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PAPERS COMPRISING A SYMPOSIUM ON THE SUBJECT "EXTRA-MURAL SCIENCE PROGRAMS OF THE FEDERAL GOVERNMENT," ARRANGED BY A COMMITTEE OF THE WASHINGTON ACADEMY OF SCIENCES (GEORGE W. IRVING, CHAIRMAN) AND PRESENTED SUNDAY MORNING, DECEMBER 28, 1958, AT THE SHERATON-PARK HOTEL, WASHINGTON, D. C., AS THE ACADEMY'S CON-TRIBUTION TO THE 125TH MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Introductory Remarks by Dr. A. T. McPherson, Presiding

It is a great pleasure for me, as the President of the Washington Academy of Sciences, to welcome you to the symposium on "Extramural Science Programs of the Federal Government." This symposium is the Washington Academy's contribution to the 125th meeting of the American Association for the Advancement of Science. As you know, Washington is the scientific as well as the political Capital of the United States. Every major scientific activity in our Government has its headquarters in or nearby Washington. Moreover, several of the national scientific societies have established their national headquarters here in Washington, owing at least in part to their desire to be near the scientific activities being conducted here at the seat of Government. Among these is, of course, our own Association.

Since Washington is unique in being the center of Federal scientific activity, it was felt in planning this symposium that our most useful contribution would be to have representatives of the principal agencies of the Federal Government describe some aspect of the research supported by them. Inasmuch as many who attend the AAAS meetings have conducted research under Federal support or may wish to, it occurred to us that the aspect that would be of most interest to the greatest number would be the extramural science programs each agency sponsors. It is particularly appropriate, we feel, that the Washington Academy of Sciences has been given the opportunity to do this since it is the one scientific society in the Nation's Capital that counts among its membership representatives of all the scientific disciplines. Included in its membership also are many of the policymaking scientists of the Federal Government.

Perhaps it is appropriate at the outset to indicate what we mean by "extramural" science programs. We mean, simply, any programs that are conducted outside of the physical facilities of an agency and staffed predominantly by non-Federal employees. This includes scholarships, fellowships, grants, grants-in-aid, loans, contracts and cooperative programs.

It would be impossible in the time allotted this session to include a description of every extramural program that is now in effect in the Federal Government. We have selected, rather, the six Federal agencies which, together, support the majority of extramural research and science education programs in the country. They are, as your program indicates, the National Science Foundation, the National Institutes of Health, the U.S. Department of Agriculture, the Department of Defense, the Atomic Energy Commission, and the National Aeronautics and Space Administration. The representatives of these agencies here with us today can speak authoritatively on the extramural programs for which their agencies are responsible, since they occupy in each case high positions in their respective agencies.

The order of presentation is immaterial except for the first. We have asked the representative of the National Science Foundation to lead off since the NSF, in addition to its responsibility for its own direct extramural programs, has certain coordinating responsibilities for science programs in all Federal Government agencies as well.

We hope that this symposium will give you a clear picture of the extramural research and science education program of the Federal Government in its entirety.

Extramural Science Programs of the National Science Foundation

By ROBERT B. BRODE, Associate Director for Research, National Science Foundation

We are here as representatives of several of the Federal agencies to discuss the nature and scope of our respective agencies' extramural programs for research and education in science. The National Science Foundation conducts no research or education programs itself. All the support of education and research by the Foundation is through extramural grants and contracts.

The nature of the activities of the Foundation and its objectives are adequately described in the Act of Congress which was approved by the President in May 1950 and led to the establishment of the National Science Foundation as an independent Federal agency. Section 3 of this Act states that the Foundation is authorized and directed "to develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences; to initiate and support basic scientific research...; to appraise the impact of research...."

In carrying out these directives the Foundation is itself forbidden to operate any laboratories or pilot plants. The Act permits the making of contracts or grants for scientific research through the utilization of appropriations available in such a manner as will best realize the objectives of the Foundation. There is very great freedom given to the Foundation in the choice of organizations or institutions to which grants or contracts may be given. While nonprofit organizations are particularly identified, the Foundation is not exclusively restricted to this type of agency. It may make grants to such institutions, individuals, agencies of the United States, and the several States as are qualified to best realize the objectives of the Foundation—in particular, the advance of basic research.

A very substantial part of the business of the National Science Foundation is the support of basic research in science through institutions and individuals that are best qualified to pursue such research. Advisory panels and program officers of the Foundation consider many factors in assessing research proposals: the qualifications and promise of the investigator; the nature of the proposed research project; and the facilities and support provided by the institution.

The Foundation is very conscious of the outstanding contributions made by a small number of scientists with exceptional ability. These men, together with a much larger number of good but not remarkable workers, will create the new developments in basic science. The Foundation is constantly looking for the young scientist who shows signs of real originality and boldness in his approach to scientific research.

In some areas of research the scientist's needs are easily met—books, pen, and paper may satisfy the mathematician. In most fields, however, the success of basic research in science depends on the accessibility of the necessary tools and assistants. Some of the modern research facilities are very costly and require large staffs of scientists and technicians for their operation. Nuclear reactors, cyclotrons, computers, radio and optical astronomy observatories have been built in part or wholly by Foundation grants.

In addition to providing the equipment required, Foundation support of research projects provides employment opportunities as research assistants for more than 6,000 graduate students studying for the Ph.D. degree.

Most of the basic research in this country is carried forward by our colleges and universities. It is therefore not surprising that nearly all the Foundation support of basic research is given to institutions of higher learning. This support is provided in almost every case through the use of a grant rather than by a contract.

In addition to its support of basic research, the Foundation supports a substantial program for the promotion of education in the basic sciences. The Foundation is directed by Congress to develop and encourage a national policy for the promotion of education in the sciences and in particular to award scholarships and fellowships. The award of fellowships to graduate students appears to have been an unusually successful enterprise, and thousands of scientists have been assisted by this program. Fellowship support has been extended to postdoctoral research workers and even to junior and senior faculty to assist them in developing new research programs or to enhance their competence as teachers. The competition for National Science Foundation fellowships is severe, and the award of a fellowship is considered as recognition of very high scholastic achievement and research promise.

Foundation support of education in the sciences extends to universities and colleges in all States through establishment of science teacher institutes. These are designed to improve the training of science teachers, especially secondary-school teachers, in the subject matter of science. Approximately 350 summer institutes will be functioning under this program in the summer of 1959. In addition, about 35 academic year institutes will begin in the fall of 1959, as well as some 200 in-service institutes designed to benefit the teacher who lives in the vicinity of the college or university by offering courses taught at night or on Saturdays.

The Foundation has developed several experimental programs in education; most of these are built upon patterns established either by the fellowship or the institute program. The Foundation is also extending substantial support to curriculum improvement programs for secondary-school science courses, in physics, mathematics, chemistry, and biology, but extending as well to many of the other sciences.

Knowledge is society's most precious possession, and a very important and rapidly growing area of knowledge is basic science. The value and use of knowledge can be assured for future generations only if we record in publications the results of our research. The critical problem of scientific literature is illustrated by the tremendous volume that must be assimilated. If the auditorium were full, all of the people in this room reading 24 hours a day could not keep up with our present output of scientific literature. The rate of increase of literature is such that the world's output in pages per year will double in the next 8.5 years. The National Science Foundation has contributed substantially to this flood of scientific literature by making grants to scientific societies to aid in the establishment of new journals or in the expansion in size of existing publications. The importance of Soviet scientific developments has been recognized in our program for English translations of important journals and books that are available only in the Russian language.

Not only is it necessary to print and store in our libraries the full account of our total knowledge, but we must also develop the means of identification and retrieval of this knowledge. We are assisting abstract journals as well as general studies of new means of searching for information. The Office of NATIONAL SCIENCE FOUNDATION



Science Information Service is a division of the Foundation that provides assistance and coordination to Government and private abstracting and information-handling services. It is not a Government office set up to answer requests of the general public or of Government agencies for information about specific technical questions.

There have been two events since the initiation of the Foundation in 1950 which have appreciably changed the anticipated growth of Federal support for this agency. The International Geophysical Year, which officially ends next Wednesday, has been an intensive burst of scientific effort with a year of preparation and an 18-month year of coordinated observations. For some years to come the results and deductions from this period of observation will be published in scientific journals. The second event that affected the Foundation's budget was the awakening of the world by the Russian Sputnik. We have suddenly realized that leadership can be substantially influenced by the intellectual and technical attainments of a nation. This leadership requires not only adequate support for the research of its talented scholars but also an educational system that identifies potential scholars and gives them the best possible preparation for their careers. Chart #1 shows the growth and magnitude of the support given the Foundation.

The National Science Foundation makes grants to scientists on the basis of proposals submitted to it and reviewed by panels of specialists and by the Foundation's program offices. Some of these grants assure support for three to five years, while others are for one or two years. The funds provided by Congress have only been sufficient to enable the Foundation to grant less than a third of the proposals it receives. It is quite natural that the scientist who has won the competition for an award will return after a year or two for further support and he will then, because of the greater opportunity provided by the Foundation funds, present an even better justification for his support. The percentage of proposals for research support to which grants were awarded is shown in Chart #2. This is by no means an established pattern of support. Many meritorious proposals are now refused grants. At times we have been able to grant less than one-third of the requests considered worthy of support by the review panels.

The use of substantial funds by the Foundation has enabled it to support the construction of such facilities as the National Radio Astronomy Observatory, Green Bank, W. Va., and the Kitt Peak National Observatory, Tucson, Ariz. These national laboratories and institutes carry with their creation an implied commitment for continued operating budgets. The Foundation is indeed concerned with the problem of providing adequate support for the major facilities, and for the continued support of able scientists who justify essentially life time support. To this committed support load must be added the encouragement and opportunity which the Foundation must be prepared to offer to the young scientist beginning his independent research activity.

Congress has directed that the Foundation avoid undue concentration of research and education activities. A measure of the needs for basic science research support may be indicated by the number of graduate students or by the dollar grants. Chart 33shows that the grants given are in reasonable balance with these two measures of need. Support for education through fellowships and institutes for teacher training has been nationwide but not in all cases as well distributed as would be desired for a nationwide program. We have attempted to correct these discrepancies as they are iden-



CHART 3

tified. A program of cooperative fellowships is being introduced this year which will provide a much wider distribution of fellows throughout the Nation, but still permit the applicant to select freely the institution through which he seeks to compete for the fellowship.

The activities of the Foundation are not restricted entirely to this country. Fellowships are granted only to citizens, but they may use their grants for study at foreign universities. Funds in support of research have frequently been used by grantees to carry on their studies in foreign countries; and in exceptional cases grants have been made to a few foreign investigators whose work was considered essential to our own programs or involved the active participation of American scientists or students. We have responsibilities for assistance to participants in international conferences and congresses. In our Office of Science Information Service we arrange for the exchange of publications and for the translation of some of these so that they will be generally available to scientists.

The principal objective of the National Science Foundation is the development of basic science in the United States. We are attempting to do this by direct support of the scientist in his research program, by supplying him with the means of publishing his results, with ready access to the results of the work of other scientists, and by improving our educational system so that promising scholars are given a better foundation for their future careers. Some very valuable and exciting advances have already been made in science through our support, but the major impact of such a broad program as we have undertaken will not be measured by the visible splashes but rather by the rising tide of general basic science development and the technological benefits that later come to society through their application and use.

Extramural Science Programs of the Department of Defense

By GEORGE D. LUKES, Executive Secretary, Defense Science Board, Office of the Director of Defense Research and Engineering¹

I appreciate the invitation of the Washington Academy of Sciences to participate in this symposium and to make the Defense contribution on extramural science programs of the Federal Government. We in Defense find a symposium of this nature an excellent opportunity to get across to the scientific community at large the nature and scope of our scientific research activities and, particularly in the theme of today's session, how our extramural activities contribute to the achievement of Defense objectives. Within this framework I shall also weave some of the more significant aspects of our policy on basic research in the hope of furthering understanding.

¹Formerly Office of the Assistant Secretary of Defense (Research and Engineering).

DOLLAR MAGNITUDE, PERFORMANCE COMPO-NENTS, AND RESEARCH SUPPORT LEVELS

It is important to provide, first, a backdrop of the total dollar effort of Department of Defense scientific research and development. The first chart shows graphically the DOD obligations for fiscal year 1959 in relation to those of the other Federal Government agencies. Something like 62 percent of all Federal funds devoted to research and development represents the Defense Department's share of the Federal effort. The second chart displays the approximate distribution of these funds in terms of the three major performance components: Government laboratories, industrial contractors, and university and other nonprofit institutions. You will note that industry performs about 60 percent of the total effort supported from the research and development appropriations of the Department of Defense, universities and other nonprofit institutions conduct about 9 percent, and Government laboratories perform the balance of 31 percent. Of funds for in-house performance, approximately 14 percent is for research and development *per se* conducted internally by Government scientists and engineers, 13 percent is for test and evaluation, and 4 percent is for contract monitoring.

I should now hasten to add that an additional source of funds is available for support of scientific and engineering activities of the Department of Defense, primarily the latter. These, in appropriation language, are principally the Procurement and Production funds, of which something like \$3.2 billion in fiscal year 1959 go to the support of development, test, and evaluation of new weapons of the distinctively hardware varietv-the B-58 and the IRBM and ICBM programs are good examples. The charts presented do not include the funds from this source; within the theme of this symposium-extramural science-their omission is of little consequence, however.

Now let us discuss the scientific research activity of the Defense effort. The third chart displays the character distribution of the Defense research and development program. Of our fiscal year 1959 research and development programs, 15 percent, or \$391 million, is devoted to research; and of this \$109.6 million is for basic research. The balance, 85 percent of the total program, is for development. We estimate that almost two-thirds of the \$391 million of research funds supports extramural activities, and at least 70 percent of the \$109.6 million basic research funds is devoted to extramural support of basic research.

NATURE AND SCOPE OF DEFENSE SCIENTIFIC RESEARCH ACTIVITIES

The science programs of the Department of Defense comprise activities in the physical and engineering sciences, in the life sci-



CHART 1. Estimated Distribution of FY 1959 Federal Government Research and Development Obligations.



CHART 2. Where Defense Research and Development is Performed.



CHART 3. Character of Defense Research and Development Program for FY 1959.

ences, in psychology and the social sciences, and in operations research.

About 80 percent of the funds devoted to scientific research support activities in the physical and engineering sciences; this amounts to about \$313 million in fiscal year 1959 Defense program. Within this broad category the typical fields of endeavor and the program objectives are as follows:

In physics the objective is the advancement, through systematic and exploratory research, of those selected aspects of pure and applied physics which contribute to an increase in military capability. The present program, totaling about \$33 million in extramural effort, includes solid-state physics, extreme-temperature physics, statistical physics, physics of atoms and molecules, nuclear physics, physical acoustics, upper-air physics, electron physics, optics, magnetism, instrumentation for physical measurements, and electromagnetic radiation.

In chemistry the objective of the program may be divided into two parts: (1) a balanced effort of selected fundamental research which serves as a foundation for the varying needs of the military and (2) specific applied projects aimed at satisfying short-term defense needs. The present program includes research support in relevant areas of analytical, inorganic, organic, physical, polymer and radiation chemistry. The extramural support runs about \$31 million yearly.

In mathematics the objective is the systematic advancement of this science, closely geared to the objectives of the other scientific programs, and in response to expanding needs for direct qualitative information about the design and operations of weapons and weapons systems. The present program includes algebra, analysis, geometry, topology, probability, statistics, logistics, communications, and computers. Extramural support runs about \$5 million yearly.

With respect to those fields of endeavor that are more characteristically the engineering sciences, the scope of the programs and the broad objectives are as follows:

Mechanics: The objective of the research program in mechanics is the systematic advancement of engineering knowledge and principles bearing directly upon design criteria for the development of new weapons systems and components. Studies on the following are included in the present program: the dynamics of gases, liquids and solids; aerodynamic problems; problems involving structural design, strength of solids, hydromechanics, propulsion, heat and mass transfer, soil mechanics; and problems involving the development and synthesis of mechanisms. Extramural support runs about \$25 million yearly.

Materials: The objective of the research program is the systematic advancement of knowledge on the fundamental properties and behavior of materials to provide the best possible selection for designers and fabricators of military weapons and equipments. The present program includes studies on metals, minerals, ceramics, elastomers, adhesives, transparent materials, organic structural materials, fibers and fibrous materials, insulating materials, and dielectric and magnetic materials. Extramural support runs about \$27 million yearly.

Combustion: The objective of the research program in the field of combustion is to gain an increased understanding of the total process of transforming the chemical energy of reactants into thermal and kinetic energy of reaction products, so the design of military propulsion devices can be put on an increasingly rational basis. The present program includes investigations of basic phenomena in selected areas of physics. chemistry, fluid mechanics, thermochemistry, and thermodynamics; and also fundamental investigations of processes that are interrelated combinations of these phenomena. Extramural support runs about \$6 million yearly.

Electronics: The objective of the research program in electronics is to ensure maximum extension and acceleration of all our senses for military purposes. The present program includes acoustics and underwater sound; antenna theory, electromagnetic propagation and reflection; communications, data handling, and information theelectronic instrumentation orv: and standards; electronic countermeasures and counter-countermeasures; IFF theory; infrared; navigation; radar; electronic tubes, parts, and semiconductors; and electron and ion plasma. Extramural support runs about \$43 million yearly.

In the geophysical sciences the objective is the advancement through systematic and exploratory research of those selected aspects which will increase the capability of the military to utilize, predict, and control the natural environment. Included in the present program are meteorology, climatology, oceanography, marine geology, geochemistry, cartography, geodesy, geography, astronomy, astrophysics, magnetism, and gravity studies. Extramural support runs about \$19 million yearly.

Turning now to the broad category of life sciences, the DOD supports major programs in the medical sciences and in biology. The scope and the objectives are:

In the *medical sciences*, to provide support of the mission of military medicine by studies in—

(a) Preventive medicine: research on methods of physical examination and health surveillance, promotion of physical fitness, preventive dentistry; nutrition, environmental physiology and pathology, disease and injury prevention, toxicology; protection against radiation and blast, the effects of chemical and biological agents, with methods of casualty prevention; industrial and public health studies.

(b) Studies relating to the medical problems of aviation, astronautics, submarine and diving medicine, man in relation to the machines of war in all media, terrain and climates; and survival techniques.

(c) Improved methods of medical, surgical, dental and psychiatric care and rehabilitation of the sick and injured.

The medical sciences program runs about \$24 million yearly, of which about \$15 million is the extramural effort.

In the *biological sciences* the objective is the systematic development of this field in areas of military interest. The present program includes hydrobiology, biogeography, ecology, the biomechanism of complex data reception and control in living systems, bacterial fungal, viral genetics and nutrition, the ecology of disease vectors, the mechanism of infection, and the survival of microorganisms. Extramural support runs about \$7 million yearly.

As to the psychological and social sciences, the support level is about \$21 million, of which \$15 million is the extramural effort. Program content and the objectives are: the advancement through systematic and exploratory research of those selected aspects of pure and applied psychological and social sciences which contribute to an increase in the military capability. The present program includes studies leading to new concepts, techniques, devices, and principles applicable to the solution of military problems, including military manpower needs and the availability, selection, classification, assignment and proficiency measurement of personnel; education; training and training devices; motivation; morale; leadership; human organization; human engineering; psychological and unconventional warfare; intelligence operations; and civil affairs and military government.

Finally, coming to operations research as a field of scientific activity in its own right, the objective is to provide quantitative bases for executive decisions on military and related scientific matters. The present program includes contracts totaling about \$28 million in support of work with RAND, the Operations Research Office, the Operations Evaluation Group, the Combat Operations Research Group, the Institute for Defense Analyses, the Human Resources Research Office, the Naval Warfare Analysis Group, and the Naval Warfare Research Center.

In total, these scientific research programs comprise a fiscal year 1959 Defense effort amounting to about \$391 million, providing about \$137 million to the conduct of intramural effort and \$254 million to the support of extramural science activities.

DEPARTMENT OF DEFENSE POLICY ON BASIC RESEARCH

Let us turn now to objectives stated even more broadly. About a year ago Secretary McElroy issued a strong policy directive setting forth the principles governing the support of a Department-wide basic research program, conceived and anchored in imaginative long-term planning and long-term funding. This policy recognizes that "the needs of national defense are uniquely characterized by pressing demands for new facts and knowledge very close to the frontiers of science" in order to protect the security of the United States and its vast Defense investment against both technological surprise and obsolescence. It emphasizes also that the costs of basic research are small in proportion to the potential military strength to which basic research is capable of contributing and that "sustained support of basic research offers one of the most promising opportunities for effecting long-range economies in other aspects of the military program."

Specifically, the directive states:

- A. It is the policy of the Department of Defense:
 - 1. To support a broad and continuing basic research program to assure the flow of the fundamental knowledge needed by the military departments as prime users of scientific facts and to evolve novel weapons of war; and
 - 2. To maintain, through such a broad support program, an effective contact between the military departments and the scientists of the country so that the military departments are continuously and growingly aware of new scientific developments and the scientists are aware of the military needs.
- B. It is further the policy of the Department of Defense to coordinate its basic research program with the National Science Foundation and to encourage the support of sound basic research programs by government and private agencies, recognizing that these programs are essential to the full development, utilization and growth of the nation's scientific resources and, hence, to national defense.

Within the guidance of this policy, the Department of Defense substantially increased fiscal year 1958 funding for some research programs judged critical for the improvement of military weaponry. The increased funding for each field was: \$31.6 million for the physical, medical, and geophysical sciences; \$10 million for materials research; and \$12.5 million for the vital areas of electron tubes and electronic parts. \$30 million of these funds went to the support of basic and supporting research programs at academic institutions. The main effect was to restore research to the level from which it had sagged over the past several years owing to inflation and the increased costs of modern instrumentation. In addition to the above funds, \$12 million was made available to the Army and Air Force in June of this year for the explicit purpose of financing certain contractual research programs for periods longer than the annual program increment or to provide for program longevity.

NEW GRANTS AUTHORITY UNDER PUBLIC LAW 85-934

The recent session of Congress saw the passage of Public Law 85-934, an act to authorize the expenditure of funds through grants for the support of scientific research. Heretofore the Department of Defense has been limited to the use of a research contract in engaging the services of an educational or other nonprofit organization. The Grants Act provides the authority to make grants to such institutions or organizations for the support of basic scientific research, where such action is deemed to be in furtherance of the objectives of the agency; it also grants discretionary authority to vest title of research equipment in the organization carrying out such research. Increased flexibility will accordingly result from this authority in Defense support of basic scientific research. A directive is presently being drafted in the Department of Defense to establish a uniform policy among all military agencies in the awarding and administration of research grants and the transfer of title to research equipment acquired under such grants.

This, I believe, covers the highlights of Defense science programs and our broad objectives in their support, the program content and technical objectives of our scientific effort in some discrete fields, and certain aspects of Defense policies designed to be constructive, forward-looking, and to lend stimulation and sustenance to science from the Defense end of the Federal Government.