THE CONTRIBUTION OF UNIVERSITIES AND RESEARCH INSTITUTES TO TECHNOLOGICAL PROGRESS

7 October 1953

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Publication No. L54-36

INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington, D. C.

Dr. Clyde E. Williams, Director of the Battelle Memorial Institute, was born in Salt Lake City, Utah, 8 September 1893. He received the degree of B.S., University of Utah in 1915; D.Sc., Case School of Applied Science in 1945; and D.Sc., University of Utah in 1946. He was metallurgist and superintendent of research at the Bureau of Mines, Seattle Station from 1920 to 1924 and chief metallurgist for the Columbia Steel Corporation of San Francisco, California, from 1925 to 1929. In 1929 he became assistant director of Battelle Memorial Institute and associate director in 1933; he has been director since 1934. As an adviser on minerals in economic mobilization he has served in various capacities in Washington. Among a considerable number of positions held in this regard have been those of chairman of the war metallurgy committee of the National Academy of Sciences and the National Research Council, chairman of the materials and metals panel of the Research and Development Board, and member of the advisory committee of the Atomic Energy Commission. He is a trustee of the Rand Corporation. He is the recipient of the Presidential citation, Medal for Merit. In 1947 he was the president of the American Institute of Mining and Metallurgical Engineers. This is his first appearance at the Industrial College of the Armed Forces.

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Dr. B. H. WILLIAMS: General Greeley, gentlemen: Our speaker, Dr. Clyde Williams, is an outstanding administrator of research and development, being Director of the Battelle Memorial Institute. His success there at the Institute is evidenced by the fact that since he has been there, the Institute has expanded many times over in the size of the research staff, in the plant and equipment, and in the research work performed (chart 1, page 2).

He has been to the Industrial College before and has spoken with great success here. He has been in Washington a great many times and has worked with the National Academy of Sciences and the National Research Council. He is adviser on the metallurgical aspects of research with the Department of Defense and with the Atomic Energy Commission.

He is extremely well-qualified to talk on this subject of research and development, and today his particular subject is: "The Contribution of Universities and Research Institutes to Technological Progress."

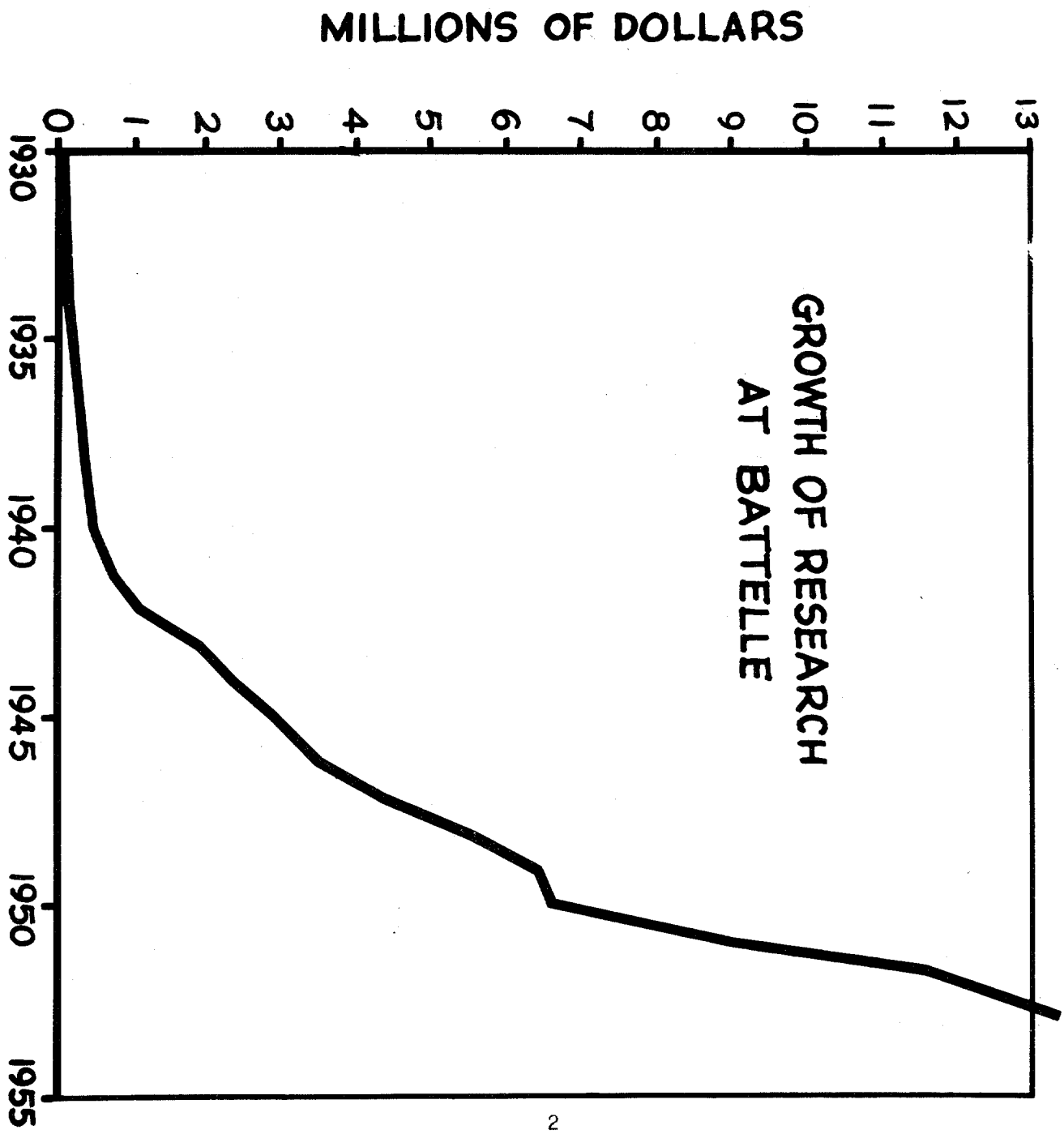
DR. WILLIAMS.

DR. WILLIAMS: Dr. Williams, gentlemen, friends. I am very happy to be here. I am, of course, very much interested in the subject of research, particularly as it applies to the special interest that you gentlemen have in it. Industrial research, or applied research, has gone ahead rapidly in recent years, and it has gone ahead rapidly largely as a result of the interest and support of the military establishment.

I recall that when I first came to Battelle in 1929, industrial research was just getting started. There was very little applied research going on, relatively speaking. In fact there was very little research of any kind in progress compared with today. The military at that time had few funds for scientific investigation.

Early in 1940 we at Battelle decided that the military ought to be looking into some things that could be of basic value to our defense in case of war. I had a little program worked up and came to Washington and talked to some of the top-ranking officers in the military organizations. I found that these gentlemen were very much interested. They were aware of the importance of applied research in solving problems affecting the supply and properties of materials, but they had no money. While they were grateful for my suggestions, they said, "We're helpless

CHART 1


GROWTH OF RESEARCH
AT BATTELLE
MILLIONS OF DOLLARS
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1930
1935
1940
1945
1950
1955

to do anything." The research budget at that time was only a matter of a few million dollars for the whole Army.

Since then, things have changed radically. Research has become an important phase of our industrial effort and of our national defense. Chart 2, page 4, these curves, with which you are doubtless familiar, show the growth of industrial and governmental research.

You will note that governmental expenditures caught up with the industrial expenditures about 1943, and, instead of sloughing off as everyone thought governmental research would do after the war, it continued up at an accelerated rate.

Chart 3, page 5, shows the combined result of those two activities. The steepness of this curve is a measure of the rapidly increasing awareness to research as a means to solve our problems.

Chart 4, page 6, shows the effect of this greatly stepped-up research activity on our national economy. Here, the growth of our gross national product in terms of uniform dollars is compared with population growth. You will note that the gross national product curve has been rising much more rapidly than the population curve and that it resembles very closely the curve for the growth of research. This relationship seems quite significant to me. It shows that our national economy has been improving and that this improvement has paralleled our increased emphasis in research. I think the military agencies can claim much of the credit for this, because it was the military agencies that stepped up the degree of research and the interest in it. Had it not been for the tremendous fillip that research was given by the military, I think we would have continued at a rather slow rate of increase, which would not have given us this tremendously improved economy and stepped-up scale of living.

Applied research really got underway in this country in the thirties. It is still a young industry, even though today it represents an expenditure of 3.5 billion dollars a year, which makes it one of our big industries.

Before World War I, there was practically no applied research in this country. There was considerable research effort in Europe, however, and many of the things that we developed commercially in this country came out of Europe. During World War I, we were caught short on many things that we had depended on from Europe, and American industry woke up to the fact that it had to provide its own bases for progress. However, by the time of the depression in the thirties, we still did not have a very large activity, as the curves we have seen show. Industry at the end of the twenties was spending two or three times as much as the Government, but in 1929 the total expenditure was only of

CHART 2

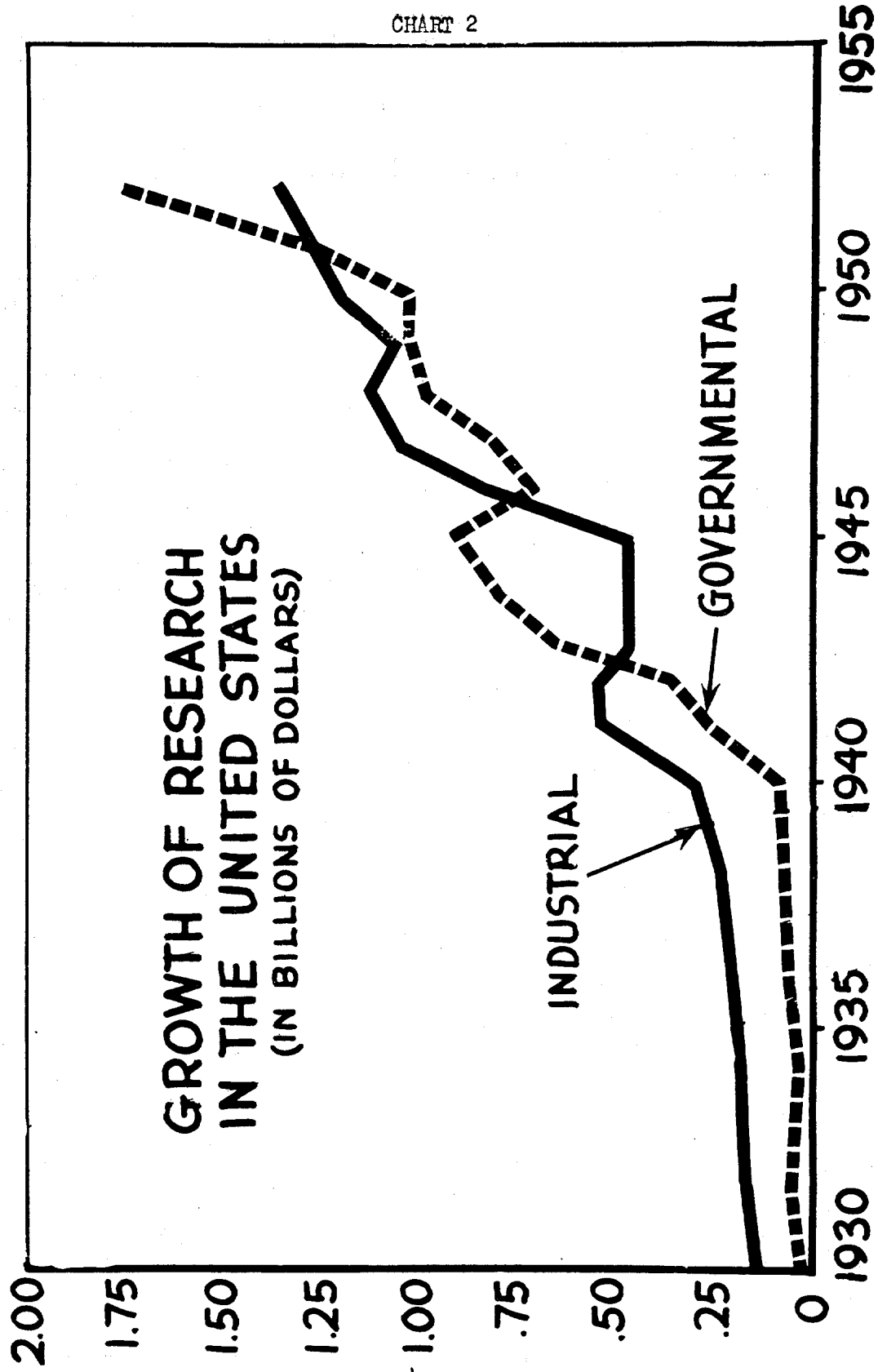

GROWTH OF RESEARCH
IN THE UNITED STATES
(IN BILLIONS OF DOLLARS)
INDUSTRIAL
GOVERNMENTAL
2.00
1.75
1.50
1.25
1.00
.75
.50
.25
0
1930
1935
1940
1945
1950
1955

CHART 3

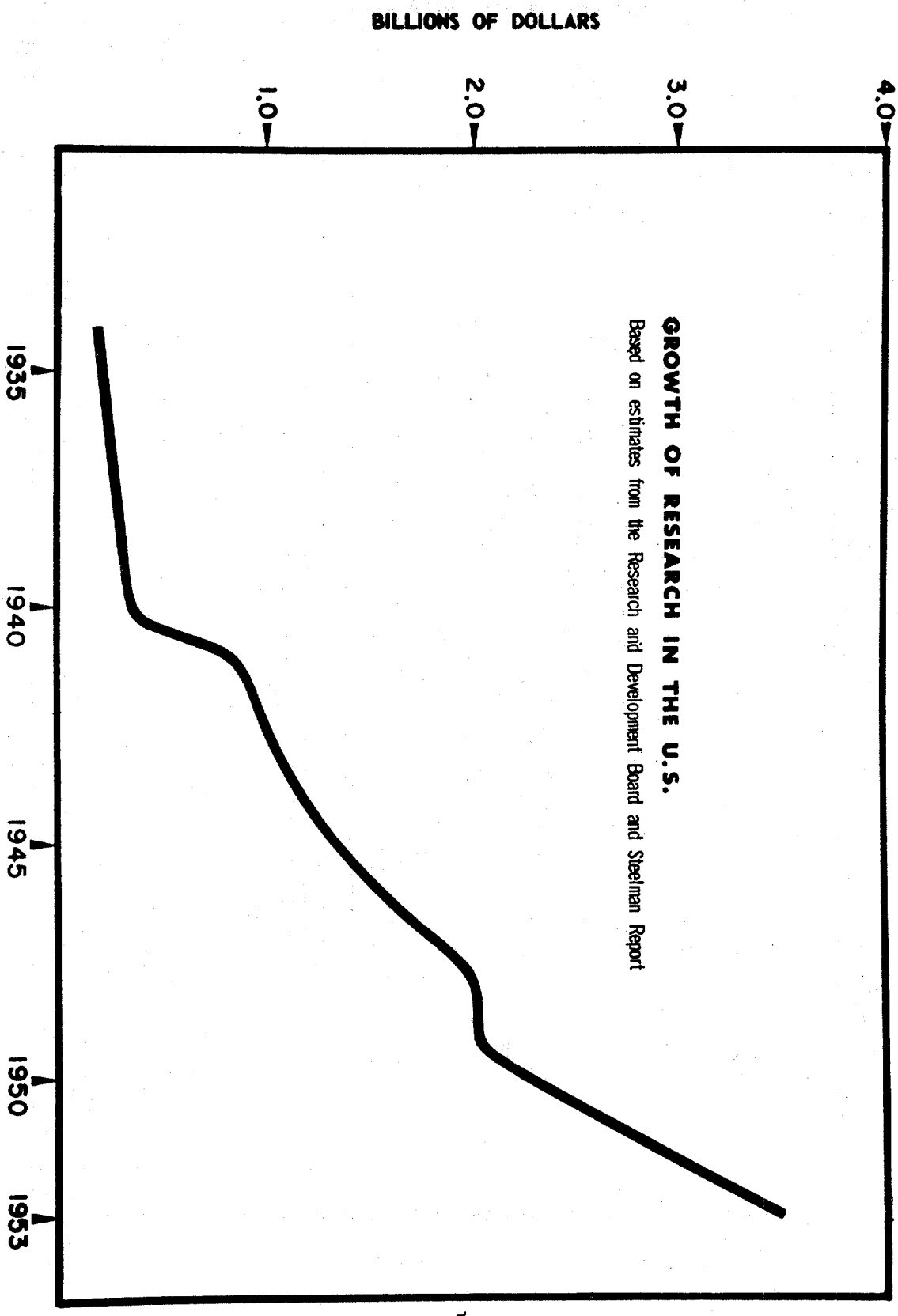
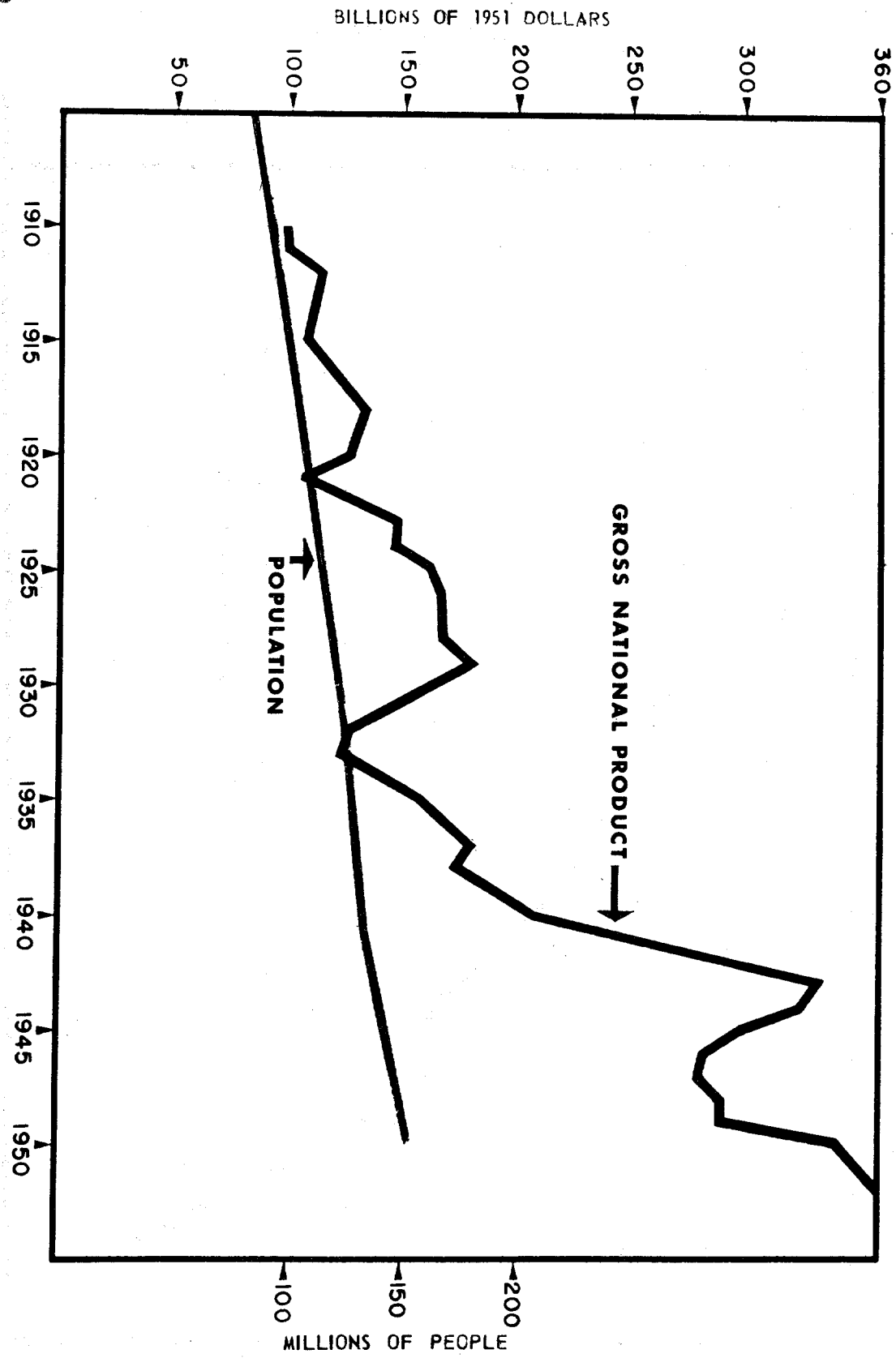

BILLIONS OF DOLLARS
4.0
3.0
2.0
1.0
GROWTH OF RESEARCH IN THE U.S.
Based on estimates from the Research and Development Board and Steelman Report
1935
1940
1945
1950
1953

CHART 4


BILLIONS OF 1951 DOLLARS
360
300
250
200
150
100
50
GROSS NATIONAL PRODUCT
POPULATION
1910
1915
1920
1925
1930
1935
1940
1945
1950
100
150
200
MILLIONS OF PEOPLE

the order of about 200 million dollars. During the depression, industry began to appreciate that research was a way out of difficulties and large central research laboratories started to take form. Then, of course, came the defense program and research skyrocketed.

The thing we have as a result is a tremendous research establishment, something that far exceeds anything that the world has ever seen before. Even at the peak of its research activity in preparation for World War II, Germany's efforts were small compared to our present activity. Germany spent only about the equivalent of 300 million dollars a year and did an effective job. Yet I do not believe that any other country has ever had the quality of applied research that we have in this country.

They do have fine research people in the European countries. Their capabilities lie, however, with fundamental research. They don't have the native American ability of being able to do things with their hands, being able to understand how things work, and being curious about machinery. America, with this curiosity in its young people, has a natural aptitude for applied research. We can make it pay off. Also our industry can quickly learn how to take the products of research and apply them successfully to commercial operations.

Most of the big companies in this country now have industrial laboratories that are called "centralized research laboratories." These laboratories don't work on plant problems or trouble-shooting jobs, company sales and service jobs, but confine themselves to new developments. They have established a pattern for conducting research that has been followed by nearly all of our successful research institutions.

These laboratories require, first, capable men. Then, they require the finest tools. They require methods for the selection of research problems, for conducting research, and for translating the results into terms that the industrial operator can understand and apply.

The research institutes have followed the pattern of centralized industrial laboratories, and in some cases have gone beyond the industrial laboratories in their scope of work. The larger research institutes have gone into many fields of industrial science and have become extremely versatile. By this versatility and by the very nature of their establishment and the type of people they attract, they have achieved an ideal degree of teamwork among their people.

Today, research problems have become so complex that one man and his assistant working in a laboratory, as is common in European practice, has little chance of making an important contribution, unless they are given a lifetime to work on a project. Science, however, can't wait a lifetime. To get research done, you need teams of research people working cooperatively on a given problem. Research institutes supply such teams and the organization to make them effective.

Teamwork research has become common in industrial research organizations and in the research institutes. They have established large cohesive operating units, organizations that have good management, extensive equipment, a good program, and a well-trained staff to do the work. Numerous universities have organized foundations similar to the research institutes and they have done a fine job, particularly in serving the military and in conducting many projects in applied research. This undertaking of large applied research programs in universities, while bringing in much-needed financial support for universities, has in some places put an undue burden on the main function of the university, which is education. Where universities have made their applied research organization separate and have run it as a business operation, perhaps the net result has been a gain to the university and to its teaching. But where universities have been swamped with big research projects for which they were not prepared, it probably has not been helpful. Universities have been swamped with big research projects for which they were not prepared, it probably has not been helpful. Universities and colleges, of course, have been faced with financial problems and have had to do applied research to retain their high-grade teachers and to attract students.

The time has come, though, when, if research is to continue to progress and grow, we must train more scientists. Primarily, a university or college is supposed to educate or train people. Certainly, we are not getting enough trained scientists and engineers. We are getting behind in our scientific manpower needs everywhere, and, according to people who have studied the manpower situation, it may be 1960 before the supply catches up with the need.

There has been a tremendous amount of competition among various lines of endeavor for our young people. The high school graduate, because of the increased tempo of our living, is actively bid for by many organizations who want him. We need educated, intelligent, and able men to support the kind of an economy we now have. Those of us in research who complain because we don't get all the people we need are just like everyone else--whether it be the military, the bank, or manufacturing or commercial organizations. They are all after the same kind of high-grade personnel.

I remember, at the beginning of World War II, talking to the general in our area and begging him not to take one of our young men on whom we were depending for a very largely increased research program. I described all of the faculties that this young man had and presented his outstanding fitness for the job at hand. When I had finished the general said, "Why, you have described perfectly the man we are looking for to send to Alaska. We will take him."

This is the manpower situation today, and something of a very major nature must be done at the high school level to encourage young people to

enter the professions where they are needed. Particularly, we must encourage and inspire young people to go into scientific and engineering work in their college programs. The problem is further complicated by the shortage of high school teachers. Proportionately speaking, we don't have as many teachers with the ability to inspire youth as we had in bygone days.

In view of the fact that the Department of Defense is the largest factor in research, and in view of the fact that it has the ability to accomplish big, basic jobs, I think it should lend its attention to this problem of education of scientists and engineers. The industrial organizations have attempted to do something. The NAM and others have looked into the problem, but the efforts that the industrial groups are making are relatively inadequate compared to the job to be done. Some concerted effort, perhaps an educational program to get people into science courses in high schools and universities, is sorely needed.

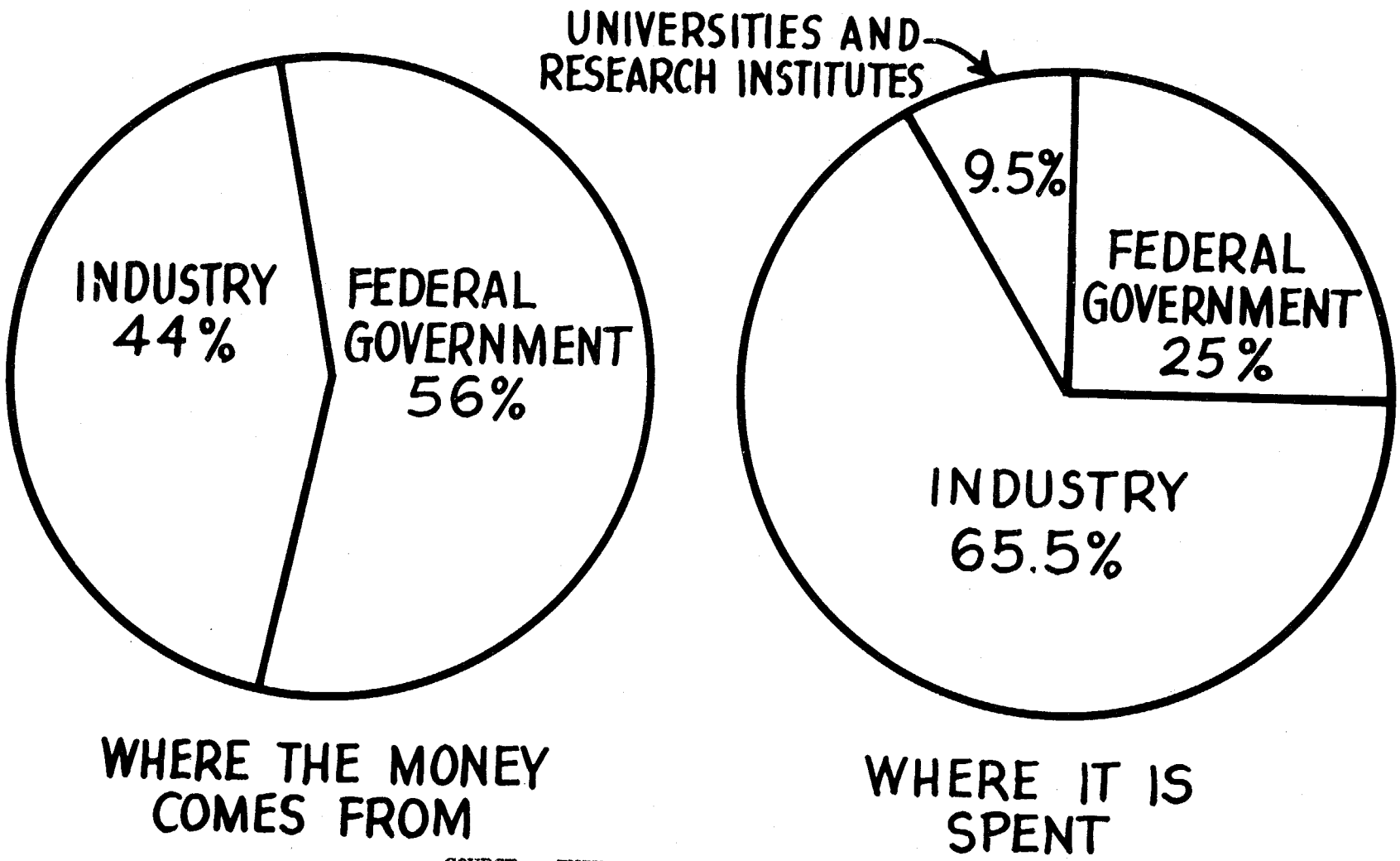
Universities seriously need financial help to carry on their job of education. Their job primarily is to teach people, and, secondarily, to develop information on which commercial activities depend. Therefore, a plan to extend the fundamental research fellowships of universities, thereby training men to do research and at the same time developing basic scientific information, would seem to be the ideal program. The National Science Foundation (NSF), which supplies funds for those two purposes, is an excellent device and perhaps the ideal organization for carrying on this program. I am very hopeful that the NSF will get adequate support.

I know that the various branches of the Department of Defense have placed a considerable amount of fundamental research in the universities.

This came at a time when it was badly needed, and it has been a very desirable thing. I can appreciate, however, that the military agencies, just like industry, can't spend too much money on what we might call undirected fundamental research, or research that is not likely to hold any immediate promise for paying off. The military is just like industry, in that its research has to pay off or it won't get money to spend.

Fortunately, military research of the applied type is almost always immediately useful to industry. That is why the military is really more responsible than industry itself for the tremendous economic upsurge we have had in recent years. Chart 5, page 10, shows that the Federal Government supports 56 percent of our research effort and industry 44 percent. I think, however, that the Government's part in our total research effort is probably even greater than 56 percent. A true ratio is probably 60-40 or 65-35, because I believe much of the research that industry reports is actually research financed by the military. My estimate would be certainly 60 to 65 percent for the Federal Government, most of which, of course, is military.

SPENDING FOR RESEARCH AND DEVELOPMENT



SOURCE: INDUSTRIAL CONFERENCE BOARD

CHART 5

The other figure on this chart shows the places where money appropriated for research is spent. It shows that 25 percent is spent in government laboratories; 9.5 percent in universities and research institutes; and 65.5 percent in industry. Again the major role that the military plays in research is indicated. Again the great dependence of our economy on a continuation of a wise and extensive research program by the military is called to attention.

The problem of scientific and engineering manpower, I believe, is the most important one facing our future growth. We must do something more about it than just hope that people get into universities and find their way into research establishments. Research is certainly going to grow. Industry, thanks to the marvelous examples set by military research, has been encouraged to do research and will continue to create demands for skilled personnel. But our progress could be stopped, not by lack of research mindedness or capabilities, but by the lack of adequately trained people.

One of the things we can do is to make our present research scientists more productive by relieving them of tasks not requiring their full capabilities. We have been working on this at Battelle. A few years ago 65 percent of our personnel was made up of professionally trained scientists and engineers. Today 50 percent of our staff is professional. What we have done is to train people with a mechanical bent, usually men without college education, to act as research assistants. These aides to our engineers and scientists handle the manual jobs, thereby saving the time of the specialists so relieved and enabling them to handle more research projects.

Furthermore, at Battelle we have developed a large number of departments to serve the research worker on a routine basis. Instead of making the research man test his own samples, we have a mechanical testing department, manned by very carefully trained workers. The same thing is true for chemical analysis and other standarized procedures. The result is that we have been able to increase the productivity of a good research man very materially, perhaps 50 percent, by giving him this help.

In still another way we are trying to conserve technical manpower. That is by planning and selecting research programs more carefully. Too often research is done, only to find that the results cannot be used by industry for economic or other reasons. This happens constantly in industrial research and I am sure that it must happen frequently in military work. It is particularly difficult for the leaders of the Department of Defense to select projects that they know will pay off if successful.

It is natural for companies to place reliance upon the judgment of their top executives when they wish to decide what steps they should

take to assure progress. This means that one or two men in a company have final say about the direction a research program should take. This places a heavy responsibility upon the top man.

Actually, most industries have become so complex that no man by himself has the capability of deciding upon the best research program, even the man who built the business. What is needed is a group of people with variable interests to design a preliminary program. Then a responsible group of scientific people should subject the program to scientific analysis to determine the likelihood of the program's being successful, and, if successful, of meeting the company's business goals.

Mathematical analysis of the probability of success is particularly valuable in connection with the development of huge military research programs. The military has been the pioneer in making these planning studies, and the military was the first to use the techniques which we call Operations Research. Logistics studies, systems analyses, engineering economic studies--all these are part and parcel of this systematic approach to analysis and planning.

We organized at Battelle a group that we put to work on the planning of research programs by these systematic means. We sought a name for this activity and came up with the term "operations diagnosis." We now speak of doing military operations diagnosis and industrial operations diagnosis, meaning the drawing up of research and development programs designed to get research answers most quickly and with the use of fewer people. This approach to making research more efficient is paying off.

I have been interested in the RAND Corporation, which has been doing a great deal of this kind of work for the Air Force. A very good example of how this sort of thing will pay off is in the field of titanium. A few years ago the RAND Corporation was attempting to design the best type of aircraft, and it asked me if Battelle would find the ideal metal for use in the airframe. So we went to work. We gave our people the assignment of finding the ideal airframe metal and placed no limitations on their thinking. They came up with the suggestion of titanium.

Then the Air Force provided money to develop methods for the production, rolling, and working of the metal and conducted basic studies in its metallurgy. About this same time, the Navy and the Ordnance Department also started research on titanium. As a result of a tremendous amount of effort by all three agencies, industry also became attracted to this metal. If titanium is successful, which it probably will be, it will be because of this planning and research that the military initiated.

My recommendation is that you continue this planning and selection of research programs, which you have done so well. I think that covers my 45 minutes and my subject. Thank you.

QUESTION: Dr. Williams, so many times in the service we are required to defend research and development programs. Do you have any

suggestions as to how we could justify programs? We can't show a profit in the military. Do you have any suggestions as to how a program should be justified?

DR. WILLIAMS: Well, yes, and I think it is a very important activity that you should develop. We have had a lot of experience in justifying research programs with our industrial sponsors. Any industrial corporation that spends a sizable sum of money looks upon this expenditure as an expense that the president of the company has to justify to his board. It just happens that, because research is a relatively new activity, most research expenditures have to be authorized by the board.

So, at Battelle, we have become more or less skilled in showing the value of research to industry. So have the industrialist executives who want to do the same as you, justify their research programs. It seems to me that you in the military should develop similar skills in justifying your programs.

I recited our experience in titanium, because it was one with which I was closely associated. I have an idea that very few people have ever heard the story of the origin of the country's titanium development program. Yet this is a story that justifies military research. This is a type of story that could be told about almost every project that the different military agencies have. The telling of such stories convince those responsible for funds of the value of research. I don't think there is any difference between the Department of Defense and a big corporation except in size and complexity. Corporations have exactly the same problems in justifying their research expenditures.

I would like to see some agency set up in the military to interpret the results of highly technical research. I think it would be one of the best things that the Department of Defense could do.

QUESTION: Doctor, since applied research must jump off from the results of basic research, I wonder if you would comment on the position industry and Government should take toward purely basic research, especially the financial side of it?

DR. WILLIAMS: Yes, I think there is a tremendous amount of basic research done, if you will accept a definition of basic research as theoretical research aimed at getting basic information which is directed toward the solution of a problem.

Now, American research establishments have been criticized because they have not done enough fundamental research, or the kind of research in which the research man doesn't have anybody to tell him what to do. In this truly fundamental work, the scientist does anything he wants, anything that interests him, and comes up with information which he publishes. It may be useful or it may not.

We probably don't do enough of that type of investigation. That is the kind of research that the NSF is supporting and it is the ideal

type of work for the universities. I hope that the Foundation will get ample funds to expand its support of fundamental research.

Industry has tried to justify putting large amounts of money into that sort of thing. Many companies are putting substantial amounts of money into such research. Some may be spending a million or two each, but it is very small in relation to the need. If the NSF would get its program of 30 million dollars, it really could do a lot of good.

On the other hand there is much very fine basic research done. Here the research workers approach the problem from a fundamental viewpoint, but the work is directed toward anticipated practical values. This leads to practically the same type of information as that acquired in undirected research.

I don't agree with people who have criticized America as running out of basic information on which our applied research depends. We are getting lots of it and our success in applied research shows this to be so.

So, I think the answer is for the defense agencies to spend most of their money on applied research and on directed basic research. Then, let the NSF which doesn't have to sell its results to anybody except Congress, finance the undirected fundamental research.

QUESTION: Doctor, with so much research going on in various components of private industry and in the various departments of Government, what sort of clearing house is available for screening the results, or even checking over these projects before they are launched, to be sure that we are not getting into a lot of duplication? With two groups of scientists in two different towns working on the same project toward the same end, what sort of clearing house do we have to prevent that overlapping and duplication of effort?

DR. WILLIAMS: Well, there is a sort of natural clearing house that exists among research workers. Those who attend meetings of their different technical societies and who read the literature exchange ideas and information with each other.

Again, I think the different military groups, the civilian Government agencies, the National Research Council, the Academy, and so on, have all contributed very greatly to this exchange since the war, and all the conferences that are held to discuss research programs have helped immeasurably in avoiding too much duplication.

I personally am not too much concerned about having some duplication of research effort. I think a moderate degree of duplication is helpful both in military and industrial research. When we want to get something done, there is usually some urgency to getting it done. If

you have two or three groups working on it, there is greater probability of getting it done when needed. Furthermore, there is the value of competition between research groups, and if each gets the same answer there is confirmation of results.

I don't like to hear too much talking down of duplication. Much duplication is inadvertent on the part of the men who set it up, but I think it is a good thing. I would rather see the effort expended on the planning of research programs than I would on the setting up of some agency to try to stop duplication.

QUESTION: Dr. Williams, do you believe there will be any impact on industry-sponsored research as a result of the death of the excess-profits tax, which in turn eliminates the 18- or 20-cent dollar?

DR. WILLIAMS: I don't think so. If you had asked that question many years ago before industry really became sold on research and much of the industrial research was being done with 50-cent dollars, I might have answered differently. But today I think industry is completely sold on research. I think it will continue to support it, even with a 100-cent dollar.

QUESTION: From reading the newspapers I find that Mr. Kyes of the Department of Defense has a very strong feeling that there is far too much research, so that industry will be unable to catch up with the information we now know for a number of years. I think as a rule of thumb he indicates that one million dollars worth of research will cost 20 million dollars' worth of plant to produce what the valuable information has indicated. Would you like to discuss that with us?

DR. WILLIAMS: I haven't studied the question from the standpoint of those figures, but it may be that one million dollars' worth of research will require an expenditure of 20 million dollars. I think that is good.

Today, every live American corporation wants to get into something new, wants to grow. This desire to grow is reflected in the valuation the public puts on these companies. The companies that are doing the most research, or the most successful research, are selling for the highest price on the basis of the business they do.

As an example, in the chemical industry the price of shares in the market is about 20 or 30 times annual earnings, even 40 times. The chemical industries are among the most active, researchwise. Another example is the electronics industry, which is perhaps the most active in research of all industry. As I recall the figures, the electronics industry in 1940 was doing less than a half billion dollars' worth of business. In other words it didn't amount to much. But this year it

will exceed 6 billion dollars' worth of business. That is a twelve-fold growth in 13 years. In order to finance that 6 billion dollars of business, there have been many millions of dollars spent on plants. All of this capital expenditure has been the result of research. And today the most attractive investments are in the electronics companies. Capital is seeking employment there.

This 3.5-billion-dollar research structure we have built is equivalent to a new resource in feeding our economy. It is as important as a newly discovered deposit of iron ore or oil. It, unlike natural resources, keeps getting more valuable all the time instead of being depleted. And this resource will help prevent serious economic depressions, because it develops a constant stream of new industries, like the electronics industry. You can recall that during 1932 or 1933, everybody was crying for something new that industry could go into to get the wheels rolling again. Well, today, as a result of this tremendous research activity, the wheels keep rolling all the time.

If you talk to people like RCA about things they have on tap to put on the market, you can see that this electronics business, which is now 6 billion dollars, will probably be 12 billion dollars one of these days. So I think research is really the life blood of the new American economy. If we shut it off, we will begin to shut off our production.

QUESTION: Doctor, I wonder if you would discuss a little more fully the extent of research in other countries, comparing that to our country and the effect on the technology of this country and the other countries?

DR. WILLIAMS: Well, that is a big order. The research in the European countries has been good fundamental research. It hasn't been to a very large extent the practical applied type of research that we do. European industry has been quite good in picking up that fundamental research and putting it into practice. But, by and large, European research has not been of the practical type such as ours and, of course, it hasn't paid off to the extent ours has.

There are exceptions, but Europe industrially is still inactive compared to America. One reason is that it has not had applied research and has not made use of it as we have. I think if all the billions we gave Europe could have been spent on research and its application, Europe would have been a lot further along--but that is a very academic question.

Unfortunately, you can't start new enterprises in Europe just because you want to or just because somebody has developed something

that looks good. As a result, Europe can't seem to get the wheels going, with the exception perhaps of Germany. Germany is more adept at taking these new things and making use of them, and it doesn't have the restrictions of strong nationalist control over the operations of the individual that the other countries do.

In most of the European countries, research is very stricly controlled by the governments. Most of the money for research comes from the governments, who also do a large part of the planning. This makes the introduction of American procedure very difficult. Without large-scale applied research producing new opportunities for industry, capital has been unwilling to go into new things. The objective behind Battelle's setting up of laboratories in Europe was to break this bottleneck. After a survey, we found that many industrialists wanted to pattern their actions after American companies, which is to perform applied research and then use it. We felt that we could make a big contribution by making available to the European industries the kind of research we have done for American industries, with the belief that enough of them would pick it up and get the wheels of progress started again.

QUESTION: Doctor, you spoke of your self-help program and the training of assistants to help your research scientist and his ability to perform more work. How far does that apply to other institutes?

DR. WILLIAMS: I think that all laboratories are making efforts to conserve manpower, although the degree to which assistants are used will probably vary from place to place. Our own cost figures may show a lower expenditure per professional worker than most others, although this is not necessarily due to our manpower conservation efforts alone. All laboratories are going into the use of assistants because of the unavailability of adequate numbers of trained engineers and scientists. It is absurd to see a man who has gone through college and had a lot of experience working at operations that some well-trained high school graduate can do just as well. A woman can perform many operations with much greater dexterity than a man. We use a great many girls. One of our best welders is a girl who formerly worked behind a 5 and 10 cent store counter. One of our machinists is the wife of an Army officer.

DR. B. H. WILLIAMS: Well, sir, from the standpoint of the Industrial College, it has been a very profitable morning for us and we are very grateful to you.

DR. CLYDE WILLIAMS: Thank you. It has been a pleasure.

(14 Dec 1953--750)S/ibc