# SCIENCE AND TECHNOLOGY IN THE UNITED STATES TODAY

16 September 1964

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NOTICE

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INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington, D. C.

Mr. J. Carlton Ward, Jr., retired Chairman of the Board, Vitro Corporation, was born in Brooklyn, New York, 21 January 1893. He attended Cornell University, receiving the M. E. degree in 1914. He was appointed to the position of development engineer, International Paper Company, 1914; became assistant to the works manager, Niles Tool Works Division, Niles-Bement-Pond Co. in 1915. In 1918, he was appointed production engineer, U. S. Ordnance Department, Watervliet Arsenal. In 1919, Mr. Ward became works manager, Pratt and Whitney Division, Niles-Bement-Pond Co. In 1926, he was appointed vice president and general manager of the Hartford Machine Screw Company. During the period 1929-1934, he was general works manager of the General Cable Corporation; was named vice president of the Rome Company, Inc., in 1934; served as vice president, general manager and director of the Pratt and Whitney Aircraft Division, United Aircraft Corporation from 1935 to 1940; became president of the Fairchild Engine and Airplane Corporation, 1940; and in the period 1948-1949, served as chairman of the board of that corporation. From 1950 to 1953, he served as chairman of the board of Thompson Industries, Inc. He is director of Stanrock Uranium Mines Limited, formerly a director of the Aeronautical Chamber of Commerce, the Aircraft Industries Association, the Atomic Industrial Forum, and currently a director of the Cornell Aeronautical Laboratory, and chairman of the Council of the Cornell College of Engineering, and is a former trustee of Cornell University. He was, until 1962, also on the Secretary of the Navy's Advisory Board on Scientific Education. In 1940, he was chief of the advisory mission to the French Government on production of aircraft engines and in 1942 was appointed member of the War Production Board Mission to Great Britain. Mr. Ward is a member of many scientific and engineering societies and associations and has written many papers and articles on technical engineering subjects. He is Chairman of the Board of Advisers of the Industrial College of the Armed Forces and has participated in the Industrial College lecture program since 1946.

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GENERAL SCHOMBURG: As a memo of formality on my leading Mr. Ward up here, he knows his way up here better than I do; they prepared a little speech for me this morning to introduce him. As usual, I kind of divert from that. There were a few statistical facts there, some of them new to me, that I thought were quite interesting. I want to repeat them to you in case he does not mention them. They have to do with the increase in technical and scientific knowledge over the years.

These say that from 1900 to 1950 the recorded technical and scientific knowledge doubled. Then from 1950 to 1960 it doubled again. From 1960 to 1967 we expect it to double again.

I thought that was quite impressive. I hope we are not getting more long-winded, though, as we write it down and give it bigger volume.

I want to introduce Mr. Ward now. He is a longtime friend of the College. I think if I were to pick out the two people who probably have contributed the most to this school I would say one is Mr. Ward and the other is Dr. Reichley. Of course, Dr. Reichley belongs here. Mr. Ward deserves a great deal of credit for what he has done for us, and a great deal of appreciation and thanks.

Today he gives his 21st lecture to this school. He is Chairman of our Board of Advisers. I know you have read the biography so I will not repeat it, but it is most impressive. I do not think I have seen one more impressive than that in a long time.

As you heard me say last week, we have started a new little custom. So we want to make Mr. Ward a member of the faculty today. I will do that right now. Mr. Ward, we are going to make you an honorary member of the faculty with this, which I hope you will put up on your wall. We are going to keep your picture in the back of the lounge, and I suppose it will be there forever.

If you are a member of the faculty, you have got to wear a badge, so we will put that on you, too.

MR. WARD: Thank you ever so much.

GENERAL SCHOMBURG: Carlton, you are on, now.

MR. WARD: As the faculty knows, gentlemen, I have gotten more from my association with the College than I think I could ever give to it. I want to thank you, General, for that very generous introduction. I want to thank you also for what I consider a great honor, to be an honorary member of the faculty. I have been an honorary member of the Alumni Association. I come to some of the meetings. I get their blurbs which I read with great interest. My wife would tell you that this is my second Alma Mater. My only fear is that I might be becoming a legend.

To quote the speaker this morning, I am not running a race with Bertrand Russell. I remind the faculty each year that they should draft some new blood into this stream of lectures which I have been honored by being able to present over the years. These lectures have covered a wide variety of subjects, and, as I look back on many of them, I wonder how I knew anything about some of them.

It is quite a sobering experience to come before such a mature group of men all of whom have made their way professionally in such a hard profession as yours, with its various components, and talk to you when one knows as a speaker that in the audience there are many specialists who know more about almost every facet of what one is going to say than one could possibly know oneself.

My present problem is to produce out of the chaos of new concepts and ideas available to us an orderly presentation leading to a conclusion. I think we can readily realize this is quite a task. I hope it will be a profitable one. I hope it will intrigue you a little.

For the first lecture this morning you heard philosophy. This is perhaps the furtherest thing from my subject. I am going to try to show you why in a moment, and so I will start with what I believe is a proper start, the definition of what we can conceive to be the subject assigned to me by your faculty.

Now, as on prior occasions, I always owe a debt to your faculty for the assigned scope. This is an enormous help to a lecturer and also constitutes one of the inhibitions which were referred to this morning, but which certainly is a healthy one. It keeps him from wandering off into areas of his own interest and thus staying closer to the assigned task, which should accordingly fit into the College curriculum.

I have reviewed the scope of the five lectures on science which you have all seen. Since, as you will see in my development here, to be the most significant force in civilization and thus in creating national power, I am glad that you have these five lectures; but I also think it is impossible to cover the enormous scope of what is meant today, which the General referred to, as the growth of science. This implies not merely the growth of knowledge but the challenge to apply it, which is the special field of technology.

Now, with that start, conceived after hearing the lecture this morning, I want to be careful that my definition of science and engineering is understood by all of us. In the first place let me dispose of one large segment of what is often referred to as science, the social sciences, the behavioral sciences. In what I say to you this morning, they do not come, into my definition for real science. They are attempts to use scientific reasoning in areas of knowledge that are intangible or incommensurable, just as the subject matter you have heard early this morning. Why? I told the speaker this morning after his lecture that I had been invited to attend a distinguished seminar at Harvard which lasted for a week and which brought together Nobel Prize people from Europe and throughout the United States--distinguished professors, leaders, and then small fry like myself--into a very distinguished group. The subject of that conference, gentlemen, was what you had in the morning lecture: What are the factors that promote creativity?

The circumstances that led to that seminar are very appropriate to your studies. It was an attempt to examine whether America and its environment inspire creativity as compared with the Old World, where historically so many of our new ideas, have come from. I am not competent to say specifically where most come from. But as an example in the whole field of nuclear science only one American name stands out all the way from Dr. Hertz of 1890 to Dr. Roentgen of 1895, Dr. Belguerel, Mme. Curie, J. J. Thompson, then Max Planck of 1900, Lord Rutherford and Nils Bohr in 1912. The group who really formulated quantum and wave mechanics, followed by Lord Aston who defined isotopes and Chadwick, the neutron, Fermi, the reactor and so many other distinguished scientists. You notice these are practically all foreigners, ending strangely enough, with Enrico Fermi and his pile, and finally, Hideki Kazawa, the Japanese who first predicted the mason sub-atomic particles. You do not easily find an American among them.

Now, if you will dwell on that example for a moment, it might have been an example cited earlier this morning. Where do ideas come from? From what sort of framework? In the case sited it was the European, or Old World background. I think it is healthy for us to recognize the interaction and the interrelation between science all over the rest of the world and science here.

While later, my figures may impress you with the idea that we are doing more than other parts of the world, I am not sure. I am able to say whether the quality is correspondingly equal.

Historically, we have been a pioneer nation, emerging from where we prodigally used nature's resources, chopped down trees, developed mines and water power and converted them all into our outstanding industry. This portrays the area of development and applied science. As in the days of the sophisticated Michaelson and Morely experiments and many others of the last century, far more was being done abroad in basic scientific fields than we did here.

This I think was true right up until considerably after World War II. Vannevar Busch sounded the real battle cry when in his book--and he was in an unique position to know, because of his war service--he said, "We have exhausted 50 years of science in 5 years of war." Now, think of it. He meant, we have taken the new knowledge of 50 years of time and, under national survival pressures, and consequently the money that freely flows, we have applied it all to end-use products. What did this do to the well of new ideas?

Fortunately this was taken seriously in many quarters and, as you will see, our universities and the American structure of science reacted. Today the situation is quite measurably different. Instead of our preoccupation with how to make better and more products, such as how to make better cloth, how to make better castings and forgings and complex machines, we have gotten down to where we are competing with the rest of the world in this exciting field of the meaning of matter and energy, solid-state physics, and the high-energy physics, and the associated fields of microbiology, et cetera.

With this introduction, my definition of a scientist is a man who deals primarily with the generation of new fundamental knowledge. Whether he discovers it, or whether he creates it, we should not be concerned. We are concerned here with the end product. The scientist is primarily motivated by a desire to increase knowledge for knowledge's sake.

Now let us talk of the technologist who is often grouped with him and confused with him. The motivation is entirely different. This has led to heartburning in the Pentagon and in the military system, throughout the Government, and in many industries. The engineer has no such motivation. His primary motivation is to apply this new knowledge to the useful purpose of man.

Think of this, if you have not thought of it in your daily work and occupations, and see how differently these two people are going to react, then you will see why they had some of the internal problems of organization in the Manhattan District, and you will see why certain large industries have had their comeuppance in an effort to build R. & D. into their structures, because you are really putting two unlike motivations together, and this just cannot be done with a common plaster of propinquity. It has to have meaningful understanding on both sides.

Yesterday I had lunch with two distinguished men, one a scientist and the other an engineer, both in the NASA organization, and both highly placed. The scientist thought this was a good opportunity to state his views on how engineering education should be changed. It was an interesting discourse, but I am sorry to say I thought it impractical. I think he missed the essence of engineering education, and he was trying to do the job as a scientist would have to do it. There the education is so completely directed along the line essentially for research.

In practice, the engineer has frequently to operate vast systems. For example, he has to operate complex utility systems, and perhaps he has to be the city engineer. Perhaps he has to be the chief mechanical engineer on a railroad or an airline. Nearly always he has to deal with people. Thus you bring man into the engineering-technological field. You seldom bring man into the physical sciences. Man and his behavior appear in economics and the behavioral sciences, which are not true sciences at all; they are arts. Why are they arts? Because, gentlemen, we cannot truly measure their manifestations. As Lord Kelvin said, in one of the most perceptive statements, I think, ever made, "It isn't scientific if you cannot measure it." It is as simple as that. So remember now that the scientist deals with accurate, quantitative data within the limit of quantitative measurements, and hence science has progressed only as fast as its ability to measure accurately.

Once in the early days of atomic energy on this platform I used an example to give an understanding of this concept. Thus, if you had a 5-ton iron ball here and you heated it up from the room temperature until it was ready to melt, at, say, 2300 degrees Fahrenheit, or thereabout, you would put a tremendous amount of thermal energy into that iron ball. Sure, it weighed five tons when we started, and if Einstein was right, that E equals mc-squared the ball should be heavier when hot. How much heavier does the ball actually become? Twenty milligrams, twenty thousandths of a gram, and a gram is roughly one-five hundredths of a pound. Is it any wonder, then, that no one discovered atomic energy? There were no weighing instruments for measuring a five ton mass that accurately. You could not really develop an understanding of atomic energy until you had a means of measuring it.

This is what determines a true science. In the social sciences one seldom if ever, can measure phenomena in this sense. So we are compelled to assert our conclusions! Thus it has been said that social scientists can seldom find universal agreement from their colleagues. They suffer from the lack of a rigorous and inexorable mathematical proof for their conclusions and furthermore have likewise denied to them the experimental verifications so essential to all new scientific hypotheses. Scientists cannot quarrel about who is right and who is wrong. They have to run an experiment, and the experiment tells them who is right and who is wrong. This separates true sciences from the quasi-sciences, the pseudosciences.

It was popular 20 years ago to put the label, "science," on any academic area or discipline. This sort of lent it a new dignity. Gentlemen, it did not change it any. Do not confuse social science with true science. It is an art, a very difficult art, an art that has far more problems connected with it, because of its inability to measure what it does. You cannot prove the law of supply and demand. Why, an American president even suspended that law.

In the Roosevelt Administration it was no longer taught in many of the colleges. It was passé. It has, in some places, come back into somewhat respectable favor today, but for a long period it was expunged.

On the other hand, one cannot suspend the law of gravitation, or any of the laws of relativity. So, if you will have in your mind that the poor fellow who is struggling with economics and the so-called behavioral sciences and who is therefore working in a field of intangibles, which are far more difficult to deal with, you can realize why it has been said that if you lay all the economists end to end they would reach no conclusion. They have not, as you well know!

Well, then, we now understand why a scientist is a scientist, how he is motivated, and what is peculiar about his lifetime discipline. You understand that the engineer is now not a scientist. He has suddenly become, like the economist, like the so-called behavioral scientist, a man who deals with men and their economic needs. He has to run factories that are made up of people. All people are different. No two are alike. For instance, a man may do remarkably well under one type of operation and yet he may fail entirely under another. But he is still a man, and the reverse may be true for another man. You cannot deal with the real applications of engineering as though it were a science. You must bring intuitive judgment to the building of a bridge. But it may be said that is a scientific problem. We know enough about the science of stresses and materials so that a man can design precisely a bridge and know what it will do. Sure. But, will it pay off the bond issue? Will it be good for 40 years or 50 years? Will the population growth be such that it has ultimately to be a double-level bridge when it was originally designed for a single one?

This is a typical engineers job. How will the population grow? What will the kind of vehicles be that will go over this bridge in 20, 30, or 40 years? They have not been thought of yet.

The scientist has no such problems. He does not have to make those kinds of judgments. He can only speculate hypothetically, but the engineer must use economic considerations and build into the product many intuitive judgments. This the engineer must do. So, the engineer's motivation is different and his education and training must be different. It would be just as wrong for a scientist to try to draw up an engineering curriculum as it would be for an engineer to decide precisely how a scientist should be trained in his own discipline.

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All right. Now, we have passed through a definition and examples of our field. Thus, when you see science and technology put together in one lecture, as it is in this one, remember, we are dealing with two disciplines that are quite different.

We should not pass on without telling you my views of their role in history. The history of science, as exemplified by the philosopher who spoke here this morning, is now a respectable study for history professors. For a great many years it was not only not referred to adequately in history books but it was not taught in colleges. As an example I went through this period as chairman of an advisory council to an engineering college when the dean of the college asked the history department of that great university to put on a course for engineers on the history of science. The history department came back with a curt note saying, "The history of science is not a suitable subject for instruction." How they arrived at that conclusion is beyond me. It does not matter. So the engineering college dean said, "O.K. We'll have a history department and we'll teach it." "Oh, no," said the history department, "you can't have two history departments competing on this campus. This is ridiculous." So they agreed to teach the history of science.

After the first year the engineering class that took it petitioned that it be discontinued. The dean of engineering said, "Why?" "Well," said they, "It's a lousy course and it's taught even worse." It was because they put a graduate student on it who really did not know his field. So, again the dean said, "O.K., we'll go back now and have a history department." But the president of the university had to step in at this point, and he said, "We can't do that. Instead we'll do it right." So it was assigned to one of the most distinguished history professors, who is one of the leaders in this field now, and who was the first president of that new group of the Association of History Professors, for those who teach the history of science.

Today it is respectable. This professor who talked to you this morning used a great volume of interesting material to show you one of its underlying characteristics. But what he did not attempt to show you is perhaps one of the aspects of the subject that we are most interested in today. This is: What is its role in national power? What purpose brings you here today with your special knowledge and proficiencies? You are here only because science and technology has made it possible for you to use weapon systems which would never have come into being without scientific research and without engineering applications and which are instruments for employing national power.

That is obvious, you say. All right, let us speculate. Why was it that Greece never became a viable, major, powerful country, except in the extension of its culture? Not in its power. It was very ephemeral. Why? Why was Rome the leading power of the world for 960 years, and it never pretended to have the culture of ancient Greece? It merely borrowed from it. Why? Why was it that Germany, in World War I , [quite a small nation in terms of European population, or of Western civilization if you like,] was on the verge of winning a war against most of the great powers? Why did that small population, with very few natural resources other than coal and iron and forests, dare to challenge the great power history of industrial England, Pax Britannica, for 100 years, and the sleeping might of the United States, and then the power of France and the allies? How could this be done?

All right. Let us pass to another. How could Japan set out to dominate Asia? A nation that was relatively uncivilized in the modern sense as late as in the year 1, 000, while the mainland of China had developed the greatest culture of the world before even the Mediterranean Basin, from which our culture stems? This great culture of China, with its enormous population--how was it that a small island kingdom, with only 10 percent of its land arable, with no suitable supply of raw materials, was able to not merely subjugate this teeming mass in spite of its ancient culture, but in addition very nearly all the rest of that hemisphere and raise hob with the kind of weapons that we, the Western world, initially sent over there?

Many of you who fought in that campaign will understand what I mean. How? The answer, gentlemen, was not politics, it was not economics in the ordinary sense. In my thesis economics tries to explain the results from applied science and technology. Science and technology provides the products and services with which economics tries to deal. It is the application of scientific knowledge to the useful purposes of men that provides the national standard of living.

In earlier lectures in this College I have shown data taken from the United Nations which showed, strangely enough, that the standard of living in the civilized countries and many of the advanced Asiatic countries was quantitatively proportional to the amount of kilowatt hours of energy per unit of population in those countries.

That is, I believe, the result from applied engineering and scientific knowledge.

As you can see from the exhibits--which are designed to present the best quantitative information that I can find available to illustrate the points which will follow, you will have a chance to see for yourselves reflections of some of the things that have already been described.

Well, then, energy is the key to national power, energy applied through science and technology, in a free economy. This is what made the American production machine the greatest one in the world. This is what gave us the greatest standard of living in the world. This is what gave us the greatest economic power in the world.

Out of a nation of approximately 3 million people, in England, this is what produced the industrial revolution, when they found out how to build steam engines. The engines displaced the old system of home industries using muscular or manual labor with readily available thermal energy, one of the natural forces to be utilized by mankind.

Thus it was Newcomen's engine in the 1700's that started the industrial revolution which provided the means to produce such a vast surplus of wanted goods that British trade spread over the face of the world and the flag followed the trade.

The study of economics did not do it. The resulting economy was the product, and it was this economy that kept England in that superior position until the enormous might of competitive, scientific, technological civilizations in other countries thrust it into its present defensive role.

The Germans attained their power largely by finding out how to use British and French basic chemical science, which with the spread of scientific and technological education created that vast German industry founded upon synthetic chemistry which produced so many of the new materials which, as you know, are now the basis for enormous American industries.

At the time of World War I, the German use of technological trained people--of which they had so many more than we, plus the fact that their universities turned out so many more than ours--caused us to rely on them for many of our essential materials at the start of World War I, during which we then rapidly had to find substitutes. This led to the first great partly understood realization of that part of our national power in the United States that the role of science and engineering, and of research and development play in total national power.

If you will accept, then, this role throughout history of the constructive use of energy through applied science and technology, and likewise that of research and development, as the main force for developing in the civilized nations their respective positions as world powers, well and good. I doubt that one can find any other substitute. I do not believe it depends upon the political system. I doubt that one can find out how it happened except through applied science and technology and its new knowledge.

Now, I would like to talk about the enormous growth of research and development in the United States. You have heard it referred to this morning and at other times, and you will have it again in your courses. But I would like to put it in a little longer perspective. Because I am old enough, I can remember things personally that you may only read about. I can remember the famous House of Magic in Schenectady, the first modern type American research and development laboratory in industry. It goes back to 1903. In those days there was little money for the Federal Government's encouragement of research except in such instances as for the Bureau of Standards to develop precision measurements for legal standards, or certain work done in entomology on bugs and insects and other pests in agriculture, or for such studies as plant science and agronomy, et cetera, all with a specific economic point of view. There was really comparatively little done until World War I, after which we woke up with a terrific headache, realizing that we did not have the needed resources in these and so many other areas.

During World War I Thomas Edison the great inventor, was brought out of retirement, to try to improvise solutions to new needs necessary for the nations war economy. He was put in charge of a committee to try to find out how to get creativity out of the American scene in World War I. This all served to emphasize our deficiencies in scientific and technological endeavors.

Even at the beginning of World War II, in the years 1938 and 1939, when any thinking member of the Armed Forces, or when those who dealt with the Armed Forces or were in touch with world currents, knew that there was about to break a world war in which we would be involved, and before Poland was invaded, the total amount of money that flowed into the American economy for research and development was a mere $300 million.

In the course of World War II, due once again to the national defense needs, it rose to $1.2 billion, and then, at the end of the war, with the "bring the boys home by Christmas" epoch, Congress responded to cut off the funds, turned the faucet off so to speak, and government-sponsored research started to collapse. But industry had learned a valuable lesson. Industry had seen so much magic flow out of the use of Federal funds for research in World War II that industry did not have corresponding inhibitions. The Government went ahead with its research. Once again, when the Korean war hit us, we had the same problem all over again in our national defense capability--obsolete weapons, insufficient weapons, even unsuitable uniforms. General Marshall called some of us down and briefed us in the Pentagon about these conditions. The state of the equipment for that first Marine division that left from Washington to fight in Korea was deplorable. This seemed especially unbelievable, in such a rich nation.

Accordingly the Korean war then inspired a new and upward push in R. & D. which has never decreased since. Thus by now with the cold war it has grown in the typical manner of American enterprise to such a vast behemoth that Congress is becoming concerned. So, for the first time we are beginning to see a plateau effect in volume for some of the government-sponsored research.

I do not say this is bad. It is merely noted for your observation. It should be obvious because we are considering the structure of American science and technology, that there also had to be some educational response to this need or it could not have occurred. We did not have enough scientists to do what has been described. We did not have enough engineers to do what has been described. In fact we did not have enough laboratories, facilities, instrumentation, and other facilities. So the educational institutions of the United States, for the most part, although not all, responded. Some were so deeply involved in liberal arts disciplines that they felt no particular responsiblity toward the economy except to talk and write about it, so they did not institute efforts on their own behalf to add their great competence to the need of the Nation. Many institutions did, thank Heaven. I can cite Stanford Research Institute as an outstanding product of this reaction, with an annual billing of approximately $40 million of research a year, and likewise my own university with its laboratories in Buffalo, with $20 million a year.

These are amongst the top 10 with large laboratories for research and of course there are a number of others. It is pointed out that these are simply examples of university response to national needs.

Of course the universities had to educate and they had to provide these facilities for extended research, and, it followed that this was also the stimulus for enriching teaching, and for expanding the areas of teaching. For instance in 1945, there probably was not an engineer in the world who knew what nuclear energy was. This is 1964, 20 years later, and we will have in use at the end of this year one million kilowatts of atomic-power-generating-capacity, pouring its electricity onto the lines of the utilities, and by 1970 it is said we will have five million, projected. In addition we also have the atom-powered Navy !

There is not a senior engineer who carried this out who was educated for it. Think of the educational problem involved. When the General told you of the startling progress and the brief period for the doubling of knowledge, he automatically inferred that the lifetime of a practicing scientist-engineer is at least 40 years. But look back 40 years. What was he taught? He never heard about the revolutionary new field of molecular biology as an example. He was not really acquainted with the relationship and properties of atoms and molecules except in a very theoretical sort of way. Today there is no such thing as a scientist who does not take due cognizance of such basic knowledge.

Well, then, the educational institutions had a problem. We will leave it at that. They responded ably. The present development, since we are asked to talk about the present state of science, is that they have a further responsibility that has not yet been suitably discharged, --and that is postdoctoral education. This means that our existing crop of Ph. D.'s--and I am sure there are many in this audience--as educated today, are going to be unable to deal with the advanced problems of 5 years from now--certainly not even for 10 years from now.

It was Dr. Eugene Vigner, the famous physicist from Princeton, who, in his annual address I believe, in 1947, /if my memory is right/ before the annual meeting of the American Association for the Advancement of Science, said, in effect, "Gentlemen, this is a revolution in our knowledge." Remember now, the atomic bomb had burst, and atomic energy was out in the open for all to see from the Smythe report, and so he could talk about it. He said, Do you all realize that until the advent of the nuclear sciences and sub-particle physics, there were scientists /he was certainly one of them/ who were competent to understand and to deal with almost every branch of the physical sciences. There could even be a one-man all-around researcher. But such a day is gone. The scientific field has proliferated with its vast, new knowledge, so that there is no such thing as the all-around competent scientist.

Now, if this were true in 1947, recall what the General just told you and imagine what is true today. So, in science and technology the shift has been largely from the mental giant, as a creative discoverer, such as the Galileo's, the Issac Newtons, to groups or teams of scientists complimentary to one another and working together. Therefore such men have been largely superseded. Even in such a theoretical area as to how the cosmos was created, the theory of the steady-state cosmos, was developed by three men, one a mathematician, Bondi, one an astronomer, Hoyle, and one an astrophysicist, Gold. Those three British members of Cambridge University faculties together developed the theory of how the cosmos not alone was not created under the big-bang theory at a point in time but instead the cosmos is continually undergoing creation, and this helps us to understand the red shift of galastic light and the fact that all great galaxies are moving away from us at speeds directly in proportion to their distance from us.

If it takes a team to come out with such an advanced theory, think what an array of specialists it would take to prove the theory, and then think what it takes to make the theory work experimentally. This is, in part, the structure of science and technology today. It is obvious that curricula in colleges have had to undergo vast changes in order to try to deal with such progress. They are somewhat like the Red Queen in "Alice in Wonderland." "She ran as fast as she could so that she would stand still."

Now, another important factor in present-day science and technology is the need for scientific intelligence. In serving with the first Hoover Commission for the Reorganization of the Federal Government as a member of the Eberstadt Committee which dealt with national defense, one of our most critical findings was that America was moving blindly ahead without having access to the vast outpouring of scientific knowledge available from the older countries of Europe, including Russia. So much pressure was brought on the then CIA that it greatly developed the gathering of worldwide scientific intelligence by that organization, leading ultimately to the Library of Congress being charged with the responsibility of translating Russian and important foreign language papers and having them available for American scientists, engineers, in government and industry.

There is a third element of the problem as yet insufficiently solved--namely, how do you get this vast, niagara of information out to the men who have to do the work, particularly since there is no such thing today as the all-competent scientist or all-competent engineer. If a man gets a new idea he should be able to go specifically somewhere to find out what the rest of the world has done in that region of his new interest. He cannot be content to just sit in an ivory tower and speculate on the problem. No, no. Then how and where does he go? The Library of Congress is set up to try to solve this.

Let us turn to science's old and new role in government. All of you must be aware of this. So today, we will not dwell on it. The President has had to call in a standing Scientific Committee to advise him. Never before had the scientists ever operated on the level of the presidency. But he came to realize he could not make some important national decisions with confidence without the advice of men competent in scientific and technological fields that were unknown to him. After this development, /as we have seen in the last year/ Congress is grasping for the same aid, and there is an attempt to set up a mechanism within the House and the Senate that will advise them on the various aspects of the impact of science on the Nation. Amongst other matters, this approach is designed to deal with the ever-blossoming demand for research and development money in all directions and the efficient use of such funds in the national interest.

As the speaker this morning told you, you with your mythical $10 million to personally invest have got to select out of the pressure for the solution of a whole host of problems that are before your attention, just where you are going to put it for your development program. You are not going to be able to cover the waterfront. So Congress must deal with this problem on a vast scale. How then do they as nontechnically trained lawmakers, decide in the national interest which part of the experimental roulette wheel to put their money on?

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At this point, and particularly with respect to the national defense, I have to say something that I firmly believe in, but which is an important criticism. Thus when the scientist was apparently discovered by the Defense Department, say in about 1946, at least as to his critical role in defense weaponry, he was assigned to somewhat of a high-level consulting basis with military policymakers as well as to advise the civilians who in turn lorded it over the military. But, as the technological accomplishments of research and of industry poured forth, and as the battle for funds for these tremendous weapon systems some of which were brought in by the outer space age with all their sophistication required a decision, I am sorry to say that, in my opinion--the military with their lifetime education and practice in their own art, yielded some of their power of decision to the scientists and the engineers. Again in my opinion this should never have been done. Such specialists cannot function either as cure-alls, nor can they be know-alls. They are merely men who possess a vast amount of theoretical and practical information perhaps not generally available to you in the course of your experience. Their valuable contribution should be used by you as the military leaders. I am assuming that this student body will some day be flag rank and that you are going to have this problem to deal with.

Do not misapply the scientists and the engineers. Do not overrate them and likewise do not underrate them. I think today in the defense area that the scientist and the engineer have, at times, been allowed and encouraged to take away a responsibility that is properly your own! They have been asked to decide, instead of to advise.

Another thing that should be mentioned about science today is the peculiar shift that has occurred in the scientific disciplines. Years ago when one studied physics, the physics book was divided into isolated divisions or chapters. For instance one was a chapter on mechanics, one was a chapter on light, one on sound, one on magnetism, one on electricity, and so on. It was not known, nor ever inferred that light is like any of the other phenomena of physics, or that sound is, or that any of them were manifestations of the others. They were presented as special phenomena of nature which the physicists dealt with, unrelatedly.

The chemist had a somewhat similar problem. But in time there grew up physical chemistry, which had one foot in physics and one foot in chemistry. It took some time before physics grew up into biophysics, with one foot in the life sciences and one in the natural sciences. So, of course, biochemistry grew up likewise.

Similarly even geology comes into the act, and you now have a science dealing with the biology of geology. It has an important significance to the oil industry--biogeology in the prospecting for new oil resources. But one also has a combination of physical geology, called geophysics, and this is used in the new method of exploring for minerals, by for example precision magnetometers. These are flown overhead in aircraft. Then too we use explosions to make seismic repercussions to be recorded, measured, and analysed. The boundaries that separated the so-called disciplines have merged, from where a professor of physics might hardly know his colleagues over in the chemistry department, or who seldom shook hands or even knew who were on the same campus as professors of biology. Perhaps they greeted each other at a faculty coffee hour, after which they rapidly moved away and went to their own colleagues and chattered.

As we view science today in the American scene, we can observe that science has lost its old traditional boundaries. It has lost its separatism, and there is now an all-pervasive growth of fundamental knowledge, and this is leading to some of the greatest challenges before mankind. This will revolutionize human life as well as national power.

Perhaps another thing we can say about the science of today is the fact that you cannot rent a small office, buy a shelf full of test tubes and a Bunsen burner and maybe a little retort and a few beakers and be in business. We have to have sophistication in our equipment. The scientific instruments of today are simply fantastic and in many cases extremely expensive. The new techniques that are required in dealing with present-day science are such that, instead of a little microscope here, which might cost about $100, one must have an electron microscope, and with it one has not alone the cost of this instrument, which is in itself quite formidable, but one has to be well trained in the art of what it means and how to use it.

This is only an example. When one considers the field of high-energy physics and with it the fundamental explanation for the behavior of matter, one is into something that I find pretty staggering--the so-called atom smashers, --which we can consider briefly in a moment. Let us agree, then, that the fact is that a scientist is no longer content with a bit of floor area and some odds and ends of glassware. If you are going to do sophisticated work in R. & D. your budgets had better be very realistic about the tools you are going to give these gentlemen to work with, remembering again Lord Kelvin who said: "If you can't measure it, it isn't scientific." Now one has to measure things that are in the order of one billion to one. It is desirable to measure the constituents of air pollution in billions of parts. Similarly it has been necessary to measure true alloys or pure metals which have fantastic strength when they meet such terms of purity that could never have been conceived of until modern instrumentation and methods were available.

We have already said that modern scientific work requires men of many disciplines, and we need not elaborate on that, because, with this proliferation of sciences, a pure physicist is not enough. A physicist in what? Optics? Radiation? Cosmic rays? Solid state physics? Et cetera.

As a concomitant of that situation, there is a proliferation of scientific and technical societies. If you were operating in this field, your mail every day would be loaded with enticing, seductive requests to join these marvelous associations and meet with your betters. Of course all of them have annual meetings and semi-annual meetings and local meetings. If you laid these all end to end, you would find, if you joined the ones of your interest, that your wife would have good grounds to sue you for divorce because you would never be home. They are holding meetings all the time. If you look at the titles of their papers you find all of them of interest, and presenting great challenges. Perhaps you would drool at the prospect of so much of this new knowledge which you might wish to get your hands on, but the total supply is so vast, for this is the array that the General presented to you, namely that this is one of the characteristics of modern-day science and technology.

How does one deal with this? How does one select from this enormous body of information organized into professional societies? Back in 1922, when the American Association for the Advancement of Science found that only two scientists from the far west came to the Chicago annual meeting because it took so long to get there on the railroad, they felt the need of some equivalent body on the Pacific Coast. They found that there were 56 separate scientific societies there even in those days. These had to be banded together to make the Western division of the American Association for the Advancement of Science. There are said to be over 560 in the United States now.

All of this rapid discovery of new scientific and technological knowledge brings out the fact that postdoctoral education is the unsolved need which is beginning to be tackled by the leading universities. Recently in connection with a campaign for money at one university it presents the urgent need for a $4 million wing tacked on to its existing chemistry building; a building which is already one of the largest chemistry buildings among the colleges in this country, thus adding 50 percent to its space. One of the stated reasons for this was the need for postdoctoral education. This means that if a chemist graduates tomorrow, it is assumed in 5 or 10 years he has got to have access to the men who are in the stream of new knowledge, so that he can go on from there. This is the "PPh. D."

As to the great cost of research-and-development facilities, no one knows better than the Government. A good example is that the Government got involved with providing a single instrument at Stanford University that costs $110 million. One could do quite a lot, in any department of the military, with $110 million. But this is only a single instrument. It is called a linear accelerator. Naturally other colleges came in with requests perhaps envying their rich neighbor, thus the one at Harvard-MIT, and that of the University of Pennsylvania, in connection with Princeton, and the one at Cornell, et cetera.

A committee of scientists was put together which follows, of course, the standard procedure for unusual problems in government, and it was put under the chairmanship of--guess who--a Harvard professor, also a nearly standard procedure in Washington these days, and out of this came a very perceptive report. It was a scientific report by scientists, not by economists, nor by engineers, just top drawer scientists. They forecast the needs in such instruments for research in high-energy physics up through 1980.

It is interesting to reflect that by 1975 the cost of supplying such instruments, manning the instruments, and the provision of supporting facilities is two-thirds of $1 billion per year; for basic research in this field only. You see why Congress needs some sophisticated scientific advice.

Another consideration is that there is a new idea growing up in science and technology; namely, the research center. It is interesting to see how this developed, apparently by accident, like the case cited earlier today of discovery by the man who tripped over the rock and found a new species of bug under it. Nobody seemed to have planned it. It just evolved. The Government put all that money into the radiation lab and into the Lincoln lab at Harvard and MIT and, when the end of the war came, there were a lot of professors who had demonstrated creativity operating under those Federal funds, and it seemed they thought it would be a good idea to go out and make some instruments and technical devices and sell them in the market place, and thus supplementing their professorial incomes.

So up sprang Route 128 in Boston, a phenomenon throughout the United States! Today there is a similar phenomenon around SRI out on the Pacific Coast. There are lesser phenomena of this kind in other areas, but these are certainly two outstanding ones. So it was natural for Congressmen to become interested for their respective areas. Likewise progressive presidents of universities who think in these terms--although some do not--and so men of the caliber of Doctor Lloyd Berkner, who was on the Advisory Board of this College, were called down to Texas to found one. There local business and community leaders promptly raised nearly $5 million almost overnight merely to start it. Another of the many interesting cases occurred out in Minneapolis. Lead by the president of the university there and of progressive local leaders, they noted that they were in an area of the country that has had a declining industrial population basis. They concluded that "if we don't do something we are going to be the forgotten part of the United States." So it was the president of the great University of Minnesota who is reputed to have said, "There should be a facility which can do research and development not appropriate to the educational process but which needs an interaction with an educational institution." Many believe that he could not be more right!

This is a relatively new development in American science and technology. It assumes very plainly that there are things which shouldn't be done on a university campus, but must rely on proximity to higher education. Some colleges and areas have not yet discovered this, but they probably will be forced to, in time.

Now I think the time has arrived for what is called the seventh-inning stretch which in this institution is the coffee break. I'll merely conclude now with one other aspect of modern U. S. science and technology. These considerations which have already been presented are a baker's dozen of 13 topics that concern themselves with what is the structure of American science and technology. It would take several more lectures to describe how differently they may do it in certain countries in Europe and why the differences exist, and so forth. That would be immaterial for your study today.

Let us merely say that the 13th consideration to be presented--others could be added, but these 13 in my analysis are the principal ones--is that of the universal use of so-called computer mathematics, computer operation, and computer application, leading partly to true automation, as apart from the more common industrial automation, where it is integrated into improved tooling and improved machinery. It is becoming quite common that many machines and industrial systems are directed by computers.

This phenomena has become an economic playground, and the economists have drawn many different conclusions with respect to it. Some say it displaces labor and it therefore should be limited. This sounds like the myth of poor old King Canute, who was wheeled in his chair down to the sea where he tried without success to prevent the tides from coming in. Well, the tides came in, and there is not any economic force in sight, or a socially-oriented economist, who is going to stop this tide, no matter what his theories are. But the interesting thing is, history has not supported these views. Automation has not displaced total labor, although labor unions will give you some very fine arguments on how it does in specific instances.

All of you are no doubt familiar with that type of logic which tries to reason from the specific to the general; and let us be on guard for this can be a booby trap. Some ancient philosopher also said, "All generalities are false, including this one." Be on your guard. Be on your guard.

I leave this thought with you, that the mathematics behind the computers, the micro-circuits that are inherent to computers, the utilization of currents of electricity that travel 186,000 miles a second but which have only a few feet to go make it possible to do computations in millionths of a second that would require many man-hours of labor and which otherwise never would get done. This concludes our baker's dozen of the major elements of the structure of science and technology in the United States today!

Now I think the seventh inning has truly arrived!

COLONEL LEOCHA: We will have a one-minute, stand-up break.

MR. WARD: Gentlemen, I feel I owe you an apology. Each year I have come down here, and it is a lot of years, I try to deal with the lecture scope that I am assigned, and I find it is not only a great challenge but a task with a wide horizon. These are not little looks through a small window. I find myself always, like the story about the fertilizer salesman, full of my subject. He was asked to speak to his annual convention, and the subject assigned was humus fertilizer. So when the secretary of the association introduced him, he said, "Gentlemen, I give you Mr. So and So, the Vice President of Such and Such a fertilizer company. He is going to talk to you on humus fertilizers, and, believe me, gentlemen, he is full of his subject."

We are going to have some slides. (Slides were used during the lecture; not reproduced.)

The first slide--we have only a few seconds apiece to look at these--shows you that the United States, with 1/16 of the world's population, has an output of 1/3 of the world's energy in the form of electrical power. How much more it has got from mobile and isolated automotive energy plus a lot of other kinds, is not on this chart, but this indicates to you why we are the leading economic power in the world. Statistics gathered from the United Nations several years ago, support the remarkable correlation between power consumed per unit population and the national standard of living for all industrially civilized countries.

This slide (slide 2) shows our present energy sources from 1850 to 1962. As you see, anthracite coal, once great, has practically disappeared. Wood has likewise disappeared. Bituminous coal is becoming a smaller percentage, although due to our great growth about the same tonnage per year. Natural gas and oil are splitting the balance. Away up at the top of the chart, in spite of Mr. Udall and these vast water power appropriations, there is a declining percentage in the form of water power as with coal, although the total output of water power has increased.

Atomic energy does not yet appear, nevertheless it is the fact that, if this was the way it was going to be in the future, our civilization would in all probability be out of luck in 100 years and we would be on the way back to living in a cave, wrapped up in a fox fur and searching for food as did our ancestors who only had their muscles to rely on. We would be running out of available, economic sources of energy, except perhaps for power from water, wind, and wood.

To me this slide (slide 3) is symbolic! I believe that a whole lecture could be made on the principle underlying that one curve. When Edison built his first electric station it took 19 pounds of coal to make a kilowatt hour of electricity. Think how rapidly this would use up world resources of coal. This exhibit could be described as an engineering curve, and I hope you can see in it a characteristic that is inherent in the development of all your weapon systems, whether it be airplanes, missiles, tanks, or naval vessels. The same characteristic underlies there all. We will try to demonstrate it by exhibits from the U. S. S. Nautilus.

On figure 3 notice that the number of pounds of coal per kilowatt hour have come down on a sort of logarithmic mathematical curve. This chart says that in about 1963 it takes .86 pounds of coal per kilowatt hour. In Dr. Philip Sporns' testimony recently presented to the Joint Committee on Atomic Energy he states the next station of the American Power and Light Company will be designed to do it for about .65 pounds of coal. Now, if one thinks of this as small progress, and thereby related the two-thirds of a pound of coal to roughly the seven-eighths of a pound of coal, per kilowatt hour for 1963, he would see the number of billions of tons of additional coal in the world that would be made usable for energy generation by just that degree of engineering development.

But the point is, that engineering progress is evolutionary, because engineers do not ordinarily deal, like some scientists, with breakthroughs. They deal with measured steps of proven development. This development involves steam pressures in plants never before used commercially in boilers supplying in some cases steam at pressures up to 5,000 pounds per square inch. Imagine what conditions the boiler tube has to meet when it operates at red heat; at a temperature which would immediately destroy the integrity of the materials available only a few years ago.

Thus it involves engineering developments and taking advantage of the research constantly going on in scientific and technological laboratories.

Figure 4 is interesting, because now we are viewing the enormous growth of R. & D. It shows the preponderance of Federal funds expended for research, as well as the importance of funds from industrial sources, and lastly it shows the funds from universities and nonprofit sources.

You know from your studies, that probably the most important sector can be that little share at the top of the graph. It is the part where creativity and discovery is high, and which often develops the basis for the applied research and developments of the next 10 years. That is what we were so terribly weak on back in the World War I period. It was the product of education and research in the foreign universities that fed us with much of our then new knowledge and ideas. (Slide 5)

This shows the sources of R. & D. funds and where the work is done. Of course the colleges cannot put much money into research, and the nonprofit institutions cannot, either. But they generally put part of their earned fees back in, because they are not allowed to make a profit.

Again we see what industry puts in as well as our government. Now let us review where and by whom the work is done. Industry performs three-quarters of the R. & D. This is where the limitations placed on procurement policy comes into play. A lecture could be given on how certain regulations make it hard for industry and even universities because of the sometimes severe inhibitions placed over government procurement procedures. It is indeed a tribute to all concerned that it works as well as it does. When shortly after World War II ONR went out and supported basic research in our colleges it then received a severe setback from Congress and others for daring to put money into our universities without having in advance a commitment to deliver. This set back some of our greatest developments, one of which has since led to supersonic aerodynamic knowledge. This apparently occurred because ONR could not prove, by scientists doing some advanced research that they were going to solve the problem.

We find that the universities do play quite a key role. On the chart this is indicated in the righthand figure when one realizes that the amount of basic research as pictured there, is performed largely by our institutions of higher learning.

It is only fair to point out here that statisticians are dealing with a precise mathematical form in an absolutely unprecise area. Anyone who thinks that he can gather such statistics precisely is indeed very naive. The study and the report on the NSF shows the problems they had in trying to define these areas. There is, indeed, much food for thought in this attempt to portray, graphically and consisely, the complexities represented by the R. & D. effort in the United States which is said to be more in volume than all of the rest of the world put together.

Figure 6 shows by a logarythmic curve, the historic rate of increase for Federal funded R. & D. Notice at the top the rate is starting to flatten out. This is because of the pressures reflected by Congress, which has become more concerned against further large increments in the R. & D. funds.

In Figure 7 we have a different view of the historic use of R. & D. expenditures from Federal funds. We saw on that last slide the effect of World War II and the Korean war, and the effect they caused. Here you have research and development expenses as a percent of the Federal budget. This means that political forces took cognizance of the role of research and development and responded to it, which they had not done prior to the World War II period, or prior to World War I. Note that they now represent nearly 16 percent of the Federal budget.

Figure 8, here are Federal obligations for R. & D. by performer. This one is an interesting one because it shows the division amongst the principal Federal agencies. This 71 percent represents defense in 1963. If we had such a graph up-to-date, say in 1965, what do you think we would see? We would see that defense was much less than 50 percent and that NASA would be 20 percent bigger than defense.

This shift in emphasis will all occur in a 2-year period.

One development that brought on the Congressional irritation was the Health, Education, and Welfare, even though it does not show to be more than 11 percent on the chart. However, it grew so fast that it has been reported to have brought in considerable inefficiency in the effort. Seemingly the availability of trained researchers and existing facilities could not be found to match the available funds.

Figure 9 shows the trends in Federal obligations for basic and applied R. & D. This may not be too obvious but it can be readily observed that the expansion of the basic research curve, even though appearing small on this chart, percentagewise was much more significant with the trend in applied science next in order and development a poor third.

However it does show that the engineering development is far greater in total effort than the combined basic and applied science role. Before production is attained it is even greater than that, because this exhibit is concerned only with R. & D. The bulk of the engineer's effort is not on the chart such as where production tooling and process engineering is involved.

So when one thinks in terms of scientific manpower needs and needs for engineering manpower, one must have much more in mind than for R. & D. alone. It is necessary to look at all the other things the engineer does that the scientist does not do including all the work until the product is put in use and serviced.

Figure 10 is one of those busy charts that I rather deplore. But it does show many things. It shows what you must already know, namely that for the first time defense is going backward in R. & D. It also shows the vast increase in R. & D. for NASA, which we have already referred to, and in which one can see fantastic percentage growth. There is nothing approaching it in the defense picture. But, of course, defense started from a higher level back in 1955 than NASA did. But even so, the chart shows how the political trend has developed for funds for R. & D.

Now if one looks next at the AEC, one sees another dying mammoth. Only recently the huge AEC laboratory operation at Hanford, Washington, has been ordered to turn that vast laboratory facility over to private enterprise. The operation of the facilities is being surrendered by the General Electric Company where it has been an annual cost-plus contract. This has led to the novel result that a nonprofit laboratory company the Battelle Memorial Institute, has accepted a contract to run such an R. & D. group whose annual budget is $36 million, and to take all the risks involved even though it has only one customer.

No other organization would meet the bid on it. They could not afford it. Even the largest corporations in America felt that they could not afford to take on such a vast risk in spite of the obvious advantages.

This is a new development in the field of technology and science in the United States.

Figure 11 concerns itself with manpower considerations. It is interesting to note the percentage of the labor force that science and technology now represents. Note also the rapid percentage growth. Now, 4. 7 percent is not big in terms of 100 percent, but it is a very significant increase from 1. 5 percent in this brief period since 1940. It has meant educating people, developing educators who can do so, and expanding our universities, which can be very difficult to expand, particularly since so many of the best of them are privately supported.

At the bottom of the chart you will notice something that is left out of so many discussions of this subject--namely, the technicians. What are technicians? They are the expert highly trained craftsmen who first carry out the work of the scientists and the engineers. The electronics industries utilized them more wisely and more fully than most of the engineering industries. These are men who do not have, for the most part, university degrees, but who have technical aptitudes. These are people who can do things with their hands, who have good three-dimentional imagination and sufficient academic aptitude to deal with the mathematical and scientific concepts, even though they cannot originate them or even in all cases understand them. But they can communicate with the engineers, and they speak the engineers' language. They are an important element which Russia has utilized to the full in that vast education system of theirs, where there are as many institutions training technicians, called Technicums, as they have in all their universities. This is believed to be a major factor in how Russia made her great stride from serfdom to a modern industrial complex in a few decades.

Figure 12 is a worrywart chart. Here we analyze the trend in supply and demand for the scientists and engineers for 1960-1970, by the NSF. What do we see? We find that the ratio of scientists to engineers has been greatly changed with the result that we are staring ahead into a vast shortage of trained engineers and a surplus of scientists.

If the children now in school knew it, it indicates that the field is more open for the future to the skilled engineer than it is currently to the skilled scientist, but, because the press calls nearly everything that occurs nowadays a scientific achievement, even when it often may be almost a pure engineering achievement--this leads to much confusion.

This has led to a great misunderstanding by the high-school vocational advisers, and by students themselves from reading non-technical magazines and the press. This is already serious.

On figure 13 we see the year by year figures for the supply of scientists and engineers which underlies the totals reflected in the previous figure. It reveals the fact that the already short annual supply of engineers increased by 18-1/2 percent while scientists increased by 105 percent. It used to be said that it takes three engineers to put into practice the work of one scientist. The problem this presents should be obvious.

Figure 14 shows a percentage distribution of funds for R. & D. by source and industry. It is interesting that only two industries shown have to use more government funds for research than they have funds of their own. We also notice that one of these is electronics, and that the other is missiles and aircraft. This hardly deserves comment.

However it is interesting that a huge industry like petroleum, which is truly enormous, as well as worldwide in its operations, supports almost wholly their own research and development, although they take some contracts principally to cooperate with the Government. Thus when the Government feels it cannot get anybody with all the capability as competent, then they do it.

Figure 15 was done by a scientist for the fifth Coleman lecture at the Franklin Institute. This is the way a scientist sees it. It expresses a very interesting and profound idea, but I will try to point out in a minute one of its limitations.

Back in history at the time of the great British scientist Farraday, who was the discoverer of electromagnetic phenomena, no one knew how to make a device to exploit it. It was 40 years from the time he discovered it till the year it was commercially used. That is the year Thomas Edison built his first electric station at Pearl Street in New York. There were no companies using commercial generators of electricity and there were no commercial motors or electric lighting in general use. Edison accomplished that, 40 years after Farraday developed the underlying science.

Now, let us turn to the present. Look at radar on the chart. You are familiar with the work originally done in the Anacostia Naval Laboratories in the twenties, when they first detected electromagnet wave echoes. It is said at that time $15,000 was requested to exploit this discovery and it was turned down, because there was not seen any end use for it.

Now we all know that it was Watson Watts of England and his associates who developed the radar that was used in connection with World War II to defeat the German air blitzes. For this he was knighted by his grateful government. This also shows the value of an ally particularly when it is an intelligent one. This took less than 20 years from discovery of new knowledge to explortation.

Thus we notice the shorter time it took to reduce a pure scientific finding into an end product of vast significance. Time marches on and now let us look at transistors which are semiconductors. The scientists had no sooner proven their existence and explored the technique involved in the Bell Telephone Laboratories than within that brief period of less than 2-years, they found their way into commercial products. This illustrates the present pace of science and technology.

The same speed up of the process is true of artificial diamonds which were developed and exploited by the General Electric Company. Now we have got super-conducting magnets, the new application of cryogenics with its vast implication in so many new directions. Let us note here that almost from the time we discovered a superconducting phenomenon we were building more powerful magnets than ever before known, and using them in laboratories in developing further the new science of high-energy physics and hydrogen fusion.

The scientist, because of his training is inclined to see events either as black or white, unlike the engineer who is dealing in a gray vista all the time and is not sure which way the light is coming from. The scientist drew these precise boundaries on the graph, which I think are like the statistician who wanted to cross the river and after looking the matter up, saw that it was 4.1 feet average depth, and so he attempted to walk across and drowned. Notice that about the point on the chart, in the 1960's, you are going to be able to apply something the minute you find out about it. That includes the time for going through research and development and merchandising and what not. If you go beyond that point on the chart, you will be applying things that you have not even discovered yet.

I purposely made a slight joke of this, even though I think it is a very serious matter and deserves very serious consideration, since it shows one of the outstanding characteristics of modern-day science and technology, namely the speed with which scientific knowledge is beginning to flow into end products. This does not reflect fully developed weapon systems, which are something else again. These are both devices and complete systems for employment tactically.

It is now time for a conclusion which I would like to state as follows.

Political aims--economic capability--and military capability and readiness--will determine our future as individuals and as a nation. Only by a sophisticated and progressive science and technology will our national power be preserved and developed to a recognized level such that we can remain free to pursue our destiny.

COLONEL LEOCHA: Mr. Ward is ready for the first question.

QUESTION: Mr. Ward, there has been a lot of criticism recently both in political and scientific circles about the Apollo Project to land a man on the moon. Would you care to give us your opinion of the usefulness of this?

MR. WARD: Yes, I would. This goes back to an old economic saying--if you can't afford it, don't do it. Now, the question is: Can the United States afford the Apollo Project? In terms of our economic strength of over $600 billion annual gross product per year, the cost of Apollo is still peanuts, provided Apollo has sufficient raison d'etre. I remember when the Navy began to spend money in the Antarctic, and Admiral Byrd was out trying with his hat in his hand to get support for that work. Any number of people said, "What's he doing down in that God-forsaken place? It has an ice cap two miles thick. One can't live down there."

But look at it today, if you are politically interested. One of the greatest innovations of modern political history has developed out of it. It is a treaty between enemy and friendly countries and neutrals to make that an international land, under treaty. All the old, predatory efforts by the South American nations and New Zealand and Australia to show that they owned it, because they were north of it, have been nullified.

But, if you are interested more than that you come to this point. They have discovered some fantastic mineral resources in that area. This is a great coal area. You may ask, "How did they ever get coal under all that ice?" Of course the answer is that the Antarctic back in those days was where the Equator is now. Antarctic had a very nice, salubrious climate. Probably it was even a tropical climate. In addition to full deposits there are potentially valuable mineral resources in that area.

Lastly, it is the seat of accurate knowledge of weather formation. The meteorologists firmly believe that before too long you will have not alone short-range forecasts of tremendous accuracy but you will have long-range forecasts of accuracy. It will come about only with the knowledge that we are developing in the Antarctic, which will have to be supplemented by some other areas; but that is what is claimed will bring it about.

If you say that long-range forecasting has no economic sense to it, that it is not valuable to agriculture, and it is not valuable to economics, I think it is like the ostrich with his vision blurred by his head in the sand.

What then is my reason for bringing up the Antarctic? Because when Byrd went down there nobody knew any of those things. Similarly no one really knows what Apollo on the moon will find when they get investigating up there. There are some people who say, "Oh, well, it is a wonderful thing, because it will settle a great many questions that have bothered people who are concerned with how the universe was built, how our planets came into being and the probable life-duration span on the earth and the sun." They see all kinds of potentials. You cannot prove any of them until someone goes up there. One cannot even prove that there are mineral resources there, and that if there are how they can be gotten out.

But when you think that one pound of uranium, if it could *produce the energy* efficiently say by 100 percent of its mass, represents 11 billion, 400 million kilowatt hours, and if you look at the tremendous progress through direct conversion of energy without going through the older thermal cycles of the steam systems and the jet systems, and when you see the progress being made in commercial and government laboratories on at least five basic approaches toward direct energy conversion, then this question of getting to the moon and back cannot be based on the kind of computations and energy sources that are used in such computations today. All these matters to hand-in-hand.

So I say--and this is only my opinion, for which you asked--that this country, leaving out national prestige, which I think is enormous, is rich enough to afford that. I think that in doing it there will be not alone a tremendous number of new knowledge discoveries, but in the long run, like Antarctica, with economic implications as well, I believe in it.

QUESTION: Mr. Ward, do you visualize any future military requirements in space?

MR. WARD: Yes, I do. If there were not anything to it but developments like the Navy satellite system for better navigation, or things like the Air Force satellite system for global intelligence, /to use the proper word/ and if there were not anything beyond that, I would think it was justifiable. But on top of all of that is the commercial end. I would enjoy giving and expanding for you my views on how military research breeds commercial products and strengthens the commercial economy. COMSAT was just financed in Wall Street, and what happened? So many people tried to buy shares in COMSAT that the stock went up by a fantastic amount, and the conservative professional people on Wall Street said, "Hey! Not so fast. We are not going to pay any dividends for a few years." But AT&T said that it would cost approximately $1.2 billion to do with traditional systems what one COMSAT system can do for a maximum of $300 million.

Now, if you can get payoffs like that, you have got tremendous commercial interest, besides which, if you are a philosopher, you can say that it will bring the countries of the world closer together. We will be seeing each other's television programs--sometimes God forbid, but we will. There will be an exchange of cultures. So I say those are the direct benefits.

On top of all this is the need to develop defenses against enemy offensive space weapons systems. About actually using space for a fighting weapon system, this is a little more difficult to prognosticate at this moment. I would rather say that if you do not do anything more than what I have discussed, you have got a big plus.

QUESTION: How would you suggest that we change our DOD procurement practice to effect improvement and utilization of R. & D. funds?

MR. WARD: Well, I believe I could answer it very nicely to you and very unpopularly to many. First off, as procurement agencies, you have got to get rid of a lot of the checks and inhibitions that are thrown around your work presumably to protect the Government. Procurement officers should be permitted to use more judgment, and to have less fear of the need for substantiation of things that go wrong. They must feel that they will be backed up on this.

That is No. 1. No. 2, after a research team is selected and the objective has been properly stated you do not turn them loose. You then proceed to monitor them in such a way as to restrict their efforts in many ways. What that does is sometimes unbelievable--to the overall cost and to the desired accomplishment. It sometimes inhibits to such an extent that it also serves to prevent some of the best brains from working on the project. Many creative types will not work under those conditions.

It so happened that I was asked to address a meeting some years ago at Wright Field, after I got out of my then aviation company and at which time I was a free agent. The address was on the subject of your question. I had the time of my life. I said, "I do not give a darn what you do to me. I'm not here to get any contracts. I'm going to tell you how it looks now from a long period of working for you and your behalf." The points expressed were some of the things that I was able to develop as facts by using specific examples. We would be told to do a certain thing--and in that day it was much more down to earth than what we are talking about nowadays--then after we had been given the job and the specifications for it, as an example, we would be told, "No, you must not use that alloy. You must use an A&N alloy of such and such." Well, you see, the A&N Standardization Boards had not gotten around yet to adapting this new alloy to their standards. But the procurement regulations stated, "You must use A&N standards and materials." In such instances the contract objective would be defeated because we would be forced to turn backward toward a lower level of performance and often a higher cost.

This is what may occur when you try to tell a contractor how to carry out his job after you have strictly defined the end objective. For Heaven's sake, do not select the research team if you do not have the necessary confidence in it. You can always find out who is reliable by the same system that engineers use--cut and try. Thus if you give a contractor a job and he does a poor job you do not give him another one of that kind.

This is a far better insurance for getting satisfactory performance than by some of the methods you now have to use.

COLONEL LEOCHA: Mr. Ward, you have indeed acquitted yourself as a new faculty member. Thank you for an inspiring lecture.

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