THE ROLE OF THE NATIONAL SCIENCE FOUNDATION

16 October 1951

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Washington, D. C.

Dr. Alan Tower Waterman, Director of the National Science Foundation, was born at Cornwall-on-the-Hudson, New York, 4 June 1892. He holds the following degrees: A.B., Princeton, 1913; A.M., 1914; Ph.D., 1916. He has been instructor, University of Cincinnati, 1916-1917; instructor of physics, Yale 1919-1922, assistant professor of physics in 1923-1930; National Research Fellow, physics, Kings College, London, 1927-1928; associate professor physics, Yale since 1931; chief scientists and deputy chief, Office Naval Research, Navy Department, Washington, since 1946. During World War II, he served as vice-chairman, Division "D" National Research Defense Committee, 1942-1943; deputy-chief, Office of Field Service, Office of Scientific Research and Development, 1943-1945, chief, 1945. For his war service the President awarded him the Medal of Merit "for civilian meritorious service." He was chief reader, physics, College Entrance Examination Board 1935-1941, chief examiner, physics, since 1937. He is a fellow of American Association of the Advancement of Science, American Physics Society, American Association of Physics Teachers; and member of the American Association of University Professors, the Phi Beta Kappa and Sigma Xi Club Graduates, New Haven, Connecticut. His editorial and journalistic work includes editor, Combat Scientists, 1947; member of the editorial board, "American Journal of Science," 1934-1942, and he has contributed scientific papers to "The Physics Review," "American Journal of Science," "Philosophical Magazine Proceedings," "Royal Society." In March of this year the President appointed him Director of the National Science Foundation.

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THE ROLE OF THE NATIONAL SCIENCE FOUNDATION

16 October 1951

GENERAL HOLMAN: Our speaker this morning is Dr. Alan T. Waterman, the first director of the National Science Foundation, a true pioneer in the field of governmental sponsorship of fundamental scientific research.

I think that all of you will appreciate the importance of fundamental research as a means of improving our economic structure, and through research, keeping our military capabilities out in front. It is to understand more clearly the national potential for fundamental research that we have asked Dr. Waterman to address us today.

Dr. Waterman has served with great distinction as an educator at the University of Cincinnati, at Yale, and as a National Research Fellow at Kings College in London. During World War II he was with the National Defense Research Committee and later with the Office of Scientific Research and Development.

Prior to his present appointment he was chief scientist and deputy chief of the Office of Naval Research.

DR. WATERMAN: General Holman, gentlemen; It is always a pleasure to be invited for a return engagement to the Industrial College of the Armed Forces.

General Vanaman has invited me to discuss with you today "The Role of the National Science Foundation." I was very much interested to note from his letter that your technological progress study this year is stressing "environmental and motivating factors and their influences upon the development and distribution of creative scientific talent among nations." From my point of view, he could not have placed my subject in a more appropriate frame of reference, for the National Science Foundation (NSF) is faced with a peculiar set of problems as it seeks to establish the importance to our national existence of basic research and education in the sciences. The course of basic research is profoundly affected by the social and economic climate of its time, and never more so than the present day.

For purposes of today's discussion, I propose to ask three questions: What is the significance of basic research to technology? What is the significance of basic research to our national culture?

What role does the National Science Foundation expect to play in furthering progress in science?

I may say at the outset that my task is made easier by the very nature and character of this class. The fact that you are interested in these questions ensures an informed background and an awareness of the problems, which makes it necessary for me only to fill in some of the details. Unfortunately, I do not always enjoy an audience of the same degree of understanding. If you have been following the fortunes of the NSF in connection with its first-year budget, you have observed that we have not been altogether successful in conveying the significance of the relationship of basic research to technology and the necessity for adequate support of basic research and education in the natural sciences.

We of the NSF staff have discovered at the outset, therefore, that one of our first tasks is to create, on the part of the general public, a greater awareness of the significance of these relationships. For when people generally appreciate the necessity for long-range planning in science, their understanding will then be reflected in the actions of Congress. If we are successful in making these matters clear to individual groups, we can then hope that the members of each group, in turn, will help to spread the story.

Let me emphasize that, in this effort to make clear how one deals with basic research, the birth pains of the NSF as an entity, have special significance, in that this is symbolic of a national attitude. The real issue is whether the Nation, as a whole, can be made to understand, in an age of clashing technologies, that the quiet research which goes on in the laboratory is the all-important seedbed from which the new weapons and new industrial devices are eventually harvested. A farmer who made heavy capital outlays for cultivating and reaping equipment, and then refused to spend any money for seed corn, would be an object of some curiosity; and yet, it is not too far-fetched an analogy to picture ourselves, as a nation, doing much the same thing.

Before we proceed to a consideration of the significance of basic research in modern society, let us define what we mean by basic research. Considered as a whole, the research and development process includes the following phases: basic research, applied research, development, test and evaluation, and production. A full consideration of any one of these phases would more than supply material for an entire lecture in itself. Today we shall limit our consideration to basic research which, generally speaking, is the starting point in the cycle, whether this occurs in a modern laboratory or is taken from the library literature which is on record there.

Basic research has a wide variety of definitions and, even within the Department of Defense, there seems to be no hard and fast agreement on any one definition.

The Research and Development Board definition at present is:

> "A theoretical or experimental study directed toward the increase of knowledge. Immediate practical application is not usually a direct objective of the investigator. Such practical application, either immediate or in the future, is however properly a concern of the Department of Defense."

A definition that I like is Dr. Bush's. He calls basic research "the ordered pursuit of new knowledge."

It is the quality of unpredictability and uncertainty that makes it so difficult for basic research to achieve the kind of financial support it must have if it is to be sustained. At the initial point of definition we first perceive the gulf which yawns between the man of science and the "practical man" who must be shown why public funds or, in fact, any funds should be invested in a series of studies for which there is at the outset no foreseeable application. I may say the military departments have found the same difficulty in justifying some of their research when of a fundamental nature. It is scarcely to be wondered, then, that when we examine the degree of support for the various stages in the research and development process, we find the balance heavily weighted on the applied and developmental ends.

A few figures may be useful for purposes of comparison, although I must warn, at the outset, that available figures on annual expenditures for research and development are, at best, approximate and inconclusive. This is true because all the terms associated with the problem--that is, basic research, applied research, development, testing, engineering, and so on--admit of a wide variety of definition. When one adds to variations in definition and interpretation--even greater variations in cost accounting procedures, it becomes apparent that the best we can do is to indicate some very general trends in the rates of expenditure for research and development.

Recent estimates prepared by the Research and Development Board place the level of total national expenditures for research and development in 1951 at an approximate rate of 2.5 billion dollars. Of this total, the Federal Government was responsible for 1.31 billion dollars. Industry spent 1.17 billion dollars, and the universities 1.1 billion dollars, for research and development over and above that for which the Federal Government contracted. If we can assume, for purposes of discussion, that much of the research and development performed in government laboratories or by industry is of an applied nature, while that done by the universities is, for the most part, basic research, it is quite obvious that a small

portion indeed of the total research expenditures is devoted to basic studies.

However, one must regard these figures as indicative only. Some of the difficulty in comparing military research and development within the Department of Defense can be gauged by the fact that the Air Force includes the construction of a prototype bomb in development costs, while the Navy does not similarly include the costs of constructing a prototype submarine. The costs of such expensive facilities as guided missile test ranges and supersonic wind tunnels also increase the costs of research and development to a point where it is extremely difficult to form a realistic picture of how much of these apparently large sums is actually going into research.

Expressing the situation in general terms, the Research and Development Board finds that "Industrial organizations generally perform, dollarwise, about 65 percent of the country's total scientific research and development; government, about 25 percent; and universities, about 10 percent."

When in the early summer of this year the President recommended to the Congress an appropriation of 14 million dollars to be expended by the NSF in support of basic research and education in the natural sciences, the sum appeared small indeed in comparison to a military research and development budget which topped a billion dollars. In spite of this, the House Appropriations Committee saw fit to reduce the amount recommended by the President to $300,000, or approximately 2 percent of the total requested.

Between August and October the scientists of the Nation came forward to reaffirm the importance to the national welfare of a sound body of basic research, and they must have been reasonably successful because the Senate Appropriations Committee, in considering the matter, added 6 million dollars to the $300,000. As of this moment, we await the final and decisive action of the House and Senate conferees. I mention this sequence of events, not in the spirit of acquainting you with our budgetary troubles, but merely to point up the strangely anomalous position which basic research and education occupies in this country, and to seek your advice, as I have asked that of other informed groups, as to what can be done about it.

It is not as if it were necessary to point out what research and development have meant to the world. We live in an age of science, and its miracles are so manifold that they have become commonplace. Yet most of the technological marvels of today came about, not in the last thousand years of human progress, but in the last century.

Caesar, in his Conquest of Gaul, comments as follows regarding a raid upon a Roman settlement by the barbarians:

> "Tidings of these events sped swiftly to all the tribes of Gaul; for when anything specially important or remarkable occurs, the people shout the news to one another through the countryside and villages, and others in turn take up the cry and pass it on to their neighbors. Thus, on the present occasion, what happened at Cenabum at dawn was known before eight o'clock at night in the country of the Arverni, about 150 miles away."

The system of communications which Caesar thought swift in the year 52 B.C. was essentially no swifter in the days of Napoleon. The fabulous Nathan Rothschild is said to have scored a coup on the market of his day through the shrewd device of sending the news of Waterloo by carrier pigeon. And Waterloo is less than 150 years from our own time.

The "London Times" once described a new weapon as "perhaps the most terrible implement of destruction ever delivered into the human hand." This was not the "London Times" of 6 August 1951, describing the bomb that fell on Hiroshima, but the "London Times" of 29 May 1851, describing a repeating pistol brought to England from the United States and reported to be capable of penetrating a seven-inch board! Between that awesome weapon of our grandfathers' time and the weapons we are testing today at Frenchman's Flat are fewer than 100 years.

And this brings us to our first major question, which is, as you will recall, What is the relation of basic research to technology?

Chart 1, page 22, Radio activity.--The basic research that culminated in atomic weapons began perhaps with the fundamental discovery by Becquerel, in 1896, of the phenomenom of radioactivity. I might apologize for bringing up this particular subject as an illustration, but, in fact, it is one of the best and its details are not always understood. Becquerel made this discovery in 1896. It would have been impossible prior to that time to have predicted this discovery or in fact to know that any such thing existed.

That is the first thing about any really fundamental discovery in research. No amount of money by the French Government would have enabled Becquerel or anyone else to find this any faster. He was completely out on the frontier. There was no way to predict this thing. So that fact came out of a clear sky. But a trained observer who has an excellent background is able to see a new thing when it appears. It is important to realize that, at this stage, no amount of money can help to make possible a capital discovery like radioactivity or X-rays, except the general support of basic research.

This is true because the field in which such a discovery lies is completely unknown beforehand.

This is the starting point. You are familiar with the work of the Curies in the isolation of radium which came at the beginning of the century when this chain of events occurred. Rutherford, beginning with the early part of this century and continuing for about 35 years, gave the chief leadership in this general progress. Chadwick, in 1932, discovered the neutron, and a few years later, the work of Fermi touched off the discovery of nuclear fission in 1939 by Frisch, Hahn, and Meitner. At this point, then, the possibility appeared for doing something with atomic energy. What I particularly want to point out is that there was no possibility of utility until nuclear fission was discovered in 1939; there was no possibility of nuclear fission until the discovery of the neutron in 1933. In those six years the basic research which took place made possible atomic energy and the atomic bomb. Without this research, of the most fundamental nature, neither could have been developed.

The three years and the 2 billion dollars which the Manhattan District spent on the problem between 1942 and 1945 represented the cost of applying the solution of a problem that had been worked out, step by step, by many men in many laboratories, over a period of years. This overwhelming engineering accomplishment by the Corps of Engineers and American industry was a dramatic translation into reality of the theoretical musings of physicists, for which no one could have predicted any practical application 20 years ago.

Chart 2, page 23, Communications and Electronics.--In passing I should just like to call your attention to the familiar case history of electronics without stopping for detail. The electronics industry, which is estimated to be a 15 billion dollar industry at the present time, came about through a well-known discovery by Faraday 100 years ago. This development would not have been possible except for basic research which led on, each one adding support all down the line until we come up to the twentieth century. All this basic research touched off the possibility of the magical electron tube which made all these developments possible--radio wave generation and detection, broadcasting, power, electronic controls, radar, and television.

The whole concept of the relationship of basic research to invention and development would be much tidier and lend itself more readily to exposition if it were true that the process proceeds always from basic research to practical application. In reality, however, we find that basic research and invention have interacted upon each other in a way that makes it possible for either to start the chain reaction of ideas which may lead eventually to an end item of great practical value. A good illustration of that, frankly, is the effect of war on medical

research. Very many of the capital discoveries in medicine come out of wars because of the need and opportunities which then exist. Sometimes it is the artisan or the inventor who provides the inspiration which stimulates profound studies of a basic nature. The concept of radar grew out of experimentation with short radio waves and was specifically suggested by Marconi, on 20 June 1922, in a speech before the Institute of Electrical Engineers and the Institute of Radio Engineers. He said:

> "It seems to me that it should be possible to design apparatus by means of which a ship could radiate or project a divergent beam of these rays in any desired direction, which rays, if coming across a metallic object, such as another steamer or ship, would be reflected back to a receiver screened from the local transmitter from the sending ship, and thereby immediately reveal the presence and bearing of the other ship in fog or thick weather."

You know the story of the development of radar. It is a matter of considerable interest to note that Albert Hoyt Taylor and Leo Cliffor Young, of the Naval Research Laboratory, were pioneer experimenters in radar work as early as the autumn of 1922. Dr. Tuve and Dr. Breit, of the Carnegie Institution were the first to use the radio technique of transmitting discontinuous pulses and measuring the time for the returning echo to reach a nearby receiver. Similar investigations were carried on in England, but each group was unaware of what the other was doing at the time. So long wave length radar was ready by World War II.

What is perhaps even more interesting is that as early as 1904 a patent was granted to a German inventor, Christian Hulsmeyer, for a collision prevention device embodying certain principles of radar. Guerlac described this device as consisting "of a spark gap transmitter, sending out a beam of very short radio waves focused by means of a hemicylindrical reflector located on the ship's mast. The echo is picked up by a second receiving antenna also provided with a reflector."

Often there is a curious lapse of time between a significant observation and its eventual practical application. The shaped charge, for example, that the Army is using so effectively with the bazooka in Korea, is based on an old principle called "the Munroe effect." Dr. Charle Munroe, who was working in the Naval Torpedo Station at Newport in the 1880's, observed that letters and figures molded into gun cotton left corresponding indentations when exploded against metal. This observation led to the discovery that far greater force is obtained when an explosive is shaped around a cavity than when it is packed into a solid mass.

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One of the popular science magazines calls attention to the fact that it published Dr. Munroe's report of his findings and photographs of his results 50 years ago, but it was not until World War II that the idea was translated into an effective weapon. This illustrates another important thing, that in furthering research we must find some way to diminish the lag between a capital discovery and its practical application. Progress can be made and is being made very rapidly.

I have chosen, as illustrations of the interactions of the processes of research and invention, weapons with which we are all familiar as being perhaps of especial interest to this group. It would be easy to cite many other examples of a nonmilitary nature.

Riding, as we are, on the flood tide of technological achievement, it may seem superfluous even to raise my second question, What is the place of basic research in our national culture?

The fact of the matter is, however, that the United States is doing relatively little basic research, when we measure it against the effort which is going into applied research. Traditionally we have depended on Europe for basic research, and there is reason to question whether this is a sound policy for the future, even if European science is eventually restored to the position it occupied before the war. There is also a question as to whether the rate at which we are exploiting new ideas may not outstrip the rate at which new ideas are being produced. Already there are areas in which further development awaits the reinforcement of new theoretical knowledge.

A question to which we would particularly like the answer is how the Russian research and development effort compares with our own. To date, we have considerable evidence that, in some areas at least, the Russian technological effort is fully equal to our own. Testifying before a congressional committee last spring, General Vandenberg emphasized the superior quality of the Russian jet engine and said that it was as good as anything we could offer for comparison. He also pointed out that it would be a mistake to attribute Russian technological achievements solely to the German scientists who were removed to Russia after the war. This is borne out in basic research where occasionally we find coming to light something which our people have not done and which we have not known about. The tragedy is that some of these are almost critical.

The principal point we have to consider here is that under the Soviet form of government, the entire technological effort can be directed as its government sees fit. This may result in the production of excellent weapons, to the total exclusion of consumers' goods, but it is still one of the factors which have to be considered when a democracy is forced to defend itself against a wholly controlled economy. If we are to assume that Russia is able to compete with us,

technologically speaking, on something approaching equal terms and with admittedly far greater manpower, it appears obvious that we must seek the advantage elsewhere. Is it not logical to suppose that the basic research we are doing today, or will be doing tomorrow, may hold the clue to some future development which will give us the undisputed advantage? As Dr. Bush has pointed out, World War II was the first war in history to be won with weapons which were not in existence at the outset. Who, then, can say with what weapons some future war may be won?

Unfortunately, we know very little about Russian research in comparison to what they know about ours. It now appears that even those few sources of information which have hitherto been available to the outside world are about to be shut off. Only last week "The New York Times" reported that the Soviet Union is abandoning the export of 10 major scientific journals. According to the Times, "The ban will cut non-Soviet scientists off from virtually all journals dealing with progress in physics, as well as most journals reporting new discoveries in chemistry. Publications reporting advances in geology, geophysics, and mineralogy are also affected by the order."

Also subject to the new export ban is the "Soviet Book," an information source on all books published in the Soviet Union. Included in the ban are magazines dealing with the automobile industry, paper industry, architecture and construction, and machine tractor stations, among others. The Times goes on to point out a fact with which we are all familiar: The Soviet Union follows scientific progress here and in the other free nations of the world very closely and subscribes to large numbers of scientific and technical journals. Here again is compelling evidence of the unequal terms on which the free world is forced to compete with an ironclad dictatorship.

Other factors influencing the amount of basic research being supported are the increasing size and complexity of applied research, which requires larger and larger numbers of scientists and increasingly expensive facilities, to the extent that through the operation of economic laws, applied research tends to drive out basic research.

There is still another peculiarly interesting aspect of the matter, that is, the attitude of Americans toward scholars generally--men whose mental labors are unrelated to practical considerations. It is said that America has produced only two fundamental scientists: Benjamin Franklin and Willard Gibbs. Without conceding that the number is necessarily so small, I can still make my point, which is that while

everyone is thoroughly familiar with the details of Franklin's life, perhaps only one in a thousand has heard of Willard Gibbs, quiet Yale physicist whose investigations established the basic theory for physical chemistry. And Franklin is well known for reasons other than his researches in electricity.

When we consider why a great thinker like Gibbs is so little known, we come back again to those environmental and motivating factors influencing the development and distribution of creative scientific talent which General Vanaman has so appropriately stressed. Part of the story lies in the general European attitude toward men of letters as contrasted with American attitudes; and part of it grows out of varying economic motivations. The scholar in Europe occupies a peculiarly honored position in society not paralleled anywhere in our own. This is as true of the man of science as of the man of art or letters.

A contemporary biography of the great Danish physicist, Hans Christian Oersted, relates that the hereditary Prince of Denmark walked in Oersted's funeral procession; Claude Bernard, the renowned French surgeon, was the first man of science to be accorded a public funeral; and when Louis Pasteur was honored by France on his 70th birthday, he walked into the Sorbonne on the arm of the President of France.

In the United States, on the other hand, it is difficult to recall any scholar who has been so honored by the Government and few who have received even local tributes of admiration. I mention these facts, not to deplore the social status of scientists, who probably do not hanker for a public funeral anyway, but merely to emphasize that in Europe the opportunity for national recognition was fully as great for the scholar as for the soldier and the statesman. In the United States our national heroes have been, in addition to our military men, statesmen and athletes, great industrial pioneers and, to a lesser extent, men of inventive genius such as Thomas Edison and Alexander Graham Bell. This attitude characterizes a frontier economy which for a long time enjoyed the advantages of endless natural resources and an inexhaustible market at home. The challenge was for the doer rather than the thinker.

It was only around the beginning of the present century that the growth of rival industries and the increasing competition for world markets pointed up the advantages of industrial research in the development of improved products.

After a slow beginning the United States made rapid and dramatic progress in industrial research, which has proven to be the lifestream of a great industrial economy. But we drew upon the basic research of Europe without feeling any real compulsion, prior to World War II, to insure the future of basic research by actively supporting it in this country.

The dramatic impact of science and technology on warfare caused a few thoughtful people to begin to worry about whether the United States as a nation was giving sufficient emphasis to the organization and support of scientific research and development. As early as 1942 Senator Kilgore, of West Virginia, began to hold an important series of hearings on the significance of scientific and technical mobilization to the war effort. Even before this President Roosevelt appointed a commission to study the influence of science in industry in relation to national welfare.

On 17 November 1944 the whole matter of the support leading to the National Science Foundation, as you know, was touched off by the late President Roosevelt in a letter to Dr. Vannevar Bush, director of the wartime Office of Scientific Research and Development, in which he asked a series of questions, one of which was: "What can the Government do now and in the future to aid research activities by public and private organizations?"

To assist him in formulating a properly considered reply to the President's questions, Dr. Bush enlisted the assistance of a distinguished panel of experts. The late Isaiah Bowman, president of Johns Hopkins University, was asked to head a committee on science and public welfare. The committee urged that Dr. Bush propose to the President the establishment of a national research foundation. This came out later in the form of a now famous answer to the President "Science, the Endless Frontier," which appeared in July 1945. I will not stop to describe the steps which led actually to the Science Foundation.

Chart 3, page 24, The National Science Foundation Act.--which will indicate to you some of its functions:

1. To develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences.

2. To initiate and support basic scientific research in the mathematical, physical, medical, biological, engineering, and other sciences; by making contracts or other arrangements (including grants, loans, and other forms of assistance) for the conduct of such basic scientific research and to appraise the impact of research upon industrial development and upon the general welfare.

3. At the request of the Secretary of Defense, to initiate and support specific scientific research activities in connection with matters relating to the national defense by making contracts or other arrangements (including grants, loans, and other forms of assistance) for the conduct of such scientific research.

4. To award, as provided in section 10, scholarships and graduate fellowships on the mathematical, physical, medical, biological, engineering, and other sciences.

5. To foster the interchange of scientific information among scientists in the United States and foreign countries.

6. To evaluate scientific research programs undertaken by agencies of the Federal Government and to correlate the Foundation's scientific research programs with those undertaken by individuals and by public and private research groups.

7. To establish such special commissions as the Board may from time to time deem necessary for the purpose of this act.

8. To maintain a register of scientific and technical personnel and in other ways provide a central clearinghouse for information covering all scientific and technical personnel in the United States, including its Territories and possessions.

In accordance with the act there is a National Science Board, consisting of 24 members who are broadly representative of education, science, engineering, agriculture, public affairs, and industrial research. Members are appointed by the President with the advice and consent of the Senate. The director is a member ex officio. The term of office for the Board members is six years with staggered two-year intervals. The chairman of the Board is Dr. James B. Conant, president of Harvard University. The Board meets regularly, on an average of once every month.

The act provides for four divisions, as follows: A Division of Medical Research; a Division of Mathematical, Physical, and Engineering Sciences; a Division of Biological Sciences; and a Division of Scientific Personnel and Education.

This is not tied in with specific reference to the divisions of the Foundation, but it illustrates how the fields of science branch out by subjects. The general idea is, if we take physics for example, this science branches out subdivisionally into theoretical physics, engineering, geophysics, meteorology, acoustics, solid states and so on. The same is true of the other sciences, as shown. The problem of the Foundation is to select areas of greatest promise and importance while keeping within the general coverage.

The act provides also for a divisional committee for each division of the Foundation. The divisional committee is appointed by the Board and consists of not less than five persons, who may be members or

nonmembers of the Board. The function of the divisional committee is to make recommendations to, and advise and consult with, the Board and the director with respect to matters relating to the program of its division.

The Foundation is further authorized to appoint special commissions of scientists and nonscientists for the purpose of making comprehensive surveys of research, both public and private, in specific fields and for recommending to the Foundation over-all research programs in such fields.

In view of the fact that medical research is closely allied to biological research in the basic phases in which the Foundation is interested, it is probable that, initially at least, no distinction will be made between the two for purposes of programming.

The Division of Biological Sciences is headed by Dr. John Field, who is on leave of absence as chairman of the Department of Physiology of the University of California Medical School at Los Angeles. In the area of biological and medical research, the Foundation contemplates the support of such studies as protein structure and synthesis, enzymology, immunology, biochemistry and nutrition, biophysics, comparative physiology, marine biology, photosynthesis, microbiology, and other important investigations which can contribute important new knowledge to the processes of life and the war against disease.

The Division of Mathematical, Physical, and Engineering Sciences is the largest in scope of the four divisions. Dr. Paul E. Klopsteg has just been granted leave of absence as professor of applied science and director of research at the Technological Institute of Northwestern University in order to organize this important division and direct the formulation of its program.

Typical of the subjects for which this division will recommend Foundation support are: mathematics; astrophysics and astronomy; elementary particles; solid state physics, physical chemistry; inorganic chemistry; organic chemistry; radiation chemistry; fluid mechanics; metallurgy; high temperature physics, chemistry, and engineering; and so on. It is in this general category of research that the Foundation is most likely to be requested by the Secretary of Defense to initiate projects.

The Division of Scientific Personnel and Education will administer the scholarship and fellowship program of the Foundation. This is a very important area of activity because it relates to the crucial problem of scientific manpower shortages which has recently had so much publicity.

Chart 4, page 25, Need for Fellowships,--indicates how the Foundation intends to initate its graduate fellowship program. This chart shows the number of students graduated from college last year--who majored in science--about 125,000 in all the institutions of the country. Of this number 83 percent, on the average, are judged not competent to go further in graduate work; thus 17 percent are judged competent to enter graduate study. Of the total number 6 percent, on the average, do not continue for one reason or another, not financial; 4.4 percent do not continue for lack of funds; and the net result is that 6.6 percent do plan to continue. Thus only 40 percent of those judged competent to enter graduate study actually do so. The fellowship program, then, is aimed at this number who have the ability but do not enter advanced study, in the hope of securing more trained scientists. That in brief is the plan of the Foundation on this chart.

Another interesting aspect of the program planned by this division relates to ways and means of assisting teachers of science to obtain information on new techniques in the teaching of science; helping them to keep abreast of developments in their own fields; giving them the opportunity to carry on scientific investigations of their own; and in other ways increasing their usefulness as developers of new scientific talent. The development of capable science teachers is a very important consideration, particularly at the secondary and undergraduate levels, since it is during these formative periods of education that students are stimulated to enter upon scientific research as a professional career. The work of this division is being directed by Dr. Harry Kelly, who was scientific adviser to General MacArthur in Japan during the postwar period.

Another interesting group of problems has been assigned to the Scientific Information Office. These problems relate to the acquisition, dissemination, publication, indexing, abstracting, and so on, of the enormous volume of scientific literature now being produced. This is a very serious problem nowadays, especially since more and more the traditional sources of scientific information, the scientific journals, have been augmented by a growing volume of reports by government laboratories and government sponsored research. These have been added to by reports from the Atomic Energy Commission (AEC), Department of Defense, Public Health, and so on, which do not have the same distribution as the other information. This is really a complicated problem and one which, if solved in any degree at all, would certainly create a far greater effectiveness in research itself.

The foundation also supports two activities not mentioned so far. One is the National Register of Scientific and Specialized Personnel, which is physically located at the present time in the U.S. Office of Education. Its study of available scientists and engineers and their

qualifications is of maximum use to the Office of Defense Mobilization.

Another activity which looks to the Foundation for budgetary support is the Interdepartmental Committee on Scientific Research and Development. The committee is comprised of the directors of research in most of the government agencies, including one from each of the military departments and one from the Department of Defense.

In considering the means by which support can be most effectively given to basic research in the natural sciences, the Foundation has concluded that, in general, the grant offers the most effective means of accomplishing the desired objectives. In recognition of the fact that basic research cannot, like applied research, be scheduled in terms of producing tangible results by fixed deadlines, every effort will be made to make time limits as liberal as statutory limitations will permit and as individual situations seem to warrant. In general, this will be the standard pattern, although the Foundation has great latitude in the manner in which it can render assistance.

Investigators will be encouraged to publish their findings in the regular media and this will also be done by special reports as needed.

I should like to stress the fact that the NSF was not intended to supersede any other Federal agencies nor to eliminate the need for existing programs. Any agency with a technical mission should have authority and funds, of a limited amount, to support basic research in fields of special interest to itself. This keeps the agency technically alert and prevents the situation arising, in military technology for instance, where accomplishment may consist of making minor improvements in obsolete weapons.

In summary what may we conclude with respect to the relationships of basic research and technology; the significance of basic research to our national culture; and the role of the NSF? We may conclude, I think, that although as a nation we have led the world in technology and inventive ingenuity, we have made only a small contribution to basic research; and the dependence of the former upon the latter is neither generally understood nor appreciated in this country.

Scholars and men of letters are not objects of special veneration and respect in the United States and there is not therefore the same incentive to pursue knowledge for its own sake as exists in the older countries of the world. Furthermore, the United States, during the greater part of its existence, was preoccupied with the challenges of a frontier economy, and up until the twentieth century lacked the motivation of competition which prompted continental Europe to turn

to research a century ago. It is only in recent years that we have been "research-minded" in any sense. However, World War II caused us to view the implications of theoretical knowledge in a new light and to reassess the place of science in our national life. In order to give this important element in our national life due recognition of its importance, a NSF has been established to develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences.

The experience of the summer has indicated, however, that even though Congress established a NSF, its real significance is still only partially understood. There is, therefore, still much work to be done toward educating the public in an understanding of, and appreciation for, basic research. Toward this end, the cooperation and assistance of all informed people are urgently needed. What this really amounts to is that we should bring research out in the open and see that it is supported for itself. That is where the difficulty is. We know that basic research is important but we have not learned that basic research of a very broad variety is needed in order to arrive at important discoveries.

I am glad to have had this opportunity to present our plans and outlook to this distinguished group, and I shall welcome your questions and observations regarding our activities.

Thank you.

QUESTION: I would like to ask a question in the area of the scientific roster that you mentioned, especially in view of the fact that you said the Foundation would not duplicate any agencies in the Government. What is the relation of the Foundation to the Scientific Advisory Committee, headed by Dr. Buckley in the Office of Defense Mobilization, on the subject of the scientific roster?

DR. WATERMAN: I am a member of that committee and the scientific manpower area is one of the areas in which we are interested. The function of the Science Advisory Committee is one of making sure that this area is handled by somebody, but it is not an operating committee. Thus tabulation is made of the activities with respect to the national register and the investigation of the number of scientists of different kinds, their qualifications, their war experience, and what things they could do besides science. This tabulation is of maximum use now to the Office of Defense Mobilization, specifically to the Committee of Specialized Personnel and the Committee on Manpower, headed by Dr. Fleming under Mr. Wilson. So you might say that the register furnishes data which can be used by the mobilization group in any way that seems

desirable. The facts are there. If we should come to the point at any time in selecting people with certain specific qualifications, as for instance, if you wanted to find a group of scientists in nuclear physics who knew how to ski, this would tell you how many there were.

QUESTION: Doctor, on the question of dissemination of information, are any attempts to be made by the NSF to establish a central library or a common cataloging system, a codifying system, and to impress upon the other agencies of the Government the need for it?

DR. WATERMAN: Yes, there is a great need. I believe it is generally admitted that for the dissemination of information the government agencies should have some sort of central group or facility which could look after the general technical information problem. That is to say, to take the problem in its simplest form--you have a technical man working on problems in the Department of Defense, the AEC, Public Health, or somewhere else. To get on with his work he needs specific information. Some of it lies directly in his field of competence; some of it outside. How can we get it to him quickly? This requires coordination between agencies. The central setup which could do this would be one which would list available information and provide quick access by way of searching so that anyone who wanted the information could get it--at least get it in the form of what is available, a statement about the nature of the research, or reports which could be had. This is the sort of thing in which the Department of Defense has made considerable progress. It should be broader. There should be complete integration between other agencies, too. This does imply a central facility; it also implies, I think, that this should not be too highly centralized. The problem should be looked at centrally, and then, as far as possible, decentralize in such a way as to fit into a general plan. It would be foolish to have an unwieldy central facility. The NSF, since it has in its charter the authority, could take the lead in handling this problem. That we hope to do.

QUESTION: Could the Office of Technical Services handle all our basic and, say, the Department of Defense handle all the technical information under their present setup or an expanded setup?

DR. WATERMAN: I think one has to view this question in the three major categories in which it belongs. One is the government agency, one is industry, and one is the university. The Office of Technical services by its charter distributes technical information to industry. So if it is handled solely by the Department of Defense and the Office of Technical Services, you will have the Defense Department with your contractors, as one group; you will have the Office of Technical Services serving industry with what it gets from government agencies, but the university is out of the picture, except insofar as it has some contact with a government agency. This is a good chance to follow the

excellent work which has been done in the Department of Defense by handling it in such a way that those three major categories are brought into a coordinated plan. This would be my view. The Science Foundation can take the lead in bringing this question to some solution.

QUESTION: Do you include nonprofit institutions in the same category?

DR. WATERMAN: If one does a complete job in dissemination of research, yes, because they all contribute and all need consideration.

QUESTION: Will you explain how the NSF proposes to operate in evaluating the government program as a whole in correlating the Foundation's program with industry and private operation in the scientific field?

DR. WATERMAN: That is a very important question and we have an answer which we think is sound. With respect to evaluation, let me first make clear that no scientist would try to evaluate current research. It is only history that can tell us whether research is good or not. If a discovery is made today, it will not be believed--no matter how well-known the man is--until it is confirmed by other people in all its aspects. Sometimes that confirmation takes time. It may go for years and then be found that something was wrong with the original work. So the evaluation of research itself is something one has to be careful about.

The NSF tries to evaluate research from the national point of view, by subject, not by agencies or institutions. That is to say, suppose we got together all the leading inorganic chemists in this country to consider and report on what work is going on in inorganic chemistry, where important problems are, what problems are to be solved, what success was achieved, what gaps existed. They will know because they are experts in their own field. They won't have to make a house-to-house canvass. The same thing is true for other branches of science. So we intend to evaluate the national picture with respect to research, done in a way which has not only quantitative judgments--how many people are working in the field--but the qualitative judgment--in what fields does good research need to be done? Having done that, the NSF can consult with each government agency as to what its research program is, what it is doing, and why it is doing it. As one compares the evaluation of the national research picture with what is actually going on, the picture begins to make sense. It will

also be possible then to make some authoritative statement regarding the country's needs for highly trained scientists, in each field of research. This step can be taken by NSF.

QUESTION: Is there any indication of what industry is doing in the way of supporting these fellowships and Ph. D.'s? What is the volume? how many each year?

DR. WATERMAN: The Government is supporting right now 1,000 fellowships annually. This is being done chiefly by the Public Health agency and the AEC. The aggregate of other fellowships, supported by industry and foundations, and so on, is another 1,000. Industry usually supports specific fellowships in certain fields of interest to them. Thus the total annual number right now is about 2,000. There are, however, almost none in the first year of graduate study. So with our original plan of 2,000 fellowships we are aiming at this group, to see if we can get the best ones to continue with graduate study, rather than leave to enter high-paying jobs. About three-fourths of the planned 2,000 would be first-year students in graduate study.

QUESTION: Dr. Waterman, with your experience in the past, What do you feel is the reaction of industry toward the NSF? Since industrialists do a large amount of work in basic research, I feel it is highly important that NSF get their cooperation and support in making a workable organization for the benefit of industry as well as that of the Nation at large. What is the reaction of industrialists toward such cooperation and what can you expect from them in bringing it about?

DR. WATERMAN: It is true this is an important matter. The attitude of industry is quite encouraging. We have talked to a large number of small and large firms. The small firms are not doing much research except of a very applied nature. The answer seems to be uniformly the same--industrialists are interested as long as the NSF backs really fundamental research. They say, "We need more information to use in development work, more than we can accomplish in our own research laboratories." That is one point. But they don't want to see universities getting into applied research in a major way. They say, "We can do that better than the universities. We have our money in that. There is no reason for the Science Foundation to back fundamental research in the universities."

The second point is, industrialists are interested in more highly trained men. Thus the support of research and graduate education is of great interest to them because then they will have more men and

better trained men in the scientific field. They are, therefore, interested in the Science Foundation on two counts--they are keen to have more basic research information, really fundamental research information, and they want more highly trained men; both of which are quite consistent with the aims of the NSF.

QUESTION: Dr. Waterman, in view of the Government's policy on foreign aid, is there anything within the future plans of the NSF to get into the international field in basic research?

DR. WATERMAN: We have authority to do various things with respect to the international field. We can send scholars abroad to study. We have authority to support research in foreign institutions. Both of these things we would do with extreme care and only on consulting the State Department. It doesn't seem likely at the moment that we would want to support or actually make research grants abroad, certainly not for the time being. So far as supporting the exchange of information, I think we can be really helpful there.

We all know we should be receiving research reports of whatever is going on in other countries. It is not uncommon in research to find a small group, headed by a very capable man, start in some foreign country and do excellent work. Unless we get reports of this we are really handicapped. So we would like to make an effort to canvass what is going on in other countries, and include going as far as we can in getting scientific information from behind the Iron Curtain. It is important to basic research and, as far as possible, we will see that this flow continues. It would be so easy for them to stop this completely. This would be a very serious matter. On the other hand it would be very difficult for us to prevent our flow going there. I think we can help in this matter.

The other thing we can do is to send distinguished scientists to other countries for conferences in different fields. That we want to do when it is of advantage to the man to attend the conference because of his interest and activity in the field and his chance to confer with the best minds in other countries. That, too, we can encourage.

QUESTION: Dr. Waterman, Why were social scientists left out of this organizational picture? I understand that they were.

DR. WATERMAN: That is a long story. The present act indicates that initially there are to be the divisions I mentioned, but it specifies that the Foundation, at its discretion, at any time can extend the scope of science.

The attitude taken by the Board and my staff up to now has been, "Let us not spread ourselves too thin. Let us go after the initial requirements stated in the act and consolidate our position there, and in the meantime consider what we should do with respect to social science." One of the reasons for this is that the Ford Foundation has already entered the field of social science so that any effort in that direction should be well coordinated with it.

At the present time, in the direction of the social science, we are only going so far as to include psychology, geography, and anthropology. From time to time there may be subjects closely allied to the corresponding physical and biological sciences which one could almost call social science and these might be taken up individually. But we will have a further look at this question as time goes on.

We are also planning in 1953 to take account of the need for area specialists and we will pay some attention to scientists who are expecting to work in this field. We are aware of its importance. We will try to contribute on the scientific side to that.

MR. BAUM: Dr. Waterman, I see our time is about up. On behalf of the College, I thank you for a very informative lecture and a most interesting discussion period. Thank you very much.

(6 Dec 1951--650)S/mmg.

CHART 1

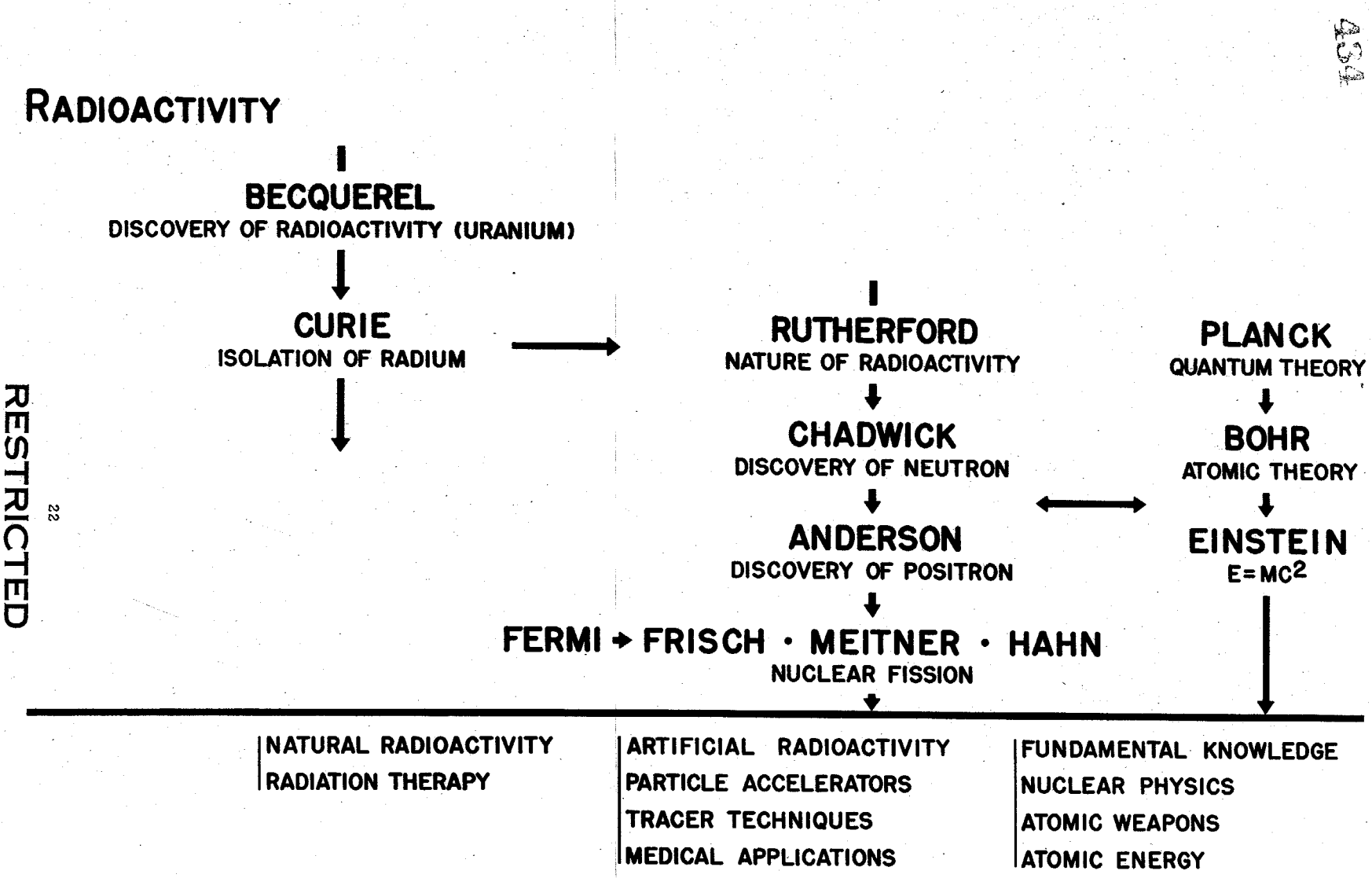

RADIOACTIVITY
BECQUEREL
DISCOVERY OF RADIOACTIVITY (URANIUM)
CURIE
ISOLATION OF RADIUM
RUTHERFORD
NATURE OF RADIOACTIVITY
CHADWICK
DISCOVERY OF NEUTRON
ANDERSON
DISCOVERY OF POSITRON
FERMI → FRISCH · MEITNER · HAHN
NUCLEAR FISSION
PLANCK
QUANTUM THEORY
BOHR
ATOMIC THEORY
EINSTEIN
E=MC2
NATURAL RADIOACTIVITY
RADIATION THERAPY
ARTIFICIAL RADIOACTIVITY
PARTICLE ACCELERATORS
TRACER TECHNIQUES
MEDICAL APPLICATIONS
FUNDAMENTAL KNOWLEDGE
NUCLEAR PHYSICS
ATOMIC WEAPONS
ATOMIC ENERGY

CHART 2

COMMUNICATIONS AND ELECTRONICS

FARADAY
ELECTROMAGNETIC INDUCTION

↓

HENRY
SELF-INDUCTION

↓

MAXWELL
PREDICTION OF RADIO WAVES

↓

HERTZ
PROOF OF RADIO WAVES

↙ ↘

MARCONI
RADIO COMMUNICATION

J. J. THOMSON
ELECTRON IDENTIFIED

O. W. RICHARDSON
PROPERTIES OF ELECTRONS

↘ ↙

DE FOREST
ELECTRON TUBE

ELECTRONICS INDUSTRY

- RADIO COMMUNICATIONS
- AM BROADCASTING
- TELEPHONY
- POWER
- ELECTRONIC CONTROLS
- RADAR
- FM & TV BROADCASTING
- ELECTRONIC COMPUTERS

CHART 3

THE NATIONAL SCIENCE FOUNDATION ACT AUTHORIZES AND DIRECTS THE FOUNDATION TO:

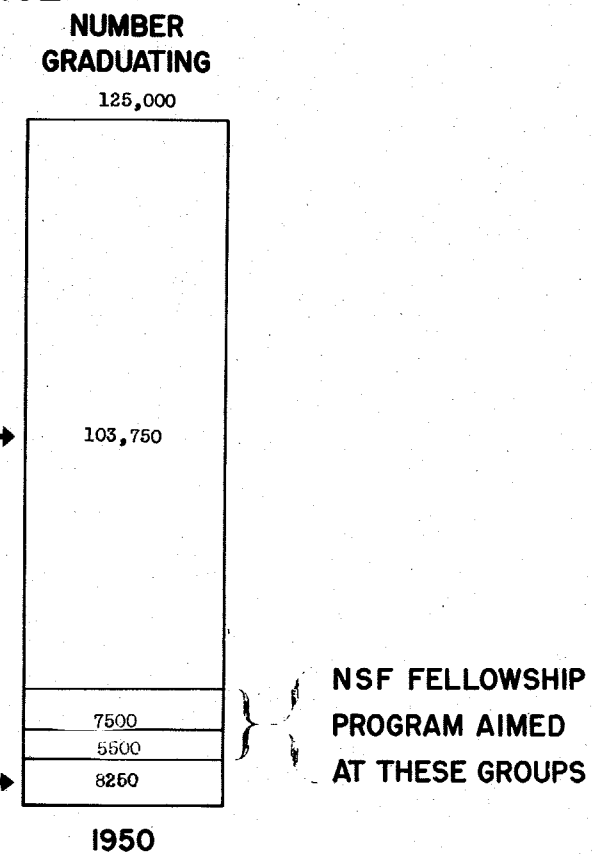
- DEVELOP NATIONAL POLICY FOR BASIC RESEARCH AND EDUCATION IN SCIENCE.
- INITIATE SUPPORT OF BASIC RESEARCH.
- INITIATE SPECIFIC DEFENSE RESEARCH ON REQUEST.
- AWARD SCHOLARSHIPS AND GRADUATE FELLOWSHIPS.
- FOSTER INTERCHANGE OF SCIENTIFIC INFORMATION.
- EVALUATE AND CORRELATE RESEARCH PROGRAMS
- MAINTAIN A NATIONAL SCIENTIFIC REGISTER.
- COOPERATE IN INTERNATIONAL SCIENTIFIC RESEARCH ACTIVITIES.

CHART 4

NEED FOR FELLOWSHIPS

FOR FIRST YEAR GRADUATE STUDENTS IN SCIENCE

- AMONG STUDENTS GRADUATING WITH BACHELOR DEGREES IN SCIENCE
- 83% JUDGED NOT COMPETENT TO EARN Ph.D.
- 17% JUDGED COMPETENT TO EARN Ph.D.
  - 6% DID NOT PLAN TO CONTINUE
  - 4.4% COULD NOT CONTINUE FOR LACK OF FUNDS
  - 6.6% PLANNED TO CONTINUE



* STATISTICS BASED ON DATA IN NRC STUDY