BASIC RESEARCH: A NATIONAL RESOURCE

4 November 1960

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NOTICE

Publication No. L61-68

INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington, D.C.

Alan T. Waterman, Director of the National Science Foundation, was born in Cornwall-on-Hudson, New York, on 4 June 1892. He received his A.B. and Ph.D. degrees from Princeton University in 1913 and 1916 respectively. He holds honorary degrees of Doctor of Science from Tufts College, Northeastern University, University of Akron, and Notre Dame University. He holds honorary degrees of Doctor of Laws from Cornell College, Mount Vernon, Iowa; American University; University of Chattanooga; University of Michigan, University of Cincinnati; and the University of California. During World War I, Dr. Waterman rose to the rank of 1st lieutenant and served with the Office of Scientific Research and Development during World War II. He has been awarded the Medal for Merit, the Captain Robert Dexter Conrad Award, the Princeton Class Memorial Cup, and the National Academy of Sciences' Public Welfare Medal in recognition of his public and scientific contributions. Dr. Waterman is active in numerous scientific organizations and societies, as well as serving on several national scientific organizations, including the President's Science Advisory Committee, as a member or consultant. This is Dr. Waterman's seventh lecture at the Industrial College.

BASIC RESEARCH: A NATIONAL RESOURCE

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GENERAL MUNDY: In our study of the relationship of resources to national security, I feel that it is essential that we examine our position in the all-important area of basic research. Our leadership in the world today is dependent, among other things, upon the stature of our scientific effort, as you know; and it certainly is evident that we've got to look far beyond our present scientific horizons if we are going to maintain that leadership.

This national scientific research effort is a very large and a very complex thing, and it is nebulous. In order to enhance our appreciation of basic research as a national resource, the College has secured for you today Dr. Alan T. Waterman, who is the Director of the National Science Foundation.

As the head of this national research agency, Dr. Waterman occupies a very unique and a most important post, and he plays a very vital role in our preparedness posture.

This is his seventh appearance on the College platform as a lecturer, and he has always shown an active interest in the College.

Dr. Waterman, it is a pleasure to welcome you back to the College for this very important lecture.

Gentlemen, I am sure you will enjoy it. Dr. Waterman.

DR. WATERMAN: General Mundy, Members of the Industrial College: This annual visit of mine seems to be becoming a tradition of which I am very proud. It started years ago, when I was Chief Scientist in the Office of Naval Research, a position I held before joining the National Science Foundation; and over the years I have been asked to address myself to the subject of basic research, one of the primary jobs of the National Science Foundation in relation to national defense and to the general welfare as well. So my title will be "Basic Research: A National Resource."

I am very happy to greet you again this year and to express my appreciation of the invitation to talk before you.

I note that this year the lecture on basic research has been transferred to the Resources Unit, which seems to be a very appropriate category. This is reflected in the title of the talk as I have it, and is also the title of the National Science Foundation Study which appeared in 1957 before the launching of the Sputnik. This subject is also--and I am sure you know this for reference purposes--covered in a report by the President's Science Advisory Committee in 1958, "Strengthening American Science."

There is no question that basic research is a national resource of major importance, and the problem that confronts us at the present time is to see that this fact is widely understood and appreciated. The decade and one-half which has elapsed since I first lectured here has witnessed enormous growth in the total research and development effort of the country, and especially in the degree of participation by the Federal Government.

The survey program that we have in the Foundation and are expected to conduct, in a comparison of the year 1953-54 with the year 1957-58, indicates that between these years research and development funds approximately doubled, going from $5.2 billion to $10 billion. This is nationwide. Basic research funds rose from about $430 million to more than $830 million, an increase of 93 percent. Preliminary estimates for 1959-60 indicate an R. & D. total of $12 billion for the country, and, by extrapolation, a basic research total of about $1 billion.

Throughout the last few years basic research has represented about 8 percent of the estimated total R. & D. funds. Foundation studies have grouped the principal organizations engaged in research and development by four sectors: the Federal Government, industry, colleges and universities, and other nonprofit institutions. "Other nonprofit institutions" include the Federal contract research centers, like the national laboratories of the AEC, which are administered by independent organizations.

There are important differences between the four sectors as sources of funds and as performers of research and development.

Thus, while the Federal Government is the source of more than half of all the basic research funds, it performs only about 13 percent of the total in its own laboratories. This is a very important contribution, incidentally. Colleges and universities, which provide only 13 percent of the total in funds, perform 47 percent. The ratio in industry is closer--30 and 33 percent, respectively--but the latter figure should be noted with caution, because there is a little difficulty in the problem of definition. Much of what industry calls basic research--or some industries in particular--is not basic in the same sense that the universities define basic research.

Industry reports that about 4 percent of the funds expended in its performance of research and development are for basic research, while in the Federal Government, estimated funds for this purpose for the fiscal years 1959 and 1960 represent, as I said, about 8 percent of the total funds for conduct of R. & D.

It is this relative apportionment of effort as between basic research and research and development that concerns us rather more than the total amount of funds available. It is important to have this balance justifiable and effective.

Although industry as a whole reports about 4 percent of its funds expended in the performance of research and development for basic research, it is significant that in industries with a high rate of growth basic research expenditures are much higher. For example: 18 percent goes for primary metals, 17 percent for drugs and medicine, 18 percent for petroleum, and 12 percent for industrial chemicals.

Let's stop for a moment to define terms. This is important, for there is a great deal of misconception at this point.

The term "research and development" is now generally used to describe the process which begins, as you know, with basic research and extends through applied research, development, engineering, test, and evaluation. The most troublesome phase to define is the first--basic research--and, indeed, no short definition has been found which has not been criticized in some quarters. Administrative people would especially welcome a definition which they can use automatically, almost, when they see a title. But this is practically impossible to do, really.

For purposes of our surveys we in the National Science Foundation have defined basic research as research in which "the primary aim of the investigator is a fuller knowledge or understanding of the subject under study rather than the practical application thereof." This has stood the test of time fairly well. It has to be understood clearly, but it really gets at the heart of the matter, for the reason that, in order to do well in the long range by our efforts in technology or in research and development, we must provide the "seed corn," which is the progress of science that underlies all these things. That is why this is a very important thing to achieve.

Historically, progress in science has been made, and continues to be made, primarily by people who have this attitude--that they are just curious and they want to find out what a particular phenomenon is, or to discover a new one perhaps by accident. These things cannot be achieved by anticipating them. As a first-class example: How could one try to discover X-rays when one never had any idea that such things existed? New things come out of this attitude, this spirit, of quest in research; and it is in this way that the most revolutionary discoveries are made, which can start whole industries.

There is a question, though, as to whether a practical-minded agency, with a definite mission to achieve, should indulge in this kind of research. The best justification I know for this kind of research for defense purposes was given, in fact, by the Department of Defense several years ago, by a Committee on Basic Research, headed by Warren Weaver, who stated the matter thus:

"It is essential to recognize that there are two aspects of basic research, depending upon who is viewing it.

"From the point of view of the research worker himself basic research is research motivated by curiosity and interest, carried out because it promises to add to knowledge, and without any necessary interest in or concern for the practical applicability of any results that may be obtained.

"Nevertheless it is most strikingly and emphatically true that basic research is not impractical research. The whole history of science constitutes a most impressive proof of this statement. And a research administrator, informed as to the history of research and aware of the interrelationships between various fields of science and various fields of application, can concerning a given body of basic research activity, reasonably make judgments concerning probable practicality, these being judgments which may be quite foreign, if not meaningless, to the individuals actually doing the research.

"Thus it is quite obvious if one is interested in, say, the development of new materials which will maintain strength at high temperatures, that there are certain areas of pure research which have probable relevance to such problems, and other areas which are clearly unlikely to yield results useful for this purpose.

"Thus, without in any way abandoning or contradicting the concept of basic research as viewed by the researcher, the research administrator can discriminate between various areas of basic research, and can sensibly judge that certain of these general areas have a high probability of producing results useful for given purposes, while others have a very low probability. In other words, having a field of application in mind, it is meaningful and sensible for a research administrator, without in any way influencing the creative atmosphere within which the researcher himself operates, to judge that certain areas of basic research have, with high probability, relevance to his practical interests."

It was on this basis that Executive Order 10521 justified basic research for Federal agencies as follows:

"The conduct and support by other Federal agencies of basic research in areas which are closely related to their missions is recognized as important and desirable, especially in response to current national needs, and shall continue."

Our present failure as a Nation to support and encourage basic research at a level commensurate with its importance to the national interests stems principally from lack of public understanding of the very nature of basic research. The public tends to confuse science with technology, as you know. Technology is defined in Webster's New International as "systematic knowledge of the industrial arts," or "any practical art utilizing scientific knowledge." The products of technology that are so numerous and spectacular--miracle drugs, jet planes, color television, and so on--are looked upon as the fruits of science. The public has no clear idea of basic research in general nor of its importance as undergirding the entire technology.

To be sure, there is usually found the vague awareness that there are professors at universities who are doing so-called theoretical work which is somehow related to scientific progress. There is the optimistic belief, one finds, that these people will go on working in their laboratories, and that the public, by some unknown means, will eventually benefit by whatever contributions they may be fortunate enough to make.

As a consequence, however, this kind of research inevitably suffers when it comes into competition with urgently needed developments for which the need is obvious. The point that is missed is that basic research is the ultimate source of important developments and must receive its full measure of support. The technical industries have come to understand this very well, of course.

It is my firm opinion that the future of our Nation may well depend upon the degree of effort we can put into this elusive basic research. There are many reasons why this is so, but essentially they boil down to two: Basic research is essential for progress in science, which obviously sets the pace for technology; and, second, it is through basic research that scientists and engineers receive their training. The quality of the training and the extent of the training will depend upon the effectiveness with which this process is carried on. The principal burden is thus primarily in the universities, but not entirely.

In the effort to enlist adequate support of the backing for basic research, we in the Government have been obliged to justify the expenditures of necessary funds for this purpose on the grounds of the ultimate applications to be derived from such research. Let me say at the outset, therefore, that, although all of these reasons are valid and important, and we must do basic research in certain areas because of the practical need, basic research has also proved to be important as an intellectual activity that increases man's knowledge of himself and his environment. This has had a subtle but very important effect over the centuries.

Although our strength as a nation is dependent upon a number of material factors, it is also dependent in a very real sense upon the strength and stability of our overall culture. This is one of the advantages we have over the countries behind the Iron Curtain. The strength of our culture in turn depends upon all the disciplines of learning, the natural sciences, the social sciences, the humanities, and the arts.

With this as a premise, let me turn now to the more practical aspects of this matter. The technological revolution, which dates back some 30 or 40 years, is much more closely linked to the progress in science than was the industrial revolution that preceded it. That was a period of adventure. Basic research has become the generative force in what the late Sumner Schlichter called the industry of discovery. Our rate of economic growth and progress is specifically related to the amount and quality of basic research being carried on in the Nation's universities, and in Government and industrial laboratories.

In our time, science and technology have become overwhelmingly important for national defense. Moreover, the new forces now available to us raise questions about the ability of civilization, or indeed of man himself, to survive if these forces are fully unleashed. When you consider the dangers inherent in such activities as the testing of nuclear weapons or the possibility of unacceptable fallout, even the unrestricted preparations for warfare become formidable--to say nothing of war itself.

Furthermore, as man exhausts his capacity to feed, shelter, and protect himself with the natural resources at hand, he must increasingly turn to science to help him meet these fundamental needs. That is the stage we have explicitly reached now, of course. He looks to science for ways to increase the productivity of the soil, to add to the nutritive value of existing foods, both plant and animal, and for synthetic substances to supplement the natural ones. He also turns to science for new sources of energy, in anticipation of the day when fossil fuels approach depletion. And, of course, as your previous speaker undoubtedly has mentioned, science helps man in the whole area of improving his health, increasing his longevity, and his resistance to disease.

Somewhat akin to this major problem is the problem now confronting new nations and underdeveloped areas where the people exist on very low substandards of living. These people must have help in developing their economies, in providing education, and in acquiring the capacity to benefit by the technological revolution. Although we have been extending this kind of help in many areas of the world, the Communist nations are also ready to step in with aid, and are doing so, of course, on a big scale; so that the leadership that we are able to exert in this area may determine the balance between ourselves and the Communists among the uncommitted nations of the world.

The great problem here is time, as it so often is these days. These underdeveloped countries are impatient. They see the things that can be done, and they want them tomorrow. This is impossible to achieve, and so the great problem becomes the unrest and worse that come out of their efforts to do these things quickly. That's where they need help and a hand that can assist them in maintaining their equilibrium while they are on their way.

The competition between the United States and the U.S.S.R. extends all along the economic front and into technology and pure science. Since the launching of Sputnik we have been indulging in soul-searching comparisons of the educational systems, the economic growth, and the achievements in science and technology. In recent weeks these introspective activities have been blown up into an unfortunate issue of the presidential campaign, as you know, with charges and countercharges about the image of the United States abroad. I don't want to dwell upon this instance. It seems to me to be a good deal of a tempest in a teapot. It has been magnified out of all proportion.

Here again, in the public concern over this whole matter, we have a good example--and this is significant--of the confusion of science with technology in the public mind. So far as technology is concerned--and I should like to speak about the facts here, because the public is continually asking questions--from what they get in the press they don't seem to understand the facts yet--I submit that there can be no question that the United States is preeminent. We have more experience, more facilities, larger industries, and more capable people; and especially we have more know-how than any country in the world--the Soviet Union not excepted. We have suffered by comparison with the Soviets in those areas where, (a) the Soviets have concentrated attention with their characteristic singleness of purpose, and, (b) where we have delayed decisions or have put forth an inadequate effort.

Our disadvantages are inherent, of course, in our democratic system, and are easy to discern. Before undertaking a particularly important development, we typically give the subject thorough study. This is followed by review and evaluation of the study. We then draw up a budget and go through the lengthy customary procedure of justifying the program and securing the funds. In principle we finally have as a result a fully developed and sound plan with adequate financing, staffing, and so on. In practice we are apt to fall short of this ideal, particularly in the matter of adequate financing. I think it can be generally agreed that only really top-priority developments would be regarded by people who understand the situation as anywhere nearly adequately financed. In these the problem becomes one of overall coordination, management, and staffing. Those with lower priority are almost inevitably inadequately financed in some way. This is a real puzzle to solve.

The Soviet Government, being untroubled by the intricacies of the democratic process, can, of course, make decisions much more quickly as to which developments should be undertaken, and can assign all the money, manpower, and materials needed for their rapid completion.

It is not surprising, then, that in certain specific fields they are offering us serious competition. This is one reason why they were able to develop rockets with sufficient thrust to lift several tons of payload. Of course, the other is, we decided not to do that particular kind of development. The sizes of their rockets, and the novelty of features such as the moon probe and placing dogs in orbit and recovering them are things that capture the imagination of the world.

Reference is seldom made to the fact that of the 33 satellites placed in orbit, 27 were put there by the United States. The United States has 14 earth satellites and 2 solar satellites in orbit at the present time, and 9 of these satellites are transmitting data. The U.S.S.R. has one earth satellite and one solar satellite in orbit, neither of which is transmitting data. Although smaller in size than the Russian Sputnik, American satellites have much more sophisticated instrumentation and have been used to acquire large quantities of valuable scientific data. They go after specific information about specific scientific problems, and get it.

The discovery of the Van Allen radiation belt, for example, is perhaps the single most important discovery resulting from the International Geophysical Year. Another brilliant piece of work, which has had very little publicity, for understandable reasons, is Project Argus, which you remember was the planting in outer space of a layer of electrified particles that interfered with radio communications and provided reflections. It was analyzed by probes sent out for the purpose, and was also detected by satellites passing through it. That was a major achievement. It demonstrated that a layer of electrified particles could be deliberately placed outside the earth which could create major effects on communications systems and react in other ways.

So far as progress in science is concerned, the conclusions resulting from visits, conferences, and discussions between Soviet scientists and ours is that, generally speaking, we are second to none in our research findings and accomplishments. In certain fields, such as theoretical physics, and some branches of mathematics and astronomy, our scientists admit that the Russians are highly competent, in fact, on a par with our own in knowledge of the subject and in their thinking. Moreover, in these fields particularly, the Soviets are training numbers of highly competent younger scientists, and the general impression is that it will take a determined effort on our part to continue to produce results more important than theirs.

In biology the Russians are years behind us in techniques and research progress. Our agricultural research is superior, and so is our medical research. However, there are certain fields that have been relatively neglected in the United States, notably oceanography and economic geology, where their coverage is superior by virtue of more facilities and coordinated planning. We are now in the process of repairing our deficiencies in these fields.

In the computer field the Soviet Union is placing great emphasis on the theory and use of modern computing machines in overall planning for the interaction of technology with economic progress. Our computers and computer techniques are superior, but we have put relatively less effort into the imaginative long-range application of computer techniques than has the Soviet Union, according to the account of our people.

In fact, speaking generally, I feel that it is the long-range aspect of the whole matter that should clearly concern us, rather than where we stand now. We are in good shape now. Our preeminence in both scientific and technological fields can scarcely be challenged by those who take the trouble to inform themselves of facts. What should really concern us is Russian capabilities for the future and where these are likely to lead the Soviets 10 years from now. All the information that we have points up the fact that they will undoubtedly continue to assign high priority to scientific and technological progress, and there seems no question that occasionally in certain fields they will come out with really valuable results. When they do, they will stimulate us out of the complacency into which we might otherwise sink.

At the present time, however, as a result of the drop in the wartime birth rate in the Soviet Union, the Soviets are experiencing deficits in the age group of about 15 to 20, and they have been obliged to take somewhat drastic measures to meet the manpower needs in all fields. Under the educational reforms recently introduced, for example, all but the most exceptional students must now combine their school work with useful and productive labor, thus becoming part-time students. At the same time, the Russians are engaging in a variety of experimental programs to reduce, if possible, the age at which persons may be fully trained for creative work in a given field.

It is trends of this type that we must watch. The establishment of the new Siberian branch of the U.S.S.R. Academy of Sciences, the so-called Science City, in Novosibirsk, is a major development. This is a recent development and we are only now beginning to receive some information about it. It was established in 1957 and has as its purpose the development of productive forces in West Siberia, East Siberia, and the Far East. The new scientific center will consist of a complex of institutes, principally in the physical, mathematical, and technological specialities. Some idea of the size and scope of the undertaking can be gleaned from the fact that in 1958 the investment in this project was expected to exceed 1 million rubles a day.

We should keep abreast of what the Russians are doing now in science, and especially we should be alert on what they plan to do in the future. But certainly we should not set our sights by their achievements. In science and technology the nation or the individual that initiates and carries forward an idea has an enormous advantage. We must therefore be strong in all fields and ready to take advantage of every promising breakthrough. We should certainly not concentrate our efforts entirely upon those areas where the Russians have already made significant advances. This is losing an important asset that we have.

This point was so ably made by Professor Charles Frankel, of Columbia University, in a recent "New York Times Magazine" article that I should like to quote from it:

"The mention of science and basic research brings us to the dangers implicit in the assumption that the be-all and end-all of every effort we make is beating the Russians.

"For, unless basic principles are clearly defined, and unless careful safeguards are maintained, the use of science as an instrument of national competition can deform the scientific enterprise itself, undermining its integrity, and in the end cutting down its efficiency as well.

"If scientific research is construed as a race, if every discovery is measured for its potential propagandistic value, then there will be a temptation to inflate modest results, to claim more than the evidence in hand justifies, and, in general, to mix science with psychological warfare.

"Moreover, the public pressure for results can lead to the over-organization of science. One of the most popular, and one of the most ruinous, assumptions about science is that it normally achieves its practical results by aiming directly at them. Much more often than not, significant advances in science have been made precisely when men have had the sense of disengagement from urgent pressures that had allowed them to ruminate, to roam around, and to work on problems in which no practical man was interested.

"The view that reduces science simply to an instrument of national power obscures its significance as a discipline of the human mind and as an agency for advancing the well-being of humanity. And there is likely to be a pragmatic penalty for forgetting the moral meaning of science: even its power to attain practical results will be materially reduced."

If we make the needed effort to be strong in science and technology, the recovery of our prestige abroad will follow automatically. Personally I feel very strongly that our prestige has suffered from the widespread attention being given it by the press and by our apparent anxiety with respect to our reputation.

As one newspaper correspondent observed earlier this week: "Despite the overwhelming agreement that there has been a drop in the prestige of the United States around the world, the survey disclosed evidence of deep confidence that this country could, if it tried, move ahead rapidly and reassert its position in all spheres."1/

One Scandinavian diplomat said he thought Americans were far too worried about what other people thought of them. "Why don't you just get on with the job?" he asked.

There is much point to that remark. If we want our image abroad to improve, our first effort should be to provide the reality of the image at home. As far as science is concerned, this means providing adequate support for science and education in science.

In making the plea for the support of basic research, I am often asked, "What constitutes adequate support?" It's always hard to answer such a question quantitatively. Full support would be justified if it provided all competent researchers with what they need. Is that what we mean by adequate? If we are in a real emergency, the answer should be "Yes." It is estimated that Federal support for scientific research is provided to something less than 50 percent of the competent investigators who apply for aid. By a margin of something of this order, then, our progress in science is failing to keep pace with our capabilities.

In all this discussion emphasizing basic research, I don't want to imply that applied research and development are not important. Of course they are. Applied research is terribly important. It has many of the problems of basic research; it needs very highly competent people, and it must be encouraged. The point is simply this: When budgets are held to a certain restricted level, the problems that are regarded as important are practical problems in general, because they

1/ William Jorden, The New York Times, 31 Oct 1960, p. 23.

can be seen clearly and something has to be done about them. But basic research does not have this tangible return, and therefore it is likely to be cut. This happens year after year, to the ultimate detriment of the effort.

A factor that looms large in support of research is the increasing size, complexity, and cost of facilities needed for basic research. The Government has been obliged to provide funds, in whole or in part, for such things as nuclear reactors, high-energy particle accelerators, radio telescopes, electronic computers, and oceanographic research vessels, because their costs cannot possibly be met by a single university or even by a group of universities.

A truly modern high-energy accelerator, for example, is expected to cost in the neighborhood of $100 million over a period of years. The university reactor built at MIT cost approximately $2.5 million. The Foundation has allocated funds to date in the amount of $12.8 million for the radio astronomy observatory in West Virginia; and about $10 million for an optical astronomy observatory in Arizona.

Figures of this magnitude pose a serious problem in planning expenditures for science. Progress in certain highly specialized fields requires the use of capital facilities that are far more expensive than those required for general-run basic research, which are usually modestly priced. Must we, for economic reasons, deny or postpone the construction of these expensive research tools? To do so is possibly to prevent the making of highly significant discoveries in basic science, or to allow other countries to do so first. This question is always complicated by our inability to predict what such significant scientific advances may be.

It may well be asked also: Will not full support of all competent scientific research lead to an impossible economic situation, since obviously we don't have funds, manpower, or facilities to carry on all the promising ideas generated by the scientists? It is true, of course, that the security of the country depends not only upon its progress in science and technology but upon many other factors, chief of which are the strength of its economy and the strength of its defenses. The latter in turn depends upon many factors, including the proper balance among these activities. Are we then in a dilemma? If we make the maximum effort in research and development, do we weaken our economy, and therefore our security? On the other hand, if we withhold adequate support to research and development, do we jeopardize our security by failing to maintain technological supremacy? This is a real question.

The answer I believe is clear. We should encourage and support the progress of science to the limits of the capabilities of our scientists and engineers. By so doing we make available to ourselves the full potentialities of all new discoveries in science. We should then give very careful consideration to which of these potentialities we should lend emphasis and support for development and ultimate production.

To support basic research in general requires relatively modest amounts of money, except for capital facilities. It is in the stages of technology--applied research, development, and production--that the large costs occur. Therefore, we are not jeopardizing the national economy if we provide full support for the advances in science and at the same time discriminate very carefully in choosing the things into which to put our large capital.

In fact, I should go further and declare emphatically that, unless basic research is adequately supported, we are certain to miss opportunities for development and application that may mean all the difference between success or failure in the race before us, whether for war or for peace.

The rapid growth of the role of the Federal Government in the support of current research and development has created the need for appropriate organizational machinery within the Government itself. This need has been recognized and implemented in a variety of ways. At the highest level, the Special Assistant to the President for Science and Technology, now Dr. George Kistiakowsky, with the assistance of the President's Science Advisory Committee, is ready to make available to the President at all times advice and counsel on the wide range of scientific and technical affairs that influence executive decisions and national policy.

The President's Science Advisory Committee, whose membership consists of non-Government scientists and engineers, considers important scientific and technical matters in relation to Government policy with special reference to national security. It has issued a number of significant and influential reports: "Strengthening American Science," "Education for the Age of Science," "Improving the Availability of Scientific and Technical Information in the United States," "Introduction to Outer Space," and "A Proposed Federal Program in Support of High Energy Accelerator Physics."

Those of you who are interested in pursuing the subject further no doubt know of these and will find them of interest.

Although some 24 Federal agencies participate in the Government's R. & D. effort, 9 of these account for 99 percent of the total obligations. These nine are the Department of Defense, the Atomic Energy Commission, National Aeronautics and Space Agency, Department of Health, Education, and Welfare, Department of Agriculture, Department of the Interior, National Science Foundation, Federal Aviation Agency, and the Department of Commerce.

The National Science Foundation (with its 24-member National Science Board, composed of persons distinguished in science, education, and public affairs, and appointed by the President) has the primary responsibility of dealing with policy concerning Federal support of basic research throughout the country.

The Federal Council for Science and Technology, established by Executive order of 13 March 1959, deliberates on matters of policy coordination and future planning among Federal agencies, and in these affairs makes recommendations to the President.

Under our democratic system, however, no level of government, Federal, State, or local, can succeed in securing necessary action programs or funds to carry them out unless our citizens understand and actively endorse, and, indeed, participate in the steps that need to be taken. In short, the wholehearted cooperation of the people of the country is necessary to achieve whatever goals are agreed upon.

Most important is the realization that this is not an ephemeral emergency but a continuing and, quite possibly, a permanent one. We are, after all, in a competitive world in which there can be no relaxation in our determination to compete successfully and continuously.

The responsibility of the Federal Government, as I see it, is to insure that the problem is entirely understood by the people, to provide direct support according to carefully devised plans, and to consider seriously ways and means of increasing substantially funds from other sources, when this can help.

The responsibility of the people is first to give these problems their careful attention, and second to determine, as their Government has to do, the degree to which they can contribute by thought, action, and money to our national goals, as well as to the satisfaction of their personal desires and needs.

In other words, each citizen should be fully and continuously aware of his active responsibility to the Nation and to its primary goals in time of peace as well as in time of war, and be prepared to make the necessary sacrifices, if called upon, in order to achieve them.

To realize our objectives as a nation, to defend our country, to achieve and maintain world leadership, to extend a helping hand to underdeveloped nations, or merely to maintain our peace and prosperity at home, the first essential is a real determination to achieve better education, better efficiency, better science and technology, and, above all, the development of quality--quality in training and quality in performance. Unless we can succeed in accomplishing these things, we can attain neither our national objectives nor the personal objectives of our people.

Thank you very much.

COLONEL MORGAN: Gentlemen, Dr. Waterman is ready for your questions.

QUESTION: How successful was the IGY? What factors may have limited its success? And how soon can we have another one?

DR. WATERMAN: The success of the IGY, in the opinion of the scientists who conducted it, and in the opinion of most of the countries officially, was that it was an astonishing success. The reason is that it was practically free from politics and disagreements between countries. The scientists are proud of the fact that they handled it. The government supported it in each country, but the scientists carried it out. There were all sorts of examples of cooperation, as there were in the Antarctic, where there really was an exchange of information.

On the whole it was a remarkable effort. We learned far more about geophysics--the earth and the space outside the earth--than we had known before; and we acquired material for research for many years to come which will undoubtedly have its most important effect in strengthening fundamental knowledge in a number of fields.

As to its weaknesses, some countries had difficulty in carrying out their work as completely as they would have liked, largely for financial reasons. This was no fault of theirs, and I don't think it was serious. Really, the only instance I can think of in which the IGY was not successful was the failure of the Russians to give us certain types of information. For example, they wouldn't tell us anything about their rocket programs or their satellite plans. And even yet they don't give us raw information about research findings by these rocket and satellite probes. They give us the results after analysis and after they have been put into a form that can be published. No scientist is happy with that. It is not a sound method, because they may have made some mistakes in the analysis. They may claim things that are not so. In science you always have to go back to the primary results before you can be sure of what the other fellow does. If this were not true, science could not make the sound progress it does. I think this was perhaps the outstanding weakness of the IGY.

As to whether we should have another right away, most scientists would say no. We are carrying on in certain fields that have emerged as continuing fields of interest. Meteorology has always been one. Certainly there is great interest in the subject of oceanography. The International Council of Scientific Unions has created, as you perhaps know, a scientific committee on oceanic research. This committee is formulating plans for the nations to cooperate in oceanographic research. The United States has agreed to participate in a special survey of the Indian Ocean, which scientifically is very interesting. From the standpoint of oceanography very little is known about it. It is a matter of great interest to our Navy, for example.

Attempts are being made to have worldwide programs in space research; but that, for obvious reasons, runs into difficulties. We have laid a plan before the U.N. in this connection. Ultimately, certainly, something has got to be agreed to. If we have freedom of the seas, ostensibly, there seems no logical reason why outer space shouldn't be subject to the same kind of rules. It's going to be difficult to get together on that one.

One of the most notable achievements of this country as a result of the IGY was the promotion and the final acceptance, which seems to be going through now, of the Antarctic Treaty, which designates Antarctica as a region where the countries will cooperate in scientific research and in excluding military operations from the area. This is a real achievement, and it is going forward.

Aside from these special fields which come up, the idea of doing the whole thing goes back to the original conception of the IGY, which started with an International Polar Year back in 1883. At that time, about four or five countries got together and learned a little about the Arctic for the first time. Fifty years later, in 1932-33, they had another Polar Year, in which 11 or 12 countries were involved. Then, just three or four years before the IGY, a few scientists from abroad were meeting out in Silver Spring with Lloyd Berkner and some others. The question was raised, "When are we going to have another Polar Year?" Someone said, "Let's make it an International Geophysical Year." Then someone else remarked: "Why wait 50 years? We've got lots of new techniques. We've got lots more scientists now. Why not make it 25 years?" That was the origin of the IGY.

The 1957-58 period was chosen because of major solar activity. The general feeling is that we shouldn't try the whole job again in a shorter interval than 25 years. But where the fields are important they are being continued.

QUESTION: Dr. Waterman, you mentioned that there are some 24 Federal agencies engaged in research and development. I would imagine that each of those 24 is doing a certain amount of what you call basic research. I suppose that they have to compete for the development projects and production and getting funds. I wonder if you or the National Science Board have any thoughts or policy formulation on whether or not these particular activities of basic research should not be put under one umbrella, so that they might have a better chance of getting their fair share of funds.

DR. WATERMAN: That's a good question and it has been asked a number of times. I think the short answer is that they wouldn't get as much money as they are getting now. If you put basic research in one pocket, say the National Science Foundation, we would not get as much money as is presently made available for basic research when it is divided among the different agencies. Probably the reason is this: When a given agency, let's say the Atomic Energy Commission, for example, or one of the Departments of Defense--Army, Navy, or Air Force--goes out for basic research, it can make a very strong case for that research, because it underlies things that everybody knows have to be done. They can say that they have to have a better background and better information in order to plan development and let our engineers have the modern data and ideas that come out of science. This is a very convincing argument, you see.

Most of the research and development agencies that have practical missions make a strong case for the basic research in that area. We in the Foundation have no such practical mission. We just support it for the sake of science. That's a very elusive method. It's a very important one, because it enables one to make this investment in research in a comprehensive way, and you don't know where you are going to get returns, except statistically, and then you know they will be good. But this is a weak argument compared to the backing of research for a particular mission, and that is why I think we gain more under the present system.

I have had direct experience with Navy, for example. I do know the value of basic research to an agency like that, which is concerned with defense matters. In planning the feasibility of development, if you have the last word in the state of the art, and the knowledge of science underlying the development that you plan, you can state much more accurately whether or not it is feasible. You can also pick out the high spots where progress is being made and possibly spot some new development to consider for the first time. These are things that matter very much to the mission of the agency. I for one am all for it.

QUESTION: To what degree, Dr. Waterman, might it be assumed that the Russian advances in basic science might be harmed by their ideology and the fact that they have control over most everything? Will this harm them in the long run in their building and missions?

DR. WATERMAN: It has the possibility of doing great harm. Whether it actually does or not depends on how they go at it. For example, the political appointment of Lysenko as head of the biological research in Russia was a terrible mistake. It set their biology back years, because his principles were unsound; and this really hurt them.

In other fields two things are happening in Russia right now, and they are things that have to be watched. One is that they are backing science in the fields that underlie the technology that they need, just as we do. The other is that in most fields of science they do not interfere as they did in biology. They do give the scientists free rein, which is not so well known. They give them high prestige, high salaries, and freedom to do as they wish in fields that don't matter directly to defense. As long as they hold to that philosophy, if they can, they have the same kind of advantage we have.

But there are curious little things about this. For example, we are doing a lot of work now in translating science out of Russian for the benefit of our people here, and we see the most amusing things. A very distinguished Russian scientist will have a regular series of papers coming out on research. On about every fifth or sixth paper he will string in a paragraph about the importance of communism, right in the middle of the paper. Apparently he has to do this or he doesn't maintain his job.

There's the trouble, you see. A man who doesn't do this may be put out of a job, and they lose a good man. Things like that are insidious. But if they keep hands off, they are to be reckoned with.

QUESTION: Dr. Waterman, you mentioned that the Russians are ahead of us in research in oceanography. I wonder if you would comment on their advances.

DR. WATERMAN: Yes. I think, as I put it, that they are better organized and have better facilities for oceanography than we have. They do not have better oceanographers. Our people have been handicapped by the lack of funds and equipment. The Russians have something of the order of a dozen ships for oceanography, and one of them visited this country. They are very well equipped for oceanographic research.

We've made do with vessels that are 25 or 30 years old and have tried to keep them in repair, and we've adapted a few Navy tugs for the purpose. Only now are we building really modern oceanographic vessels. The Navy is building at least one. We have one under construction now, and we will have another one next year. Our shore-based facilities associated with these vessels need jacking up, too.

The quality of the work done by our people is good. There is no question about their ability in their field. It's really the facilities that we have given them to work with that are at fault. If you don't have facilities to explore the oceans, then you don't have data, and you can't do research. The Russians are doing that.

QUESTION: Doctor, would you care to comment on the effect of military security on research and development?

DR. WATERMAN: Well, this is a subject you have all no doubt discussed many times. I have been involved in it many times, too.

Of course, if you are talking about research and development in general, and development projects in particular, there is no question about the need for security. In applied research, when you are getting an idea and you are trying to see whether it is feasible or not, it has to be watched for security reasons, in just the way that an industrial company keeps such things under wraps in order to maintain trade secrecy. It's a similar kind of thing, but of course it is much more important in national security.

When it comes to science and basic research, the way I would put it is this: Generally speaking, the discoveries in basic research are not made by one nation 25 years before the others get it. The scientists in the world have pretty good communication, by and large. They see each other's reports and they talk to each other. So the state of the art, we might say, in basic research is very nearly simultaneous in the advanced countries, such as the UK, Germany, and Russia. So there isn't very much chance that you can steal a march on someone else and get away with it for very long.

Besides, in this matter of science, the communication of scientific results is a great asset toward progress. When a man makes a discovery, if he can talk to all the people in that same field, they are stimulated to confirm what he does, they get ideas for expanding his work, and he himself benefits and makes greater progress. So there is a mass effect which means that if you have good communication, you make much more rapid progress.

I am sure you have all seen this in highly secure projects, where it is difficult to make progress, because you can't bring in enough of the right people. So again in basic research you have an enormous advantage if you can have free communication. It strengthens the whole effort and increases its pace. It may be, and I am inclined to think so, that in science and especially in basic research your best asset is keeping ahead and never mind trying to keep it under wraps unless it gets into application. It is far more important to put all your effort into trying to make progress and keeping ahead of the other fellow.

I will say that there are some points that are troublesome here. I would agree that certain matters that are very critical to a development would undoubtedly need to be kept secure, but I would hope that this would be done for a limited time only.

At the time that Germany overran France there was a somewhat analogous situation. All the countries had very elaborate methods for projecting orders in such a way that the enemy wouldn't get them, of course--the old system. But, as I understand it, when Germany started overrunning France, she didn't bother about the security system and put orders right out in the open when she went into action. The time advantage of getting these things understood quickly made a great difference.

It's a little the same kind of thing with this basic research. If you can keep ahead of the other fellow, then you've got the advantage, and if you try to withhold the information you may not stay ahead. It's a troublesome question.

QUESTION: Dr. Waterman, the Soviet Navy maintains perhaps the largest submarine fleet the world has ever known. Do you have an opinion, sir, as to the relation of their oceanographic research to the operation of this submarine fleet?

DR. WATERMAN: It's very important. There is just no question about it.

STUDENT: In what areas, sir, would you say that their research is being assisted?

DR. WATERMAN: In oceanography?

STUDENT: Yes, sir. The research in oceanography.

DR. WATERMAN: Oh, in an enormous number of ways. I am sure that if there are submariners present they can back me up on this. I used to know a good many.

In the first place, you have the contour of the ocean floor, which is just like the land. It goes down to depths corresponding to the height of Mount Everest, or more, and it has mountain ridges and valleys and plateaus. In order to navigate nowadays, one needs to know these very precisely, for all sorts of reasons: to avoid running into trouble, to know places where you can hide, or where someone else may be lurking. Just the navigation is an important problem, but the importance of oceanography to submarine operations goes away beyond that. For a submarine to operate successfully, it has to know the temperature, the salinity, and the direction of currents.

Also we need to know much more subtle things. For instance, can we use other devices than the common ones for navigation? If so, you've got to have much more in the way of geophysical measurements under the ocean--gravity measurements and things like that--for matters of location. The degree of transparency of the water for sonar or any of the methods for communication has got to be studied. One has to know not just average conditions but special conditions in certain localities and how to find them. It's a large subject.

QUESTION: Dr. Waterman, my question concerns the exchange of information and data on research within the free world. About a year or so ago I was in London and I was struck with the friends there of ONR and who were engaged in it. I wonder if there are any other organizations doing this and if there is a need for more of it under more centralized supervision.

DR. WATERMAN: You mean just in the way of keeping in touch with what is going on abroad? Yes. One way in which science does this is through the people in all the fields of science who travel abroad.

When we send Science Foundation people to international meetings or on special research missions, we always ask them to give us a report of what they have found. Then we pass this on to the interested people.

The systematic collection of information, such as ONR in London does, is a very valuable thing. This was taken over from the OSRD after the war, and it has resulted in a very good knowledge of what is going on in science in Europe.

The State Department now has science advisers in about six countries. When they get well worked in and have their feet on the ground, their offices will serve as similar centers with the assistance of interested agencies. As a matter of fact, we have agreed to furnish the State Department assistance in securing scientific information in other countries. We have just sent two people to Tokyo, for example, as the result of a lot of deliberations, to do that kind of exchange of information. The Japanese are a little jittery about this kind of thing, so we are going about it a bit slowly. The chances are that we may expand this operation to other countries.

Apart from that, the three services are supporting research, as you know, in Europe and a few other places; and the reports that come back on that research give us information about what the scientists of those countries are doing. But this is not a systematic effort, as the other is.

I think one can say, then, that the kind of thing ONR in London is doing is valuable and, if this expense is regarded as justifiable, it could well be done in the Far East and in Europe and in any of the regions where active work is going on that we need to know about--in Moscow, for that matter.

QUESTION: Doctor, we have read over the last several years a lot about the shortage of youngsters entering the science field. How serious is this, and is the shortage in numbers or in quality? Or both?

DR. WATERMAN: It's really both. I suppose one can say that the people who have a yen for science and know it right away, who know what they want to do, will come in under any system. Talking first about the gifted people, the loss in this country is quite serious in all fields from high school to college. Of those who have the capacity and the ability to develop their education in certain lines, especially in the sciences, a lot are simply not going to college. This is sometimes owing to lack of financial resources, but in our studies we find it is more often a matter of just lack of interest on the part of the family. There is no college tradition and no reason that they can see why their son can't get a job in the trades. There are good jobs available on which he can raise a family and that's what he wants. So why should he bother about going to college?

We do find something of the order of 200,000 high school graduates each year who are in the upper 25 percent of their classes and who do not go on to college. I am not maintaining that they all should, by any means. But these are gifted people, and probably many of them are simply not developing their capabilities. Among them are quite a fair number who would be good in science.

In that sense we are losing the gifted people. Down through the general population the same thing is probably true; and what hurts us is not so much those who are not going into science--because they may not have the capability of going very far--but what does hurt is that many of those who have personal qualifications and could go into teaching are not doing so. If there is one thing we need now, it is better teachers, especially in science. We need them not only because of the importance of the subject; but, with the emphasis on science, people who have training in science are in so much demand that the secondary schools, for instance, are raided, and the colleges are raided, simply because the jobs are not attractive enough salarywise and otherwise. That's where we are losing a great many teachers.

QUESTION: This question, Doctor, relates to the one that was just asked. I would like to say that in recent months, in fact, ever since the first sputnik, there has been a great deal said and a great deal written with respect to the inadequacies of our public school system. My question is: Has the National Science Foundation addressed itself in any qualitative way to this question? If so, what has been the general nature of your findings, with specific reference to the charge that our school systems are putting too much emphasis on method and too little on course content, with the current result that too much emphasis is being placed on human relations and getting along with other people rather than on the discipline of the subject itself?

DR. WATERMAN: That's a subject that has been under considerable discussion in the past few years. I think the present trend is to acknowledge this: that, although a great deal of effort has been devoted to improving education as a guide to social adjustment, to developing one's character, and all that, this has needed attention and it has had it. But the other has been neglected. I think this is gradually being realized.

I can illustrate this fact, too, and at the same time answer your other question on what the Science Foundation has been doing about it. One of the first things we did, before sputnik, in recognition of the shortcomings of teachers of science, was to establish some experimental summer institutes that were attended by 40 or 50 secondary school teachers; and we did it by fields of science, you see, to get away from the pedagogical attitude and to see what we could find with respect to their knowledge of their subjects.

What we did was to give a grant to a given institution (college or university) in response to an application to hold such an institute. The institution, in turn, accepted applications from secondary school teachers, and on the basis of these invited 40 or 50 high school teachers, say of physics, to spend six to eight weeks during the summer. The first thing that developed was their eagerness and their need to know more physics. They just weren't sound in the subject. They didn't know much about it, and they wanted to know more. Through an invited staff, the host institution gave them a course in physics. The main thing was to straighten them out on that, and then, in the process, they also discussed techniques of teaching, you see.

Well, this had immediate success. Now we have in the neighborhood of 300 institutes every summer. We estimate that something like 72,000 high school teachers in science have attended these. In every case it is the same. Teachers themselves feel a lack of knowledge of the subject, and they are immensely pleased when they get it. I think these efforts are having an impact, because we now find that the teachers' colleges are getting interested in some of these things.

That's one side of it. Another thing we are doing, and which perhaps is the most significant of all, is to support a thorough-going revision of the course content of the four fundamental subjects in high school science--mathematics, physics, chemistry, and biology. This was started by a very interesting movement among the physicists. They took a look at the secondary school textbooks on physics and found them very out of date, and often inaccurate. They decided they would do something about it. So, led by Professor Zacharias of MIT, whom many of you may know, they did a remarkable job getting Nobel-prize winners, college teachers, and secondary school teachers in physics to go over the situation and decide what a good physics textbook should be, and to write one experimentally. The same sort of thing is now being done in mathematics, in biology, and in chemistry, under very good leadership.

What this will do, you see, will be to provide up-to-date, modern textbooks, which are, incidentally, far more interesting than the old ones, and along with them teachers' manuals, laboratory methods, movies, and possible uses of closed-circuit TV. Everything goes with it.

We are backing these efforts as an experiment to show what can be done. What the schools do with the results is not our business. If they want to benefit, they can. But the effect is to show the great importance of modernizing content. We tried this out in schools and had a very surprising result. The best students, of course, in the opinion of the teachers who tried it, obviously liked this new method best. They went further faster. But what was very surprising was that the poorer students did better with the present text than they had done with the others.

Now, to answer your question: The colleges where teachers are trained and get their certificates noted this, and they are paying some interest now to course content. I think this is good. You see, if you are after gifted people in science or in any other field, the worst thing you can possibly do when a person is first exposed to a subject is to give him a dull teacher who doesn't know anything about it. If we want our gifted people to go on, we must put them with stimulating teachers. If you think back over your schooling--and we have all had the same experience--the teachers you remember are the ones who were stimulating. The subjects that they taught, in most people's view, have always been live subjects, because they were well taught.

So, if we are going to get people with a better knowledge of science, or anything else, we must cultivate this side of it. The only way you can interest good students is by teaching the subject well. I think we are making progress, but I may be optimistic.

QUESTION: Dr. Waterman, our previous speaker mentioned the disappearance generally of the general practitioner in favor of specialists in medicine. With the development of technology the jack of all trades obviously doesn't exist. I wonder to what extent in basic research you find difficulty with a specialist in one field sharing ideas with a specialist in another.

DR. WATERMAN: You do find that, of course. As science moves on, especially as it gets more difficult and you have to spend more time to master it, a very interesting thing happens. Other fields of science which are on the fringes or the periphery of a man's own specialty are becoming important and significant to what he does. So there is an offsetting tendency to establish fields of study which will bring in, say, a physicist, a chemist, a mathematician, and an engineer. The whole project can't be done without their common efforts, you see. So there is a trend to establish interdisciplinary subjects, and there is a trend to set up methods of communication so that the specialists can have a better knowledge of what is going on about them, in addition to what they have to know for their own specialties. This is the best tendency I know ofto counterbalance specialization.

Now, of course, you also have to have people who have an overall view of science. You get them as college deans, heads of departments in Government agencies, heads of R. & D. , in different places. These people have a real problem in keeping up to date, as you all know, with the things that apply to their own specialty, which may not be science directly. I mean, they may not be scientific specialists.

There is a problem, and the problem will remain as long as it is necessary to specialize so intensely for so many years in order to make progress in a narrow field. But the progress of science is emphasizing the need for contact. And perhaps that is our best cure. Whether we do it or not, I don't know.

COLONEL MORGAN: Both your lecture and your answers to the questions have been outstanding. On behalf of the Commandant, I wish to express appreciation for your visit with us today and to thank you for a very significant contribution to our course.

(14 Sep 1961--5, 400)B/rb:eh