INTRODUCTION TO TECHNOLOGICAL PROGRESS

2 October 1953

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Publication No. L54-33

INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington, D. C.

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COLONEL KLEFF: General Greeley, gentlemen: The weekly schedule for the Industrial College of the Armed Forces shows that there is to be a presentation on the "Introduction to Technological Progress" by Colonel D. B. Diehl.

Colonel Diehl is ill this morning therefore I am substituting for him.

What is technological progress? Perhaps the best concept of this subject is given in your curriculum book: "Technological progress: A study of scientific and technological resources in their relationships to the mobilization of the national economy and to the maximum development of the Nation's economic war potential. Included are studies of the nature and conditions of research and development; organization, operation, and interrelationships of governmental, industrial, educational, and private agencies concerned with research and development; the relation of joint planning in research and development to joint logistic, strategic, and national policy planning; representative programs and special projects such as atomic energy; and the logistical problems arising from developments in new weapons and weapons systems."

To be more specific, the following is a definition of "technological progress": Technological progress may be defined as the improvement of man's control over his natural environment through the application and utilization of scientific and engineering knowledge in any of the practical arts and sciences.

There are other definitions; for example technological progress is the application of scientific and engineering knowledge as a means of multiplying our manpower, conserving and extending the use of our natural resources, and making it pay. This definition includes the multiplication of manpower as the means, perhaps, of meeting the Russian manpower situation, and of conserving and extending the use of our natural resources, inasmuch as we are gradually becoming a "have-not" nation. We add on "making it pay." If we work in the reverse, we are not progressing; we are retrogressing.

Another short definition is: A better way of making a better item is technological progress. However, I think the first one is perhaps the most all-inclusive and best definition which we have been able to obtain.

Now, the key word here is the word "improvement." Man may be born into a culture very rich in scientific knowledge, capable of very

great engineering achievements, and yet technological progress as such may not exist, because there is no improvement, there is no progress. All such cultures degenerate and fade from the face of the earth. We have seen many examples of this. The great Incas of South America are a very fine example.

Why should we, as military men, be interested in the subject of technological progress? What is the objective? Again I can refer to the curriculum book. It says: "The objectives of the study are to develop an understanding and appreciation of technological progress as an element in the national economy, and to assess the capabilities and limitations of research and development in advancing national security."

It seems to me that it is self-evident that we must develop an understanding and appreciation of technological progress as an element in our national economy and that we must be able to assess the capabilities and limitations of research and development in advancing our national security. Further, we should know something of the strengths and weaknesses of the United States position in technology; the effect of technological progress on the economic status of the United States; and perhaps last, but maybe not least, an appreciation of technology in the Soviet Union. These are but a few of the many reasons why we should be interested in the subject of technological progress.

In defining this term a minute ago it was mentioned that the key word was "improvement." All improvement depends upon some form of research. There are two general types of research. We refer to them as basic research and applied research. The basic, or pure, research is the foundation for all technological progress, whereas applied research, as its name suggests, is the application of this knowledge to some practical pursuit. Development, which follows research, is the production and modification of prototypes and experimental or pilot-line production models so that we produce the proper item. Within the military we sometimes break down this basic research in two ways. We have basic research performed as an integral part of programmed research committed to specific military aims. Then we have academic research that promises some ultimate military application.

Now, it is characteristic of the first, what we sometimes call basic research, that the immediate aim of the sponsoring agency is to discover and exploit applications to particular military problems with which it is confronted; whereas in the second one, the academic type, it is the desire of the sponsoring agency to foster basic research in a field in which it believes new information is likely to find important application to military problems. Both of these types of research within the military must be wisely planned and energetically supported.

Probably the best concept of basic or pure research may be obtained from Doctor DuBridge, President of the California Institute of Technology,

who stated: "The chief goal of science is not to develop weapons of war; it is not to develop new or improved industrial products; nor even to find cures for human diseases. The primary goal of science is to understand nature. Its purpose is not to invent but to comprehend; its aim is not to produce gadgets, but to discover knowledge; its most valuable products are not atomic bombs, radar, or penicillin, but new facts and new laws concerning the behavior of the natural world."

This, then, is the beginning or the foundation of all technological progress. It is from this spring of knowledge that all technology flows. According to Doctor Vannevar Bush, head of the World War II Office of Scientific Research and Development, there are eight "essential elements of technological progress."

First, there must be "an extending body of science in general; that is, a storehouse of fundamental ideas constantly being replenished through basic research."

Second, there must be "a constant alertness to discern in this growing body a basic knowledge, those points from which practical applications may grow."

Third, the "ideas thus discerned must be tested to determine whether they have merit." This is the stage known as primary applied research.

Fourth, there must be "reasoned and deliberate examination of the possible outcome in terms of technical performance and of development of ideas" which have stood the test of the primary applied stage.

Fifth, the "setting up of programs for the purpose of producing prototypes." It is here that careful attention to the second and the fourth steps begin to pay off. By the second step, we increase the number of possibilities to be explored; and, by the fourth step, we eliminate the least promising of these possibilities. Thus, in this fifth step, and this is the expensive and time-consuming step, the building of prototypes is undertaken only when a worthwhile development is almost a certainty. Thus to pin down an idea may only consume paper and pencil whereas building a prototype my cost millions of dollars.

Sixth, the "testing of the prototypes and re-examining them in the light of these test results."

Seventh, the "incorporation of changes and adaptations as incidated by the test results of the sixth step, and the setting up of experimental or pilot-line production models."

Eighth, this step is not, as you might expect, the production of the final article, but rather another "evaluation and analysis conducted, where possible, through the field testing of the pilot-line or experimental model for final elimination of difficulties before going into large-scale production."

To Dr. Bush's eight steps, our experience indicates that we must add a ninth step to complete the cycle. This ninth step is the "continuous follow-up of the article while it is in service," with the changes and modifications needed to meet the ever-changing service requirements. It is through this ninth step that we determine the need for and the timing of new programs to develop improved models or replacement items.

The important thing, perhaps, to remember about these steps is that there is no clear line of demarcation between the various stages of research and development. Although the first step is basic research; the second, third, and fourth may be considered applied research; and the remaining steps are considered development, each of these overlaps. Thus basic research, applied research, and development are three facets of the emergence of technology achievement, no one of which is absolutely exhausted prior to the consideration of another.

Now, in looking over those essential elements, the question naturally arises as to how long it takes from the beginning of step one until the cycle is completed. No definite general answer can be given to such query. However, it does bring to mind the importance of time and one should never underemphasis the importance of time.

This point of time--we can talk quite somewhile about that. It will come up in some other courses. In looking at those nine steps, I think we might realize right here that time is a very important consideration. We have time against effort; we have time against money; and time versus expediency. It is always there, and it may be the determining factor in shortening, in combining, or in lengthening some of these steps.

It has been said that time is now and yesterday. This reminds me of a little poem I heard many years ago. If I can remember it, I will give it to you. It runs something like this:

"Yesterday was yesterday--
Today is today;
There is no tomorrow,
Until tomorrow is today."

I heard that many years ago in school; but it comes back now in the consideration of time. It goes with the statement that time is now and yesterday. Now! It comes to us in the military very forcibly, because

the things we need, our requirements which must be filled to do the things we need right now, must have been thought of and started a long, long time ago. These requirements of today are the products of the research of the past.

There are many examples of this. I know you all can think of any number. For example, there is the famous atomic bomb that was preceded by over 40 years of basic research by more than a dozen different scientists. This includes six years of very exhaustive research work. Following this, there was the Manhattan Project for the development of the atomic bomb. The Manhattan Project lasted three years, from 1942 to 1945, and cost over 2 billion dollars. Also some of you, I know, are familiar with the development of the B-29. That lasted seven years from the drawing board to mass production. And there are many other examples.

What is the extent of technological progress in the United States? Perhaps the best way to obtain some concept of this is to examine research and development as it is performed in the United States. There are numerous research and development facilities in our country. These are located in universities, in industry, and in government; in universities, such as Cal Tech and MIT; within industry, such as General Electric, Bell Telephone, DuPont, and many others; in non-profit research laboratories, such as the Mellon Institute and the Carnegie Institution; in government, such as the Atomic Energy Commission facilities at Los Alamos, Oak Ridge, Hanford, and Brookhaven; and within the military, each Army technical service has at least one research facility; the Navy has several, particularly the Office of Naval Research, which does basic research only; and of course, you are all familiar with the more or less recent Air Research and Development Command and their extensive facilities.

Naturally, all of these facilities require considerable sums of money to keep them in operation. Just how much money is involved in these over-all expenditures for research and development? Here I would like to refer again to the curriculum book. On page 3 it states:

"The revolutionary change in attitude toward research and development in governmental and military circles and the greatly increased understanding of the importance of these activities to national security may be shown by a few budgetary facts. The national outlay for scientific research and development totaled more than three and one-half billion dollars in 1952, over four times the yearly expenditure at the beginning of World War II. Two-thirds of this tremendous sum was for work performed in laboratories and other facilities owned or operated by private industry. Almost one-fourth was for research and development carried out by the Federal Government in its own laboratories, and the remainder was for work done by colleges and universities."

That's quite a sum of money and it represents a great deal of research activity.

In addition to the facilities and the financing of research and development, the scientific personnel problem is indeed a difficult and complex one. It suffices to say that research and development, the backbone of technological progress, is dependent upon trained scientific brainpower. This has been very forcibly stated by former President Conant of Harvard University, as follows:

"In every section of the entire area where the word 'science' may be properly applied, the limiting factor is a human one. We shall have rapid or slow advance in this direction or in that, depending on the number of really first-class men who are engaged in the work in question. So in the last analysis, the future of science in this country will be determined by our basic education policy."

Thus, today we must find some way to advance as rapidly as possible in basic science while, at the same time, meeting our immediate needs in technology. The question therefore naturally arises as to what is the Federal Government doing, if anything, about the scientific personnel problem and basic research in general. The answer probably lies in the National Science Foundation, established by the National Science Foundation Act of 1950. This Act authorizes and directs the Foundation to perform the following main functions:

First, "develop national policy for basic research and education in science."

Second, "initiate support of basic research."

Third, "initiate specific defense research on request."

Fourth, "award scholarships and graduate fellowships."

Fifth, "foster the interchange of scientific information."

Sixth, "evaluate and correlate research programs."

Seventh, "maintain a national scientific register."

Eighth, "cooperate in international scientific research activities."

You may feel that I am giving undue emphasis to the National Science Foundation. However, I feel that the National Science Foundation perhaps holds within its grasp the answers to many of the problems which we will face in this field in the future.

That is the over-all picture on research and development within the United States. But what is the relationship between research and

development on the one hand and national security on the other? And where does the military fit into this picture? The importance of technological progress in contributing to the maintenance of national security may be exemplified by a few facts:

First, new tactics of offense and defense are developed around the new weapons which have been created by scientific research and development. For example: the jet fighter, the atomic-powered submarine, atomic artillery, the H-bomb, and you can think of others.

Second, the competitive time element, which I mentioned a few minutes ago, in developing new weapons and their tactical employment may be decisive. For example: What might have been the outcome of World War II had the Germans developed the atomic bomb one year before we did--say 1944? Think about that! The war might not have ended just exactly the way it did.

Third, war increasingly demands the use of the most advanced scientific techniques, for example, the many electronic devices which we find today in military materiel. I don't need to mention any more about that.

What are the strengths and weaknesses of the United States position in technological progress? We look first at the strengths of our position. We must give consideration to a number of environmental factors, such as our free-enterprise system, educational opportunities, educational and industrial facilities, scientific and technical societies, trade associations, and the like. To these we must add our healthful climate, good topography, strong, virile races of people, and our freedom of religion. Another strength has been indicated by the billions of dollars being spent on research and development, not only by the Federal Government, but also by industry, private institutions, educational institutions, and such. To these we might add the interchange of scientific knowledge through the multitude of published articles, documents, and so on. There are literally thousands of lectures, informal letters, articles, periodicals, books, and abstracts published annually. And, more recently we have radio and television programs.

Before leaving the strengths of the United States position, it is right that we mention the general public. World War II was the first war in human history which was effected decisively by weapons which were unknown at the outbreak of hostilities. From this we learn several important lessons, each of which is a strength in itself. First, there is an informed public regarding the significance of new weapons. Second, there is a realization that we must rely on continual technological progress to keep us secure against any possible competitor. Third, there is a basic loyalty and understanding in our democratic way of life which must be maintained.

Now, our strengths may be many, and they may be great; but we do have certain weaknesses. The picture is not all one-sided. There's the darker side, too. Perhaps our greatest weakness lies in the fact that the supporting basic research of the past, the very foundation upon which our technolcgy is based, has been imported from the great scientists of Europe. That we as a nation have no peers in applied science, there is little question; but, likewise, there is little question but that we are extremely weak in basic research. During World War II practically no basic research was carried on in the United States. This point was emphasized by Dr. Bronk in his lecture here to the Industrial College last October. I quote: "I need not remind you, for it has often been said, and with justification, that we in the early days of our country, and until recent years, depended largely upon the scientific discoveries of Europe." And the disruption in Europe, both during and since World War II, has done much to curtail this great flow of basic scientific research to the United States. That this great fountain of fundamental knowledge is gradually drying up, there can be little doubt. It is a foreboding thought for us and probably our greatest weakness.

The scientific personnel problem, I have already mentioned. This growing shortage of scientific personnel, together with its maldistribution, is another one of our great weaknesses.

What are some of the effects of technological progress on the economic life of the United States? Looking at it from the point of view of industry, technological progress has been such that, in 1939, millions of people were employed in industries which did not even exist at the end of World War I. This situation, as you know, has increased rapidly during the past decade and one-half. The present position of the United States as the leading nation of the Western World has been built largely upon our skill in utilizing technology advances to develop our resources, both material and human, for raising our standard of living. The United States progress in peace and its strength in war is built largely upon our ability to maintain our technological supremacy and our industrial know-how.

Another word on the effect of technological progress on the economic life of the United States. As a young nation we were primarily an agricultural nation. Through technology we have gradually become the most industrialized nation of the world. Today, we moderns ride around in high-powered cars; we travel in airplanes; we listen to radios and watch television shows. All of these great technology advancements are taken for granted. This is a most extraordinary thing--that people do not have to understand science in order to make use of it. From this arises a fact of very great significance; namely, our almost terrifying reliance on the fruits of modern technology. Stop and think for a minute what would happen if suddenly all of these things were taken away. The results would probably be disastrous. It is probably not an overstatement to say that perhaps not more than one-tenth of our population could survive!

No introduction to technological progress would be complete without saying just a very few words on Russian research and development. Our intelligence in this field is probably no better, or no worse, than in any other field. It is a mistake to attribute Russian technology and their achievements solely to German scientists taken to the USSR after World War II. This is borne out by the Russian basic research over a period of many many years.

The Russian technology as evidenced by their jet fighter, the MIG-15, is not to be sneered at. They have developed in a comparitively short period of time, a fighter which is lighter and faster and which has heavier armament and a greater rate of climb than anything we have been able to develop. In addition to this, and this is important, they have used less critical materials.

We might also consider for a moment the Russian tank, the large Stalin tank. Its mobility and fire power are probably the match of anything in the world today. And I need only mention their most recent development, the H-bomb.

So don't be complacent about Russian technology. There's very good evidence that their technological effort is fully equal to that of our own. The principal point of consideration is that their entire technological effort can be directed as the Soviet Government sees fit. This may result in the development and actual production of quantities of very excellent weapons. This may be, and probably is, to the exclusion of consumer goods. But the Soviet regime has complete control. Therefore, it is absolutely necessary that we keep far in advance of them in our basic research; for the basic research of today may very well be the clue to the future development of weapons unheard of today. This may be our advantage. I trust we make the most of it.

I have one concluding thought I would like to leave with you. We might say that "technological progress is the most dynamic force acting on the world today. It is based on science, and science is advanced through research and development."

Now, this morning I have only glossed over the subject of technological progress.

This ends my substitution. I would like to say a few words about Colonel Diehl's presentation.

Chart 1, page 10--"The trouble is that all the important discoveries have already been made."--This chart portrays a concept that has been felt by many individuals over the centuries. In fact this concept is held by a number of people today. I suppose we are no exception. At times we have felt the same way. (Reproduction of charts canceled after typing was completed.)

To indicate that this has been thought of as a concept by many people, I have another quote I would like to read from Dr. Bronk's lecture of last year.

"There is all too prevalent a feeling that we have developed maximum potentialities. Nothing to a scientist could be burther from the truth. It is an old statement, often repeated, to say that science opens endless frontiers for the future. The fact is nevertheless true."

Chart 2, page 12--"The Key to Survival--Technological Progress."--This chart portrays the attitude of advanced thinking people. It shows all too well the possibilities of the future. In fact it lend emphasis to the statement that science is an endless frontier. We have not discovered everything that there is to be discovered. We have not reached the end of our knowledge. In thinking of that, who can really predict the future of things to come? Things we have today, certainly in many minds, were not thought possible merely one-half century ago.

I would like to close with two quotations. The first is another quote from Dr. Bronk's lecture here last October.

"The characteristics to which I have reference are a keen desire for freedom, freedom to develop as best they could their latent potentialities, and a thirst for adventure. If we have these two characteristics still well developed, I for one would have no fear concerning the future vigor of our way of life."

The second quotation is taken from the Christmas broadcast, 1949, of King George VI.

"If we are convinced, as we are, that the democratic way of life offers man his greatest happiness, his greatest security against all forms of tyranny, it is essential that we make every effort to keep that way of life vigorous and strong, now and in the future."

I thank you very much for your very kind attention.

(26 October 1953--350)S/sgh

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