practical application. How did this important advance in electronic technology—the basis of a multibillion dollar industry—come about? It was not by a single invention, not by the results of one experiment or even one program. The applied research and development that brought the transistor into being rested on a great store of basic knowledge—especially in solid state physics and in the field of very pure chemical materials—accumulated through the work of many individuals in many academic and other institutions, including the Bell Telephone Laboratories where the initial development took place. Without this basic knowledge, the development—and indeed the idea itself—would not have been possible.

Apart from the ultimate practical importance of basic research, we must not overlook its intellectual and cultural value—a quality it shares with all forms of knowledge, literature, and the arts. Scientists as well as others make the mistake of referring to "the sciences" as being clearly separate from "the humanities." This is unfortunate, for science is not inhumane, and it is easily demonstrated that the life of the human race has been enriched by the ideas of science, as well as by the material benefits which science has made possible. In a deeply meaningful sense, science is one of the humanities.

Because of the dramatic and spectacular associations surrounding space vehicles and sophisticated items of military hardware, the public is sometimes prone to lose sight of the broader spectrum of Government interest in science and science education. The national effort to foster scientific progress has been likened to "pushing back the darkness" and it goes forward on a wide front. Research and training programs in oceanography, the biological and medical sciences, the atmospheric sciences, the social sciences—to name just a few of the areas of interest to the National Science Foundation—are all properly included in programs of Government support of one kind or another. Nearly all Government agencies provide some kind of support to science, but necessarily, in the general case, along lines that are oriented to their mission responsibilities. The involvement of the Department of Defense, the Atomic Energy Commission, the National Aeronautics and Space Administration, and several other departments and agencies is well known and the reasons for their interest in science are clear. But it is not widely recognized that significant sums are obligated for research and development by the Treasury Department (through the U.S. Coast Guard, mainly), the Post Office Department, the Veterans' Administration, and 10 units under the Department of the Interior. Altogether, depending on how one counts Bureaus and other units of major governmental entities, several dozen Federal components can be identified as substantial contributors to the scientific and technological enterprise in the United States.

How did we reach the present stage of involvement of the Federal Government in support of science? What historical events and points of view can we call on to give us understanding of where we now find ourselves?

## The Historical Perspective

In science, perhaps more than in most other areas, "what is past is prologue." The history of scientific progress in the United States is important, both in its own right and as a necessary part of our background if we are to understand what is now feasible and desirable. Because science and education are inextricably intertwined, we must also bear in mind what has happened in education over the years.

It has become obvious to most Americans that continued progress in science and technology is essential to further development in pursuit of the American dream, or the "Great Society" as it has recently been described. It has also become inescapably clear that the Federal Government must continue to shoulder a substantial share of responsibility to insure that the pace of progress does not falter. The principle of government responsibility is accepted, and we are faced with the task of making the wisest possible decisions concerning the direction and intensity of support for science and education.

Government interest in promoting scientific progress and education is historically an integral feature of the American tradition. From the very outset, our forefathers expressed eagerness to assume a role as patrons of science in the light of its usefulness to the development of the nation. It was no accident that the Declaration of Independence appealed to "natural law." Jefferson and his colleagues were wholly conscious of the potential benefits of science and its implications for the infant nation.

It is notable that the Constitution empowered the Congress to "promote the Progress of Science and the useful Arts" at a time when the very word "science" had not yet become a part of the popular vocabulary. There were numerous suggestions submitted, by James Madison and Charles Pinckney in particular, which would have included in the Constitution specific provision for the establishment of a national university devoted in large measure to education in the sciences. Both Washington and Jefferson favored such an institution. There was widespread discussion of Government charters for scientific societies, and special incentives or subsidies for creative effort in science and technology.

Some of the suggestions submitted by the architects of our society were surprisingly imaginative. Many emphasized the need for a national system of education, and urged study of the sciences and utilitarian subjects rather than a continuing overemphasis on the study of the classics. Among the foremost advocates of educational innovation was Jefferson, who believed that merit rather than wealth should determine the educational opportunities of youth. Public education, commencing with the primary school and closing with the university, should be open to anyone whose abilities warranted these opportunities.

The educational ideas of Jefferson and his contemporaries are important, not so much for what they accomplished immediately—the country was still too poor to support a full-scale revolution in education—but in that they provided guideposts for the future.

The educational foundations upon which our forefathers so courageously set out to build a great society were singularly unimpressive by the existing standards of European countries. The president, three professors, and four tutors comprised the entire instructing staff at Harvard in 1800. The Harvard medical school had three professors and graduated only two or three students each year. When Franklin died in 1790, America lost its only scientist of international repute.

But if Federal funds were scarce, the Congress nevertheless did much for education as the United States moved through the years of the 19th century. When the Northwest was opened, not only was one section in each township granted for schools, but a donation of two townships was made to the Ohio Compay to found a university, thus establishing the original endowment of Ohio University at Athens. When Ohio became a State in 1803, Congress likewise granted a township to establish Miami University for the settlers around Cincinnati. As each new State was added to the Union, similar grants were made, with the result that 17 State universities were in existence by 1860.

The Morrill Act of 1862 was a great step forward in Federal aid to education. Under this legislation the Government granted public land to each State—30,000 acres for each senator and representative—for the establishment of mechanical and agricultural schools. These land-grant colleges include some of the most productive and progressive educational institutions of the present day. It has been estimated that the Federal Government in one way or another has donated altogether some 118,000,000 acres to education.

In addition to these farsighted efforts in support of education, the Federal Government, very early in its history, assumed positive responsiblities in a number of other areas associated with science and technology. The Patent Office, one of the oldest Government agencies, was established in 1790—indeed, its function was provided for in the Constitution. Its purpose then, as now, was to encourage and protect inventors so that they might receive just reward for their contributions to national progress.

In the early years of the 19th century, the Congress approved funds for an ambitious coastal survey to promote shipping, and authorized construction of a national turnpike leading into the new country opening up in the West. The Army surveyed the Great Lakes and lent technical assistance in construction of canals and railroads. Beginning a little later, the Army Medical Corps started contributing an invaluable service to the Nation with its work in the control of epidemic disease and in other areas of health.

Thus it is clear that the Government has been in partnership with its citizens in the fields of education, science, and technology from the beginning of our history. Moreover, the climate of burgeoning America was highly favorable for scientific and technological development, a condition stemming from the philosophical and political convictions that constitute the basis of true Americanism.

Against this background, Americans built a model of modern society, and emerged from the wilderness to assume full stature in the community of nations. From a small trickle in the beginning, technological advances soon reached torrential proportions, with problem and solution following each other in dramatic succession.

Beginning with the textile mills of New England, the wave of technological development swept the Nation. The shipping industry flourished as Yankee clippers took to the seven seas. Introduction of agricultural machinery, new processes for smelting iron, the cotton gin, steam engines, electric motors, and a score of other innovations contributed to the building of industrial America. On the western prairies, the telegraph replaced the pony express.

A new profession came into being—the mechanical engineer—as one discovery followed fast on the heels of the last. The sewing machine, invented by Elias Howe in 1846, revolutionized the textile and shoe industries. The electric light and the telephone appeared on the scene as the century of progress reached a climax. When the Patent Office opened its doors in 1790, the clerks waited three months for the first applicant to present himself. In the hundred years that followed, nearly two million patents were granted, remarkable evidence of "Progress of Science and the useful Arts."

The first hundred years of existence as a free nation were truly eventful for the United States. The material wealth of the country multiplied several hundred times over—but a nation's advance should not be measured in material goods alone. Similarly, it would be difficult to estimate the fiscal investment of the Federal Government in its efforts to promote education, technology, and science. Speculation on the "might have been" is fruitless, and there is no way to measure the debt we owe to Jefferson and the other pioneer giants who charted a course for the ship of state.

The great majority of scientific work in the United States during the 19th century was devoted to the solution of practical problems, the invention of "things" and processes that would immediately become useful and profitable. Science lived in close proximity with trade and industry and material development. In satisfying the insatiable hunger for technological advances, there was even ample room for the talented and lucky amateur. Emerson, with his lofty disdain for society as a "joint-stock company" and for the "education at a college of fools" was representative of the element which hung a sign on the door of American intellectualism reading, "Scientist Kindly Use Rear Entrance." It was an attitude, unfortunately, that spilled too far over into the 20th century.

It is quite true that the pursuit of intellectual excellence for its own sake in 19th century America was directed mainly along the avenues of philosophy and the arts. Science gave little time to basic research—the quest of new knowledge for its own sake and without thought of practical application. All of the inventions and technological advances that went into building industrial America were based on an inherited body of scientific knowledge—the sum of scientific discoveries which had originated largely in Europe. The fund of mathematical knowledge which enabled the Army Engineers to build canals and survey the Great Lakes in the 1840's was substantially unchanged 50 years later. Science as an intellectual process was, if not ignored, at least neglected. Expansion of the intellect in the simple pursuit of excellence was overshadowed by the dramatic demands of technology.

But with continuing heavy emphasis on the technological applications—and little effort in pure research as was the case in the 19th century—one might be moved to ask if the bank of scientific knowledge may not eventually be exhausted. If science becomes bankrupt, can material progress continue? We know that past civilizations have withered and died from stagnation.

To the great good fortune of science and of the Nation, American universities began in the latter part of the 19th century to engage in scientific research. Leading scientists on their faculties, many of whom had studied in the great universities of Western Europe, clearly perceived the scholarly virtues of research, both in its impact on the faculties themselves and in the role that it could play in the education of budding scientists. Beginning in a few of the leading institutions, recognition of the importance of academic research gradually spread, often under great handicaps with respect to time and money, until by the end of World War I it had become traditional in all the major universities and many others. This trend grew throughout the 1920's and the 1930's, in spite of financial setbacks during the Great Depression. During this whole period great and vital financial assistance was rendered through the generosity of many of the privately endowed foundations. So firmly did the importance of research become recognized by the well-informed that increasing numbers of forward-looking industries engaged in it themselves and in some instances supported it in the universities. A few private nonprofit research institutions, usually supported by a private foundation, also came into existence. Thus, by the advent of World War II, research had become a widespread enterprise, though its value had not yet been recognized by the public as a whole.

The unprecedented accomplishments of scientists during World War II led to a new and general awareness of the importance of science, especially research. It was, therefore, not surprising that President Roosevelt a short while before his death requested Vannevar Bush to prepare for him recommendations detailing how:

> The information, the techniques, and the research experience developed by the Office of Scientific Research and Development and by the thousands of scientists in the universities and in private industry [can] be used in the days of peace ahead for the improvement of the national health, the creation of new enterprises bringing new jobs, and the betterment of the national standard of living.

Bush responded in less than 8 months with his well-known report, *Science—The Endless Frontier.* The central point of view that the report emphasizes has come to be an unquestioned principle over the intervening two decades. In the summary of his report Bush said:

> The Government should accept new responsibilities for promoting the flow of new scientific knowledge and the development of scientific talent in our youth. These responsibilities are the proper concern of the Government, for they vitally affect our health, our jobs, and our national security. It is in keping 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 land grant colleges and the benefits have been great. The time has come when such support should be extended to other fields.

Bush's wise advice was heeded in many quarters, eventually in its broadest sense. In the initial postwar years, however, support for science and its applications was largely motivated by the goals of national security, better health, and other practical needs. The Office of Naval Research, the Atomic Energy Commission, and later, the National Institutes of Health instituted vigorous programs backed by increasing financial support. Although justified by practical ends, these programs served as salients from which grew support for basic science. Wise men directing the programs of these and other agencies saw that progress in the applications of science could flourish only when resting on a base of fundamental knowledge and understanding. As this realization grew within the public and the Congress, basic research began to be accepted as a proper objective for Federal support without regard to foreseeable applications for each component part. This realization reached maturity in the Congress in 1950 with the act establishing the National Science Foundation as an independent agency devoted to the support of science and science education without regard to specific practical missions. No limitations were placed upon the activities to be covered so long as they were scientific.

In addition to bringing about a greatly increased realization of the important role of science in society, World War II resulted in adoption of a remarkable invention in the methodology by which the Federal Government conducts its scientific work. During the war, the Government turned in large measure to private institutions to carry out military research and development. The success of this method led to its continuation into the peacetime era. A growing majority of the work was conducted under grants or contracts with universities or industry or other institutions, depending on the nature of the work. Even many federally owned laboratories, some so large as to be national in character, were operated under contract by such private institutions. So complete was the adoption of this method that the Atomic Energy Commission and, later, the National Science Foundation were barred by statute from the direct conduct of scientific work themselves. This trend continues. As contrasted with the prewar years when a large majority of Federal research and development activities were in intramural laboratories, less than one-fifth is found there now. Notably, almost half of the expenditure for basic research support is in the colleges and universities where it has a strong impact on higher education. Indeed some programs, notably one supported by the National Institutes of Health, explicitly combine the objectives of research and graduate student training. It is worth noting that approximately one-third of the almost $1 billion in support of research in the universities' own laboratories comes from the Defense Department. A like amount comes from the National Institutes of Health—most of it going to the medical schools. NSF supplies about 15 percent; AEC, eight percent; and the rest is scattered.

Nearly all of the work in the educational institutions and much of that conducted elsewhere is supported through so-called "project" grants or contracts. Under this system individual scientists or groups of scientists apply through their institutions for funds to support fairly well-defined research. These proposals are scrutinized by the particular agency, which selects the most meritorious ones for support within the limitations of its funds. Many of the agencies, notably the National Science Foundation and the National Institutes of Health, base their judgments largely on the recommendations of experienced scientists from outside the Government who work in the same or closely related fields. This system of "judgment by the peers" brings into the evaluation the most highly qualified scientists in the country and is furthermore a protection against the possibility of errors in judgment that might result were programs determined by a relative few within the Govenment who were not in immediate and constant touch with the progress of the various fields.

In addition to support of the conduct of research, the various agencies have supplied specialized facilities for research in such fields as nuclear physics, oceanography, astronomy, and many others, in addition to computers for use in virtually all fields. Some of the agencies have provided funds, often on a matching basis, to construct general laboratories for graduate research.

Forming an important component in the total research effort are the so-called "national centers" operated for the Government by individual educational institutions, by corporations sponsored by such institutions, or by industry. In many instances they serve as centers where equipment so large, complicated, and expensive as not to be feasible for individual universities can be located to serve the needs of the scientific community as a whole.

The magnitude and complexity of the Federal Government's research and development programs are so great as to make it increasingly necessary to have continuous coordination. In the first place, one is always confronted by limitations of manpower, of facilities, and of fiscal resources. Secondly, it is necessary to guard against fragmented research efforts where pooled resources would accomplish much more than merely the sum of individual items. Thirdly, many scientific activities transcend the responsibility or interests of a single agency. Then too, one must safeguard against any unwarranted duplications or important omissions resulting from peculiarities of Government organization or of agency jurisdiction. Finally, the increasing knowledge of science and technology leads to the recognition that many problems are never completely resolved, but must be looked at continuously from new vantage points.

The key individual in the coordination of the research and development programs of the Federal Government is the Special Assistant to the President for Science and Technology. He is also Chairman of the President's Science Advisory Committee and of the Federal Council for Science and Technology, as well as head of the Office of Science and Technology.

The President's Science Advisory Committee is comprised of leading scientists and engineers from outside the Government who review the status of important fields of science, utilizing, as appropriate, special panels whose total membership includes several hundred scientists from all over the country. This arrangement not only brings to bear on Government problems the wisdom and experience of all these individuals, but also is an effective mechanism for communication among scientists in the universities and industries actively engaged in research and development and between them and the Government, thus providing an important clearinghouse for information and ideas.

The Federal Council for Science and Technology consists of the chief scientific officers of the nine Federal agencies most heavily involved in scientific activities. It is concerned primarily with resolving problems of a multiagency nature and with coordinating the work among the agencies. It leans heavily on the scientific advice of the President's Science Advisory Committee and the National Academy of Sciences. Through various committees and the staffs of the agencies and of the Office of Science and Technology, it examines areas of primary national interest where a concentrated effort and Governmentwide approach is deemed essential, either because of the magnitude of the activity or because of the multiplicity of agencies involved. Whole scientific fields are reviewed with respect to scientific expectation and national goals as well as to possible gaps and overlaps. Noteworthy success has been achieved in oceanography and in the atmospheric sciences. In these cases reports from the National Academy of Sciences have been particularly helpful.

The Office of Science and Technology is concerned primarily with national policies of science and technology, both the role of science in policy and the complementary role of policy with respect to science. It also provides staff assistance to the President's Science Advisory Committee, the Federal Council for Science and Technology, and the Science Advisor, and it is the official channel from the Executive Branch to Congress.

These various mechanisms combine effectively to provide the Executive Branch with the best scientific wisdom both inside and outside the Government and to bring about effective coordination in all the multitudinous scientific and technical activities while leaving the intimate direction and decisionmaking to the agencies wherein lies the detailed knowledge of requirements for the various missions.

## The Role of the National Science Foundation

The National Science Foundation, an independent agency of unique characteristics, was established by Act of Congress in 1950 to support science in the broadest sense. Thus, it may be said that the Congress laid out the Foundation's mission in strategic terms, leaving to the agency wide discretion in choosing its mechanisms or tactical approaches to the problem of helping science move forward.

The Foundation has chosen, wisely I believe, to stress investment in people as a broad element of the strategic approach. Science advances through the creative efforts of well-educated, gifted people. Identification of such people and appropriate support for their endeavors constitute a logical approach to assuring that progress will indeed take place.

NSF grants in support of research mainly have supported established investigators, or new people with outstanding promise. Fellowships for graduate study—and beyond—have been awarded to young people of great intellectual merit solely on the basis of ability.

In the past, the Foundation has relied heavily on project grants in making funds available for support of research. This has proven to be an effective mechanism, and is still considered basically sound. With the passage of time, however, certain inadequacies have come to light; as will be pointed out later, we are finding it desirable to supplement the research project grant system with other devices.

In the area of science education, heavy emphasis was originally placed on graduate education—particularly on support of graduate fellowships for predoctoral study. However, early in the Foundation's history, the staff became aware of the need for additional activities at collegiate and even precollegiate levels. There were many problems uncovered at these levels, leading to initiation of a number of programs.

Because of the very broad mandate contained in its authorizing legislation, the National Science Foundation has been able to play a unique role with respect to education in the sciences. The authority for such activities resides in the portion of the act which authorizes and directs the Foundation to "initiate and support . . . programs to strengthen scientific research potential in the mathematical, physical, medical, biological, engineering, and other sciences. . . ." Thus, while the Foundation properly supports science education programs at many levels, the goal is to strengthen the potentialities for national research capability.

When an individual assumes new responsibilities, he naturally brings to the new task certain attitudes and points of view which derive from his own experiences and concerns. In taking over from Dr. Alan T. Waterman as Director of the National Science Foundation, I found a number of questions and problems which seemed to me in need of resolution. Many of these problems had been recognized by others—including my predecessor. All pose substantial difficulties, and it is clear to me that many of them will require a great deal of attention before they are satisfactorily resolved.

There are a few of these problem areas that I consider to be of particular moment, and it seems to me appropriate and even desirable that I make use of this opportunity to present my point of view as to how the Foundation can move toward acceptable solutions of such issues as these:

- Should the Foundation attempt to devise new or modified support programs rather than continuing to rely mainly on the project grant method?
- How can one be sure that the relative amounts of support being provided by NSF to the various fields of science are approximately correct?
- What changes, if any, should NSF make in its policies and procedures in response to the increasing concern over geographical concentration of Federal funds for research and development activities?

Clearly these problems are not uniquely relevant to the National Science Foundation; the other agencies of Government concerned with scientific and technological matters must also address themselves to essentially the same questions. Nonetheless, there are two senses in which these problems and others of comparable importance are particularly relevant to the Foundation's assigned responsibilities. In the first place, NSF was created in order to provide a governmental unit which could look at problems of science and technology in the broadest possible sense. Hence its task has been and still is to consider the health of science now and in the future, without regard to specific short-range goals associated with a limited mission. Thus, the nature and scope of its programs can be adjusted in flexible ways, over relatively short periods of time, to make them responsive to new or changed needs.

The second sense in which such questions can be viewed as particularly relevant to the Foundation's role derives from the charge given NSF by the Congress to develop and encourage the pursuit of a National policy for the promotion of basic research and education in the sciences. In carrying out this assigned responsibility (which, by virtue of Reorganization Plan No. 2 of 1962, it shares with the Office of Science and Technology), the Foundation must of necessity take into account the activities and procedures of other Federal agencies and all other public and private groups that are concerned with improving the nation's scientific potential. This means that NSF must inform itself and others concerning the actualities of Federal and other support of science and technology. This is accomplished by means of comprehensive and thoroughly detailed surveys of research and development expenditures, scientific and technical manpower, and other related matters that lend themselves to statistical treatment. Moreover, NSF has a central responsibility for presenting special analyses which will help all those concerned with policymaking in this domain to base their decisions on the most accurate and significant information available. Therefore, while it is obvious that the search for solutions of these problems is important in terms of the Foundation's own programs and procedures, it is necessary to remember also that these efforts must take into account our statutory responsibilities as they relate to policy formulation.

There is overwhelming evidence that the project grant system—as used by NSF and other agencies—is desirable no matter what other steps are taken to strengthen the relationship between the Government and the colleges and universities. Even those advocating the need for new or different kinds of support have, in the majority of cases, conceded that new types of support should be used only as a supplement to the project grant mechanism. But inherent in the system are some defects. For example:

- Decisions are made outside the institution on the nature and amount of support to be provided the various components of a given institution; the institutional leadership has either limited or no opportunity to make decisions relative to assuring balanced growth in the various departments and other units.
- Scientists or administrators may alter the preferred balance of research in order to favor those efforts they judge most likely to receive Federal support.
- Younger, unknown investigators have difficulty obtaining support.
- It is difficult for an institution to establish new activities, such as interdisciplinary units or programs.
- Funds are often not available for flexible use; in particular it is difficult to support activities of common benefit to several projects—for example, libraries, shops, and electronic computers.
- Experienced, proven research workers are sometimes required to resubmit applications for continued support every year or two, when the nature of their work makes it evident that the completion of their projects would require much longer.

There is no simple way to overcome these defects. If it were possible to support much more research, several of these difficulties would immediately become less worrisome or disappear. Given continued hard choices, however, it appears desirable to work toward at least partial solutions to some of these problems.

NSF is looking for solutions along several different paths. For one thing, presidents and deans are being reminded that they must concur in the submission to the Foundation of research proposals; they can therefore, if they feel sufficiently strongly about a given case, refuse to forward to NSF a proposal which they do not think would fit into the long-range plans of the institution.

Project grants are also being broadened so that in many cases fairly large areas can be encompassed within a single grant, thus assuring consideration for and coordination between relevant groups if a grant is eventually made.

NSF is actively seeking new administrative devices which will make it possible to give assurance of longer-term support, even in cases where it is not possible actually to obligate funds for the support to completion of lengthy projects.

Because all of these changes in point of view and approach still leave something to be desired, the Foundation continues to seek out new and better ways of allocating its funds so as to optimize their usefulness in advancing science. Since project grant funds are of necessity limited in their use to certain purposes associated with a specific research activity, even those departments which receive fairly generous project support from NSF and other agencies frequently call attention to their need for relatively small amounts of flexible money. There are many ways in which so-called "free" money can be used to improve the research capability of a department or other institutional unit. The Foundation has, since 1961, made available "Institutional Grants" to help meet this need. The grant amount in each of these cases is determined by formula from the total of research and research training grants awarded an institution during a specified 12-month period. The funds thus made available can be used by the institution for any purpose which, in the judgment of the institution's president, will advance scientific research or education in the sciences on his campus. During fiscal year 1964, Institutional Grants totaling $11.4 million were made to 370 colleges and universities in all 50 States, the District of Columbia, and Puerto Rico.

Although all of these steps are useful, more must still be done to help build up institutions in those parts of the country which at present are not particularly strong in science. To accomplish this, programs different in kind from the traditional project grants will be needed; substantial funds will be required in order to have any significant impact on the national situation. The Foundation should focus attention primarily on the problem of institutional development rather than on regional development *per se*, but it is obvious that strengthening a number of institutions would provide opportunities for achieving a considerable degree of geographic dispersion of "science development" funds. It is my conviction that NSF— and other agencies to the maximum extent possible—should take advantage of any opportunities they can to improve scientific capabilities in all parts of the country.

During fiscal year 1964, the Foundation initiated a new Science Development Program which is designed to help a small number of institutions move forward rapidly to a new level of quality both in research and in education; under this program, relatively large sums—up to about $5 million—will be granted to a few institutions which can make the most convincing cases that they are prepared to move ahead on a fairly broad front toward significantly higher quality in both research and education. The funds are to be used over a 3- to 5-year period, and the institution must provide assurance that it will be able to carry on at the newly achieved level of excellence when the NSF grant expires. The first grants under the NSF Science Development Program will be made during fiscal year 1965. It is my hope that we can proceed quickly to a point where at least some science development grants in a second category can be made. Under this newer scheme (not yet approved), smaller renewable grants would be made to a somewhat larger number of institutions to enable departments or groups constituting "pockets of strength" to accelerate their qualitative growth to a point where they can become significant centers of research and education. It would be premature to predict a specific time when NSF will find it possible to make grants of this kind.

A related though separate matter has to do with the Foundation's initiation, also in fiscal year 1964, of a new Graduate Traineeship Program. This activity, limited during its first year to engineering, resulted in the award of grants to 109 institutions; each grant provided for a specified number of Graduate Trainee stipends, totaling 1,220 altogether, plus special allowances to help defray the institution's costs incurred in providing a year of training for each graduate student receiving an award. Akin in several respects to the Foundation's fellowship programs, the Graduate Traineeship program differs substantially in that it passes on to the grantee institution the responsibility for selecting the students to be supported as Trainees. Because of the intimate connections between graduate education and research, it is clear that departments that are moving rapidly toward educational and research excellence need to be in a position where they can build up their population of graduate students by offering support to carefully selected individuals. Since the Graduate Traineeship program makes this possible in many cases, it can also—though to a limited degree—be considered a program devoted to developing science potential throughout the Nation. In fiscal year 1965 this new activity is scheduled to grow markedly and to be extended to the mathematical and physical sciences. Still later it will be extended to the biological and social sciences. As it increases in size and scope, we believe the program will become an important factor in assisting both well-established and newer departments throughout the Nation.

The second problem or issue mentioned in the above listing involves the question of priority. How can we best determine when a "proper balance" of support has been achieved among the various fields of science?

It may turn out in the long run that the correct answer to this question is "We cannot." But additional efforts to arrive at more nearly optimal levels of support—given limited resources—seem desirable. The Foundation, in its operational activities as well as in its various studies on behalf of the Government as a whole, plans to give additional emphasis to the compilation and analysis of data which bear specifically on the question of relative total levels of support and measures of apparent needs. The techniques for obtaining reliable data in this area are still relatively primitive, but we believe that they can be improved and that substantial progress can be made in a few years toward a system which will be somewhat more clearly rational than that which we now are forced to use. Thus, we hope eventually to be able to cite fairly precise figures relative to the average amount of total research support available to academic scientists, by field of science, and to augment such data with judgments from competent people in the various fields on the question of reasonable ranges of support levels for each discipline.

In some relatively small fields, such as astronomy, we can even now come close to developing a national picture of the capabilities of the existing group of research workers, their facilities requirements, and the potentialities relative to training of additional specialists in the field. Such detailed analysis is beyond our present capabilities for most of the larger fields of science, but we are currently supporting and conducting studies designed to shed light on these problems within specific disciplines. The problem of making interfield priority judgments should become more manageable if somewhat more complete information on a field-by-field basis can be made available.

The Foundation is also attempting to formulate an approach to interfield priority assessment which would take into account the probable contributions of NSF-supported basic research to the solution of a variety of national problems. Thus, for example, it is possible that a whole cluster of basic research activities might justifiably be supported in several fields of the behavioral and environmental sciences, all of which would in one way or another shed light on what is now called the "transportation-urbanization" problem. The complex of scientific and technological issues surrounding the increasing needs for water will continue to focus attention on such interacting areas as hydrology, weather modification, and desalinization. Research and training activities specifically oriented toward the solution of some of the identifiable problems in this complex may prove to be particularly important. Obviously, such an approach would not supplant other efforts to determine relative priorities but further investigation may demonstrate that this approach is a useful way of supplementing other mechanisms.

It is clear that determination of appropriate levels of support by fields of science is a problem that will continue to require judgments which take into account policies, attitudes, and political realities—none of which can be treated quantitatively. These may, in a good many cases, turn out to be the most important elements in setting priorities. For the immediate future, therefore, the Foundation has no alternative but to continue basing its decisions relative to support levels on judgments which take into account both quantitative elements and more subjective considerations, all the while pressing its search for facts and analytical techniques which, hopefully, will assure an increasing degree of validity in such decisionmaking.

The issue of increasing the geographical spread of federally supported research and development (the third of the problem areas outlined above) began to reach significant levels of concern in fiscal year 1964. Various groups in Congress have taken an interest in this matter. In particular, the Subcommittee on Science, Research and Development of the House Committee on Science and Astronautics carried out an extented series of hearings which focused on this issue late in the fiscal year. This group asked NSF and other agencies to comment on the following question:

> Is it possible to achieve greater uniformity in the geographical distribution of Federal contracts and grants without affecting the quality or cost of research and development?

In testimony before that subcommittee on May 6, 1964, I responded to this question in the following terms:

> If I correctly interpret the meaning of its various terms, I have to say that the answer to this question is unequivocally "no". Briefly put, to achieve high quality results requires going where the best capability exists. That capability is now quite concentrated geographically. Hence the maintenance of high quality results will result in concentration unless and until we build up a broader geographic base of capability. And this will require additional expenditures.
>
> This does not mean that we are helpless in the effort to assure a more widespread distribution of support for research and development. What it does mean is that we cannot hope to obtain maximum output of research and development results unless we support and use the facilities and the scientists and engineers in our great centers of scientific and technological activity. Hence if we are interested in research of high quality, done with minimum delay, we must not go to those institutions which would first have to build up a capability and then begin to accomplish the job that we want done.

I might have added that it is from the presently strong institutions that the men must come who will lead the way in the improvement of the others. Hence, merely to divert support from the stronger to the weaker would defeat the very goal of broadening our base of excellence.

With respect to the Foundation's future attitude and probable actions in connection with this issue, I noted in the same statement that:

In keeping with my conviction that we must try to find new and more effective ways of helping build increased strength in science throughout all parts of the country, I have instructed various staff elements at the Foundation to give increasing attention to this issue. As a result, it now seems clear that we will wish to seek funds for fiscal year 1966 which can be specifically devoted to helping departments of science which show real promise as future centers of strength to accelerate the rate of growth in their scientific capabilities. I have discussed this matter with the National Science Board and the Board is in agreement with my position that such a move is both desirable and timely. Although the precise mechanisms for accomplishing this goal are still being developed—and therefore have not yet been approved by our Board—I am reasonably certain that next year we will be launching one or more new programs designed to develop the nation's research and science education potential.

In the meantime, we intend to continue our efforts to assure a wide and yet effective distribution of the funds entrusted to us by the Congress. We believe we have obeyed the Congressional injunction to "avoid undue concentration" of our support, and we shall make sure that we continue to do so.

Obviously, this is an issue that we must not ignore. But it is not so critical that we should allow our justifiable concern to stampede us into hasty actions which might prove harmful.

We have heard the phrase "centers of excellence" used many times over the last few years. NSF, along with various other agencies, has been trying to find ways of giving this concept meaning and of helping create new scientific capabilities of high quality where only the potential exists at present.

NSF believes the phrase "centers of excellence" should be interpreted broadly. It should not be reserved for use only in connection with an entire institution. It is conceivable that a really first-class department of oceanography might be created in an institution which, overall, is not among the leaders, and which has only marginal strengths in, for example, psychology or astronomy. Thus, we would want the term to be thought of as usable in reference to: a coherent unit within a department, a department, a small group of related departments, a "school" (of engineering, for example), or an entire institution. So conceived, an effort to build up the scientific potential of the Nation by the creation of new centers of excellence becomes mainly a problem of bringing to bear one or more of NSF's present programs on the present "pockets of strength" in many institutions. The Foundation's newly developed Science Development Program can have a significant impact in this area, and I am convinced it will. But it should not be thought of as the sole or even the primary way now available to obtain either training funds or research support from NSF. Depending on the specific status and needs of a given institutional component, any one of several Foundation programs might be helpful. The range of programs now available can help with: the purchase of undergraduate instructional equipment, the construction or renovation of graduate research facilities, the provision of research equipment through project grant funds, and the further training of faculty members—to cite a few of the most pertinent program activities now being carried out by NSF.

No matter what steps we may find it possible to take in helping to increase the number of outstanding departments or institutions, we must preserve our programs of support in which present excellence is the prevailing criterion in order that the institutions that have already achieved high standards in science will also continue to improve. As we intensify our efforts to broaden the regional distribution of high quality research and education in the sciences, we must avoid policies that would weaken those institutions that have made U.S. science strong, and that are also our major sources of the highly capable teaching and research personnel needed for the development of new centers. Substantial and arbitrary changes in the distribution of Federal support for scientific research and education at the expense of support for the already strong institutions would not, in the long run, benefit any geographic region and would almost surely damage the national interest.

The Foundation is sometimes subjected to criticism for having too many programs. This is indeed a problem, both for the colleges, universities, and other groups with which we do business as well as for the Foundation itself. There are, on the whole, good reasons for having a wide variety of programs, and it is clear that every program we now have can claim ardent supporters. Even so, we must avoid unduly increasing the complexity of our activities, and it is my intention to do all I can to keep this from happening. To this end, we will be making careful studies of our current activities to see where it may be possible to introduce simplifications.

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In this statement I have tried to convey the challenges and changes, the problems and responsibilities which have confronted the Foundation during my first year as Director. I do not anticipate that the future will bring any magical solutions for our many problems, nor will we find any miraculous process by which we can do without effort what must be done. But our goal is a worthy one, and I find the pursuit of it eminently gratifying.

## ORGANIZATION

During fiscal year 1964 a number of organizational changes were effected in the staff of the Foundation both to reflect my ideas regarding administration, and to fill vacancies.

The post of Deputy Director (vacant for some time) was occupied during the fiscal year by Dr. John T. Wilson; I count myself fortunate in having been able to persuade Dr. Wilson that he should relinquish a responsible administrative post at the University of Chicago to return to NSF (where he had held several responsible positions for almost a decade).

My assessment of the administrative task facing the Foundation in July 1963 convinced me that the steadily increasing managerial load demanded a somewhat more decentralized organizational structure. As a consequence of this decision, a modified pattern of organization was established a few weeks after I became Director. The most significant change effected at that time was the redefinition of the functions of the Foundation's Associate Directors and some regrouping of the functions assigned to them. Each Associate Director now has full "line" responsibility for the Divisions and Offices which report to him. An important step in a specific case was the creation of a new post (at the Associate Director level, though not so called) to manage the highly complex Project Mohole, involving very deep drilling in the ocean bottoms.

As a result of the expiration of the terms of several members of the National Science Board, the statutory governing body of the Foundation, new members were appointed by the President, and a new chairman—Dr. Eric A. Walker, President of the Pennsylvania State University—was elected. Dr. Philip Handler, of Duke University, was elected Vice Chairman.

The new members of the Board, whose terms expire May 10, 1970 are: Dr. H. E. Carter, Head, Department of Chemistry and Chemical Engineering, University of Illinois; Dr. Julian R. Goldsmith, Associate Dean, Division of the Physical Sciences, University of Chicago; Dr. William W. Hagerty, President, Drexel Institute of Technology; Dr. Mina S. Rees, Dean of Graduate Studies, the City University of New York; Mr. John I. Snyder, Jr., President and Chairman of U.S. Industries, Inc.; Dr. Julius A. Stratton, President, Massachusetts Institute of Technology; and Dr. Frederick P. Thieme, Vice President, University of Washington.

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In reporting on my first year as Director of the National Science Foundation, I wish to acknowledge with respect and admiration the work of my predecessor, Dr. Alan T. Waterman. Under his leadership, the Foundation moved forward steadily and purposefully during more than 12 years of continuously expanding responsibility. The precedents he set during this period, and the counsel he provided in the months immediately before and after I assumed direction of Foundation activities have been of great importance to me.

It is generally recognized that no two individuals approach an administrative responsibility in precisely the same way. When a position changes hands, it is to be expected that new courses of action and new organizational patterns are likely to result. Furthermore, the rapid growth of the Foundation in recent years, itself gave rise to new requirements. Thus, I have felt no constraint in making certain changes in organization and procedures which seemed to me appropriate. These changes which I deemed desirable are, however, collectively secondary in comparison with those elements of the Foundation which remain much the same today as they were when Dr. Waterman retired.

It is a pleasure for me to acknowledge, for myself and on behalf of science in general, the impressive and lasting contributions made by Dr. Alan T. Waterman as first Director of the National Science Foundation.

LELAND J. HAWORTH.