DEVELOPMENT OF NATIONAL SCIENCE POLICY

In his Budget Message to the Congress, January 1952, the President of the United States outlined the broad policy-making functions of the National Science Foundation. He wrote:

> During the last decade we have seen how basic scientific research can alter the foundations of world power. We have seen that this research yields a stream of new knowledge which fortifies our economic welfare as well as our national strength. We have learned that a strong, steady, and wide-ranging effort in science is as essential to our sustained national security as the production of weapons and the training of military personnel.
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> The National Science Foundation has been established as the Government agency responsible for a continuing analysis of the whole national endeavor in basic research, including the evaluation of the research programs of other Federal agencies. On the basis of studies now under way, the Foundation will formulate a broad national policy designed to assure that the scope and the quality of basic research in this country are adequate for national security and technological progress.

Earlier, the President had indicated that the Foundation "was conceived as a much-needed keystone in the structure of the national research program. Its principal task is to appraise the rapid growth of research activity, both public and private, and to recommend the broad goals toward which this massive effort should be channeled."

This concept of a Federal agency devoted to the formulation of national science policy followed the recommendations of the Hoover Commission. In its report the Commission itemized the major functions of such an agency as follows:

1. To examine the total scientific research effort of the Nation.
2. To assess the proper role of the Federal Government in this effort.
3. To evaluate the division of research effort among the scientific disciplines and among fields of applied research.
4. To evaluate the key factors that impede the development of an effective national research effort.

METHOD OF ATTACK

The necessary first step in policy development is the assembly of an adequate body of fact about the current status of science in the United States, including an inventory of our present resources of trained men and facilities. During 1952 steps were taken along three different lines to supply such information. These are:

1. Studies of existing Federal, university, and industrial research support.
2. Analysis of the current status of science and research by fields of science.
3. Special studies on urgent topics.

To assist in the collection of facts necessary to policy formulation and evaluation the Foundation has established a Program Analysis Office and has assigned it the responsibility for:

1. Planning and scheduling, with the cooperation of interested divisions of the Foundation and other Federal agencies, the studies necessary to discharge the Foundation's policy formulating functions.
2. Acting as a focal point within the Foundation for coordination of such activities, and serving as a repository of reports, data, and other material relating to program analysis.
3. Carrying out such studies, primarily those of a fact-finding nature, which because of their over-all character cannot logically be carried out by another division of the Foundation or another agency.

The Program Analysis Office is supported by the entire staff of the Foundation. The Foundation, in turn, draws upon all Federal agencies engaged in research or manpower studies, and the scientific societies. In certain areas the Foundation intends to establish special scientific investigating committees composed of industrialists, representatives of Government, economists, scientists, and teachers.

THE NATIONAL RESEARCH EFFORT

For the past 3 years the Bureau of the Budget has compiled statistical information on the amount of funds obligated by Federal agencies for research and development at colleges and universities. This information has been used in arriving at broad conclusions concerning the effect of this support on the educational system of the country, and as an aid in

fiscal analysis of the Federal Government's budgetary programs. The Foundation has assumed responsibility for the annual compilation of this information and expects to complete its first report for fiscal years 1951 and 1952 early in fiscal year 1953. In order to obtain comparable information the Foundation provided each of the reporting agencies with working definitions of the classes of research and of the content of the various fields of science. See Appendix V, p. 72.

Preliminary figures from this survey show that Federal agencies made available a total of $297 million in fiscal year 1951 and $341 million in fiscal year 1952 for scientific research and development through grants and contracts at nonprofit institutions. Funds administered by the Department of Defense made up over 50 percent of the total in each year, compared with about 35 percent for the Atomic Energy Commission, almost 6 percent for the Federal Security Agency, and slightly less than 5 percent for the Department of Agriculture. The remaining agencies accounted for less than 3 percent of the total.

Obligations for basic research for the 2-year period totaled $147 million, compared with $317 million for applied research, $131 million for development, and $43 million for increase in research and development plant. See Appendix V, page 72.

In 1952 the total national expenditure for scientific research and development was estimated at approximately $3 billion. Nearly two-thirds of this amount, $2 billion, was provided by the Federal Government, one-third from industry and 3 percent from universities. A score of Federal agencies and bureaus now carry out scientific research and development programs in government-owned laboratories or administer research under contract with non-Federal groups. Normally the scientific activity supported by a particular agency relates to the operating responsibilities of that agency.

Nongovernment industrial research and development are aimed primarily at new products for wider markets or cheaper, more efficient processes. Here, likewise, research is closely tied to specific operating goals or missions. The vast bulk, then, of the total national expenditure for research and development, and as a corollary, the major part of available research facilities and specialized manpower are committed to the furtherance of specific program goals.

Therein lies a serious threat to the security and future well-being of the United States, for the great forward advances in science have seldom come primarily from applied or programmatic research. In the opinion of the Foundation and its advisory groups the cornerstone of national science policy is to assure adequate support—not only in terms of funds

but in terms of qualified scientists and research facilities—for basic research in the sciences.

STUDIES BY FIELDS OF SCIENCE

Consideration of the current status of each domain of science will enable the Foundation to make realistic estimates as to the amount of support that can be effectively utilized in each field, what can best be accomplished in Government laboratories, what research can more efficiently be accomplished by nongovernment research institutions, the resources of manpower and facilities which are available, and the current status of development of the field.

Studies of the type described will supplement information obtained by other means. They can be successfully completed only with the full cooperation of scientists who are working in the field under review. A general survey of an entire field of science, including its research, training, and educational aspects, will require from 1 to 3 years to complete. Other survey methods include the employment of standing committees to consider progress in research only and the holding of conferences or symposia on special topics at appropriate intervals.

The first study started in fiscal year 1952 has to do with the physiological sciences. The American Physiological Society, under contract with the Foundation, is investigating the content and scope of the physiological sciences, the role of physiology in American education, the professional personnel now engaged in the field, the scientific contribution which may be expected of physiology in the future and the plans that have been made or are in the making to achieve it. This study which was proposed by the Society will be carried out by a central committee of physiologists. Working subcommittees have been established for personnel, research, communications, applications and consequences, and control and trend.

It is expected that the physiological survey will be completed during fiscal year 1954.

A similar study in the field of psychology as a science has been planned with the American Psychological Association. The Foundation jointly with the Army, Navy, and the Air Force also will support a survey of applied mathematics. In this case an appropriate committee of the National Academy of Sciences will undertake the investigation.

SYMPOSIA AND CONFERENCES

A closely related method for organizing information about a field of science is the assembling of experts for scientific symposia and con-

ferences. The Foundation, with the assistance of several other Federal agencies, is supporting a committee of experts to survey current work and research potentialities in the low-temperature field. At the invitation of the General Electric Company a symposium was held at the Knolls Laboratory, Schenectady, N. Y., in October 1952, with joint sponsorship of the Foundation and the Office of Naval Research.

A conference on high-energy particles at the University of Rochester will also be sponsored by the Foundation in December 1952 to appraise recent progress in the physics of the elementary particles—one of the most important fundamental problems in physics at the present time.

Another conference at the University of Chicago will be sponsored by the Foundation in November 1952. This meeting on the abundance of the elements will bring together an outstanding group of astronomers, physicists, geologists, and chemists to consider recent findings in a subject of great interest and importance in many fields of science.

SPECIAL STUDIES ON URGENT TOPICS

In view of the nature of basic research it is ordinarily impossible to outline specific areas for investigation which promise short-term results of a practical nature. From time to time, however, it is possible to isolate certain areas in which the need for basic research is clearly urgent from the standpoint of the national defense, the general welfare, or promise in science itself.

Here again basic research is the pacemaker for applied work. Basic research aimed at producing more adequate data and at times new fundamental scientific discoveries hastens the progress of applied research. It serves to clarify the practical problems to be solved and enables the applied research scientist to lay out the course of his work in the most direct and economical manner.

The Foundation has made plans during the year to undertake short-range studies in three such areas, to determine the extent of research now being conducted, the extent of present Federal support, the need for expanding such support, and the specific areas where basic research may be necessary to make maximum progress.

High temperature physics, chemistry, and metallurgy comprise such a general area at the present time. Research problems in this field are critically related to the development of jet motors, rockets, and guided missiles. Here, the Foundation is following closely the work of the Minerals and Metals Advisory Board of the National Research Council and will expect to contribute to the work of this group.

Utilization of solar energy is a second field in which it seems clear that additional basic research will yield information of great potential value. In this case, the Foundation has attempted to coordinate the interests of other cooperating Federal agencies. One result of this cooperative effort is the scheduling of a series of National Research Council conferences on photobiology to review and evaluate current research. A counterpart study in the physical sciences will be concerned with the utilization of solar energy by physical and chemical rather than biological methods.

MATERIALS POLICY STUDIES

The Foundation is cooperating with the National Security Resources Board in undertaking activities recommended by the President's Materials Policy Commission. Four subjects in the Report of the Commission, *Resources for Freedom,* are of direct interest to the Foundation. These are:

1. Research to improve methods of exploration for hidden minerals.
2. Research bearing on the more effective utilization and conservation of scarce metals and other materials.
3. Research to make possible a future technology for the utilization of renewable sources of energy.
4. The training of qualified persons to do research in the sciences and engineering.

The first area of interest is defined in Recommendation 3 of the Report (Vol. I, p. 29), which reads as follows:

> That an intensive program of basic scientific research and technical development be undertaken on techniques and instruments of exploration for minerals. The first step should be the appointment of a special committee under the National Science Foundation, made up of outstanding experts from Government, private industry, and universities, to make a full inventory of existing scientific and technical knowledge and research projects in the field, to determine the areas of greatest need for further research and development, to devise a coordinated program to be carried out by private groups and such Federal agencies as the Bureau of Mines, Geological Survey, Bureau of Standards, and Office of Naval Research, and to estimate the cost of the program and the extent to which it will require supporting funds from the Government. The National Science Foundation could call upon the National Academy of Sciences (National Research Council) for assistance in laying the groundwork of a program.

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This recommendation is based on the recognition that technical developments almost invariably rest on a foundation of research and that there is small hope of significant advances in the exploration for hidden minerals unless there is a solid foundation of knowledge which has been developed through basic research.

Systematic search for ore bodies in the rocks of the earth's crust can be directed intelligently only if accurate and reliable knowledge is available concerning the mineralogy, the physical and chemical properties, and all aspects of the geologic character and history of such deposits. Much is of course known, as an inventory of existing data will reveal, but there is still a vast amount of additional work of fundamental nature to be done to provide an adequate scientific understanding of the many varieties of these unusual and complicated concentrations of metals or other valuable elements. The National Science Foundation recognizes that programs of research to advance such ends may very properly be considered one of its major concerns.

A special committee of the National Science Board of the Foundation has been appointed and the Foundation will support a group of experts from Government, industry and the universities to review the recommendation of the Commission and to plan appropriate steps by which the Foundation can carry out its part in this important enterprise.

GENERAL POLICY CONSIDERATIONS

The third paragraph of the section of the President's Budget Message devoted to the National Science Foundation calls attention to the responsibility of the Foundation to stimulate or sponsor basic research. He wrote:

> The Foundation also will stimulate or sponsor basic research in subjects which otherwise might receive inadequate attention. While the research program of the Foundation is not intended to supersede the basic research programs of other agencies, the Foundation should ultimately become the principal agency through which the Federal Government gives support to basic research that is not directly related to the statutory functions of other Federal agencies.

In carrying out these objectives, the general goal of the Foundation is to make certain that the scope and quality of basic research in the United States meet the requirements of national security, national welfare and continuing progress in science and technology. In particular, the Foundation lays stress upon the fact that adequate general support of basic research and training in the sciences is indispensable to the

emergency effort. It constitutes a *defense in depth* which is essential to establishment and maintenance of technological supremacy.

At the close of fiscal year 1952, the Foundation was in position to take the lead with respect to Federal support of basic research. It was able to consider support of basic research in fields now receiving inadequate attention. Also, it was prepared to stimulate or sponsor basic research in scientific subjects of general importance to the interests of other Federal agencies. In so doing, however, the Foundation recognizes the desirability and importance of support by other agencies of an appropriate amount of basic research directly related to their statutory functions.

In attempting to lay the groundwork for national science policy the Foundation realizes the necessity of achieving full cooperation on the part of scientists in educational institutions, industry, and the Federal government. There can be no monopoly on the constructive thinking which must be brought to bear upon the problems facing science or created by it in the United States.

The Foundation, however, can do much to speed the process and to buttress scientific progress, particularly to meet the unique requirements of the United States. This country has achieved its present agricultural, economic, industrial and military position because of its ability to turn scientific knowledge to practical account. Over a century ago, Alexis de Tocqueville, shrewdly detected and remarked upon this American trait. He wrote:

> In America the purely practical part of science is admirably understood, and careful attention is paid to the theoretical portion which is immediately requisite to application. On this head the Americans always display a clear, free, original, and inventive power of mind. But scarcely anyone in the United States devotes himself to the essentially theoretical and abstract portion of human knowledge.

Although the last statement is no longer true, as a nation we do not yet fully appreciate the importance of basic research to technology. The technological sequence consists of basic research, applied research, and development. Historically, this Nation has placed emphasis upon these stages in reverse order. In times of crisis the pressure of events tends to throw the balance still farther away from support for basic research on the one hand and toward applied research and development on the other.

This tendency must be resisted, for as Vannevar Bush has maintained, "basic research is the pacemaker of technology." Basic research charts the course for practical application, eliminates dead ends, and enables

the applied scientist and engineer to reach their goal with maximum speed, directness, and economy.

Basic research, directed simply toward more complete understanding of nature and its laws, embarks upon the unknown. Clearly, that which has never been known cannot be foretold, and herein lies the great promise of basic research. It extends beyond the fringes of knowledge, beyond existing limitations and preconceptions. Basic research enlarges the realm of the possible.

Applied research concerns itself with the elaboration and application of the known. Its aim is to convert the possible into the actual, to demonstrate the feasibility of scientific or engineering development, to explore alternative routes and methods for achieving practical ends.

Development, the final stage in the technological sequence, is the systematic adaptation of research findings into useful materials, devices, systems, methods, and processes. From engineering development come the models, the prototypes, the demonstration methods, and the experimental clinical procedures. Development leads to production of finished products, built in quantity and to definite specifications.

From these definitions it is clear that each of the successive stages depends upon the preceding. Unlimited expansion of effort toward applied research and development, without corresponding support for basic research, will defeat the entire effort by limiting technological progress to minor improvements and refinements of obsolete processes and equipment.

Moreover, of the three stages, basic research is the least, and development the most, expensive. For maximum economy as well as maximum rate of advancement, development should follow only upon an adequate foundation of basic and applied research. By eliminating guesswork, waste effort, and aimless trial-and-error methods, every dollar spent for basic research returns tens of dollars in developmental savings.

Study and analysis of the three components of technological progress, of the expenditure of trained manpower, resources and funds that can be appropriately utilized by each, and of the proper balance among them will continue to be of major concern to the Foundation.

Finally, basic research in the sciences, largely carried on in educational institutions, is of vital importance in training scientific manpower. Analysis of the technological components will of necessity include evaluation of the impact of research and development activities upon science education and the institutions for advanced training in the United States.