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SCIENCE AND TECHNOLOGY IN THE UNITED STATES TODAY

Mr. J. Carlton Ward, Jr.

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Reviewed by Col. R. W. Bergamyer, USAF on 18 October 1963

INDUSTRIAL COLLEGE OF THE ARMED FORCES

WASHINGTON, D. C.

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SCIENCE AND TECHNOLOGY IN THE UNITED STATES TODAY

18 September 1963

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Reviewed by: Col. R. W. Bergamyer Date: 18 October 1963
Reporter--Grace R. O'Toole

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GENERAL STOUGHTON: Gentlemen: In furtherance of our objective in Unit I in order to establish a foundation for the balance of the curriculum, we turn our attention this morning to the fields of science and technology.

It is staggering to one's mind to look back over the last 20 years and see the progress that has been made in these fields. Further, if we look forward to the future you can really let your mind run rapidly over what might happen yet and will probably happen in our lifetime.

In referring to our speaker today in this important field, I use the maximum meaning of the word, fortunate, when I say that we are fortunate in having with us Mr. J. Carlton Ward. It would take a lecture on my part to recount his many accomplishments as as a leader of American industry and as an adviser to many government agencies. Further, I am sure that such an outstanding biographic sketch as his has merited your attention in your essential reading last night.

The Industrial College has been extremely indebted to Mr. Ward through the years for his service and advice to the school. Currently in his capacity as Chairman to the Board of Advisers, he has been extremely helpful to us.

Mr. Ward is also the all-time grand champion of our guest lecture program. Today he gives us his twentieth lecture, the subject, "Science and Technology in the United States Today."

It is a real privilege for me to welcome Mr. Ward and to present him to this audience.

Mr. Ward.

MR. WARD: Thank you very much, General Stoughton. I only wish I were half that good. It make me think of a Provost of a University who was introduced in a somewhat broad fashion--as he was leaving the university, I might add--with all of these great virtues which were apparently all welling up in the mind of the introducer. This frien of mine, who, incidentally, was a graduate of the Naval Academy, was in the front row lapping it up. He got starry eyed and, as he got to the platform, he looked around and said, "My! I can hardly wait to hear what I am going to say."

Gentlemen, this is a tremendous challenge, and every year I come here it takes about four cups of coffee before my knees stop clacking together, when I recognize that in this audience there will be men who are experts in science, men who are experts in technology and in many, many fields, and that at the same time in the audience there will be gentlemen whose life work has directed them into other channels. To talk in a meaningful way to a group of such a complex makeup requires, perhaps, that to some of you I will be telling things that you know better than I, in order that we can all come along together to a better understanding of what probably--I won't be challenged on this statement--is the greatest single force and development in national life today--in fact one might say in international life today.

I think if you haven't had advantage of the correspondence that I have received from the College and the staff, I am going to pay a tribute to the staff and at the same time give you an idea of some of the questions they would like to have developed today. This is the reason why this is a sort of endurance contest for you as an audience. This is going to run on, as you know, until the midday break with, I hope, a few small breaks in between.

Now, these are the subjects. The major assignment is an examination of the major developments in the contemporary world of science and technology and their trends for the future; an appraisal of the position the United States has attained in these developments, and the strengths and weaknesses in our capability for maintaining and improving our future position. The appraisal should include the magnitude of efforts measured in manpower and dollar resources devoted to R&D and to scientific and technological education.

That's the material for a one-year course, there. Now here are suggested questions:

1. World leadership has been characterized as a race for scientific and technological achievements. To what extent is this true, and why? Well, there is another course lecture.

2. If the United States is to maintain its position of world leadership and provide for the welfare of its expanding population, what portion of our national resources should be allocated to basic and to applied research?

3. Today there are numerous departments and agencies within the Executive Department of the Government which support major problems in our need. A Department of Science and Technology, headed by a Cabinet Secretary, with responsibility for a broad range of government scientific and technological programs has often been proposed. What are your views as to the necessity for such a post?

4. Some members of the scientific community have questioned the worth of allocating billions of the Nation's resources to a lunar landing. What are your views and thoughts on this national effort?

5. In your opinion, what do you feel should be the role of scientists in the formulation and execution of national security policy, in view of rapid technological advances?

6. What major United States scientific and technological developments can be expected in the future, and what impact do you foresee of these developments on United States economic and security problems?

As if that isn't enough: With the increased emphasis by the Industrial College on management at the upper levels of national security administration, you might highlight some management problems in research and development at the national level, such as organization and control, resource allocation, skilled manpower and education, and exchange of scientific information. Further, your observations and comments on current and expected future developments in space, new energy resources, new materials, biological and medical sciences, mathematics, and physics would be most appropriate.

Now, you are going to be here until noon, all right. This is a tribute to your staff. Just think of what they have dug up here. Of course, I asked for it. I always ask them to please tell me what it is I should do which is of greater service to the College. I am not here to air my lack of knowledge of the English language or any other defect or pursuit that I might enjoy myeslf. I am here to do a service. So this is the response, and I can only say that it pays tribute to your staff.

Now, how do we go about this? I have said that this audience is a mixed audience, so I am going to start by trying to define the field that we are talking about, and I am going to probably upset some people slightly, I hope, and challenge you in your own thinking a little as to what this is we are talking about. Then, after defining the field and giving you what I hope will be some useful and fruitful examples--because I am not trying to give you my own opinion, I am trying to lead you into an opinion of your own; it may not necessarily be mine or

even parallel mine, but it should be an opinion, and it should be based not on other people's opinion, which is the way we often do in this world; it should be based upon an examination of the underlying facts out of which opinions can be generated--I want to, as far as I can today give you examples, and not say that Ward thinks so and so.

So this first part will be entirely without the aid of slides or exhibits, and the second part of the lecture will be slides and exhibits which I have used in formulating some of my own opinions, and you can formulate yours. There are quite a few. I am going to have to go through them more rapidly than I would desire, because some of them tell a whole story, a story of great interest, a historical story that points a lesson.

Let me also warn you that they are statistical in their nature. If you are not practitioners in the art of statistics, which is much closer to necromancy than a real scientific art, I warn you that there are jokers in statistics. There are jokers in my statistics, but they are the best that I can find. You should challenge them. If they lead to a conclusion you cannot accept, go and look for the errors in these statistics.

Now, gross national product appears on a number of these slides. As an example, I want to tell you that there is a real argument going on in economic areas and statistical areas as to whether this figure is what it says it is. I don't think it is, but it is the best thing that we have had of its kind, and from this I would warn you that people who look at it and draw a neat conclusion are making a mistake. It isn't that neat.

The President has said that the United States has lagged in its economic progress and the gross national product is one of the main props of this argument.

People who differ with the interpretation placed on it say that, instead of the two and a fraction percent that our economy is supposed to have expanded in the past period, and which the President has used in his statements to the public, we have expanded at better than 4 percent, and that this 4 percent is traditional and it is the rate that we have been expanding for a great many years, and it is the rate that has brought us to the high level of where we are today, and that we do not need to fear that we have slipped behind as the GNP and the President's advisers' interpretations have indicated to you.

I am not arguing which is right or wrong. I happen to believe that the gentlemen who are talking about 4 percent are much closer than the President's advisers who talk about the two and a fraction, which they have scaled down to one and a fraction by some adjustments that they make to it.

This is not a lecture on statistics, but I have to throw this in because I am using gross national product and because I want you to question statistics. I am sure you are all familiar with that old story of the statistician who had to cross a river. He got his facts together and found that it had an average depth of 4.1 feet. So he walked across and drowned. This is what a lot of people do with statistics. Don't make the mistake that maybe some of the remarks that I might make to you might indicate to you I have made.

Well, then, this is the way we are going to approach the subject, so now let's see if we can dive into it. First, let's define science and technology in terms in which we'll all at least know what I am talking about.

Science is unlike any other body of human knowledge, for this reason. The word, science, has slopped over into areas that are quite unscientific, because it has a kudos, it has an aura about it, that makes it a very fine word to marry

into whatever you are doing.

I was with some university professors most of this week on various assignments in various places. One of the principal subjects is a hot subject in which this College is involved, the so-called science of management. I challenged these professors. I said, "I don't think there is a science of management. I think there is an art of management." Now, what did I mean? The professor was upset. I meant that he takes computers, he uses mathematics, and he combines them with ideas, challenges, problems, decision-making processes that are not quantized. What do I mean by that? Quantized means capable of precise measurement in units that are absolute, such as science deals with.

Now they are using the science of management--their words--to try and resolve problems of management decisions: Is my sales department organized to meet the needs of my business? Have I used the right number of salesmen? Have they been put in the right centers or cities? Have they been divided functionally correctly? These problems are being put on computers and called science, because the computer is scientific. That isn't science. In algebra, as you have all gone through it, you will remember that an equation in which there are trancendental functions--what is a transcendental function?--a function that escapes precise measurement but has general meaning--zero happens to be one, but let us just say a transcendental function--can never be precisely measured. Once it has a transcendental function it is a tiny bit pregnant--if you follow me.

Now, this is true, then, of some of the so-called alleged sciences. So now we are going to define what we mean by science. There were some lectures given at Yale University by Dr. Conant, called the Messenger Lectures. He defined it, and many others have, as a process. In other words, a scientist observes first. He

observes. He observes a set of phenomena which he tries to isolate and see that they have relation. Then, having observed it, he tries to find what the relation is. He does this by deduction. Now, this is the first process of science, but it isn't yet scientific. Then he turns around and he says, "Now I ought to prove that or disprove it." So then he sets up an isolated experiment in which he measures everything, and he holds all but one thing constant. He tries to. If it is a temperature phenomenon he is looking in, he holds all the other conditions constant--we'll say humidity, we'll say volume, and we'll say all the other boundaries of the experiment--so that he can vary temperature only under assigned conditions. Then, if that temperature behaves the way his observation of natural processes behave, he says, "By golly, I think this is no longer a theory, this is a law."

This is the way Boyle's Law, one of the great fundamental stones in chemistry and physics, was developed. Now, having done this, his next stage, before he is accepted by other scientists, is to predict something that no one ever did and then go out and run an experiment, and if it says what he predicts he is then accorded the honor of having stated a law.

Now try to apply that to management science and see where you come out. There aren't any two sales patterns alike. There aren't any two salesmen alike. There aren't any two products alike. So there are no units alike. There is no quantized phenomena there. Am I making fun of management science? No. I can see that an art is more difficult than a science. So I am not playing down an art. I am saying the fact that because it is more difficult it deserves every possible attention.

Now I want to tell you that I do not consider the social sciences as

sciences. They are arts, because in every instance they have these imaginary concepts: A unit of population. Which one of you is a unit? What are the rest of the units? Are you all interchangeable? Do you eat the same food, wear the same clothes? Have you the same behavior? No. In order to get around this they pool you all, put you in a pot, divide by the total, take the total consumption of clothes, and say that the average person uses so many clothes. This is ridiculous as far as science is concerned. It is most useful as far as the art of social studies is concerned. And it's a difficult art. But, as we meet here today and examine what I am going to try to present to you, social sciences are not sciences; they are arts. They are the handmaidens of science.

Further, let me tell you, an engineer is not a scientist. This is a mistake that the military made in the early days right and left. This is a mistake that the Manhattan District made, and it cost them plenty. Engineers are not scientists. Some engineers begin to think like scientists, to work like scientists, and may in later years almost convert themselves into scientists, and sometimes--not so often--scientists can convert themselves into sort of engineers, but they are not the same.

Today we want to have this distinction clearly in mind, because you deal in your professional military capacities with these kinds of gentlemen. Never use an engineer for a scientist and never use a scientist for an engineer. Why? Because the scientist, if he is true to his craft and profession, thinks, as I have already outlined to you, in these simple steps: "If I cannot measure it precisely it is not precisely scientific."

Now, the engineer does not measure in that sense. But he uses science. Let's take the old example of designing the bridge. An engineer designs a bridge

and what does he do? He uses the science of the knowledge of materials and their behavior. He knows all about stress and strain as far as science has revealed them. And so, in his mathematics of design of structural elements for this bridge, he can be said to be scientific. But, what about the bridge? Now, if he is an engineer the first thing he knows is, he's got to appear before the town council. He has to assure the town council that the bridge can be built for X dollars. It hasn't been built yet. All of you must know that's not scientific.

Now, the second thing he must do is tell them how wide the bridge is going to be. To do this he's got to know what the traffic is going to be. But, in a sense, it's got to be built with a bond issue that has to be paid off in 50 years by tolls which they collect from you and me. Then it means that the traffic 50 years from now can move over that bridge.

But, what are the axle loads of the trucks 50 years from now? What were they 50 years ago? There were horses and carriages. What about the gentlemen who built bridges. They had to have a crystal ball. So the engineer must have a crystal ball which the scientist is not allowed to possess. He must look into the future and see economic factors which involve the social sciences, so-called, really the social arts. He must predict the growth of population. He must predict the traffic densities in the future. He must predict the road networks of the future. He must predict the size of vehicles of the future. He must predict the speed of these vehicles of the future, because he enters it into his formula. The minute he does that he is not a scientist. Now he is a social artist. He is right back with the social scientists, of which he really is one.

Now, if a man is good at intuitive judgment of that kind, he is not good at science. If he is good at science, he is so inclined to be so exact and precise

that he is not too good at intuitive judgment. Any statement I make to you as a generality is subject to the old Greek statement that all generalities are false, including this one. However, we have to indulge in generalities in order to get on with our assignment.

Now, then, all right. I have defined a scientist in a precise way. He is a man who measures all of the subjects of his interest. Lord Kelvin said, "If you cannot measure it, it is not scientific." I now tell you quickly that science can only progress as fast as it can devise instruments for measurement. Let me give you a very good example that I used, I think, some years back. There is a 5-ton ball sitting on this stage, iron. We are going to prove that E equals mc squared of Mr. Einstein's famous theory that energy and mass are interchangeable, and we are going to prove it, because a scientist has to prove these things, and we are scientists. We build a fire under this ball. It was originally 68 degrees, if that is the temperature of this room. If we build a fire under this ball, we are putting energy into this ball. If we heat that ball up until it's ready to melt, we've put a lot of energy in it. Any of you who know about mining coal know that it takes a lot of energy to mine the coal. So we have put a lot of energy into the ball.

Now, if E equals mc square is correct, the ball is heavier. Let's say we'll put it on the scale. Now, the ball weighed 5 tons. That's 10,000 pounds. That would be 160,000 ounces. That would be 50 million grams. How much heavier do you think that ball is? Twenty-thousands of a gram. Why, then, did we not discover the greatest force in nature until Einstein first deduced it mathematically? Because we couldn't measure that close. It has always been with us.

I'll bet you have asked this question yourselves: If neutron forces are

millions of times greater than the chemical forces of chemical fuels--and they have always been with us--why is it that no one has ever been conscious of this? Here lies the answer. This is the role of science. Until science has instruments of measurement science cannot precisely define the behavior that it is concerned with.

Well, then, we have defined science, and, in a way, we have defined engineering. And now, this is what our subject is about. Now let us see if we can progress on to what role these areas of knowledge play in national power, in the subject that I have been assigned today, and in history.

Now, my examples are going to probably disturb you classical historians, but this is quite all right with me, because I never cared much about whether Henry VIII had 8 wives, 7, 9, or 5. I knew he was quite a boy. I didn't care too much that he was born in the year X and died in the year Y. So I never got top honors in history, because I couldn't remember those things, because I didn't consider them important. They are important, but for my purpose they weren't.

How am I defining history to you? I am saying, for the purpose of today's lecture, that Henry VIII, like all other rulers, was a puppet of his times. He was a product of the national forces that he found himself immersed in and leading him. He could act only within the boundary of those forces. He could act only from the base line of those forces.

Now let's examine what this means. Why was it that Greece, in the books on philosophy, literature, the arts, and the old humanities, was called the Golden Age of Man? I once lectured at Groton, a very fine boys' school, they tell me. The Head Master is a reverend. I tried to jog the boys, because some parents had told me that at the time the atomic bombs were being so heavily

discussed by gentlemen who didn't know what they were the boys were becoming pessimistic. They felt that civilization was doomed. They didn't know whether they should go on with their studies. What was the use? They weren't going to be alive very long. They thought: "Why don't we go out and have fun?"

The reverend who headed that school, a great educator, had indicated to them that the greatest period of man's history was the Golden Age of Greece. Why did he tell them that? Because he believed it. Was it? Let's take a look at it. Yes, it made some great statues. Yes, it wrote some great literature. Yes, it explored some great philosophical ideas. Much of this it gathered. Euclid's book on geometry that you have all studied was merely the collecting of information largely developed in Egypt, because the Nile River overflowed every year and because, when it overflowed and receded, they couldn't find out what each man's land was, because all the land marks had been washed away. So the art of geometry was born as a civil engineering need in surveying, and the Egyptians developed it. Euclid was smart enough to say, "This is a higgledy piggledy bunch of knowledge here. We ought to codify it and put it in some fine literary fashion." So the books of Euclid appeared.

There's a beautiful example of Greek philosophy, and Greek philosophy was tremendous. Well, here were the Greeks. Let's look at them as a nation. Outside of one or two military campaigns in terms of history, their country was a major power for only a very short period of time.

Now let's look at their competitor, Rome. Rome never had the literature of Greece. They never had the philosophy, they haver had the art. They borrowed it all from Greece. They thought it was pretty good to use. The Greeks didn't know how to build an arch. All their buildings had to be flat stones laid on pillars.

Frankly, gentlemen, they were lousy engineers.

The Romans were natural engineers. You see a division creeping in here between the thinkers and the doers. So the Romans came along and they built tremendous aqueducts. They carried water with the knowledge of hydraulics a long distance, and they were the first nation in the world to ever show how a million people could live in one place together and not all die of the plague. The largest cities of Greece never got over 200,000 plus because at that point they withered away. You couldn't save them. They didn't know transportation. They didn't have the road systems. They didn't have the methods of distribution. While they had the philosophy and the art and the literature, there they were, stymied, because they were lousy engineers.

Now, the Romans, who had none of those things, learned how to build these great cities, how to build great road systems. You know, it's a wonderful thing to study the Roman water system, because they had a public utility. They learned how to make lead pipes and bring them into every man's home. Then they billed him, monthly, and they collected their bills, monthly. They even had fellows to see that you didn't cheat the meters? What did they do? They bored a hole in the lead pipe and measured the hole, and you paid the water bill on the basis of the size of that hole, which was the stream of water that you were entitled to in your particular home. Then they had inspectors go around to see that you didn't kindly enlarge that hole on the quiet. You got a monthly bill.

The water came from a long distance away. It had to follow the laws of nature, because it had to go over mountain ranges, or hill ranges, and through valleys. So they built a vast aqueduct system, the like of which could not be found in Greece. There was their road system, and there was their development of Roman law, which

grew out of all of this. These are applications of knowledge. The Greeks knew all about the theory of law but the Romans built the Roman law which today is the basis for all world law, in the Western nations, certainly, both ours and the Napoleonic code systems. With all of these inventions--transportation, signalling, and communication, public works, structures, bridges--Rome lasted 960 years, Rome was not the Roman emperors. The Roman emperors were a hard-drinking bunch. You can read about some of them that were wasters and some of them that were on the whole very unpopular leaders of their time. They were the puppets of the fact that the Roman nation as a nation of that time was a nation of engineers. Rome built its great empire that extended from almost Scotland, and certainly the border countrirs, all the way down deep into Africa and over into Asia Minor. They were able to rule that empire. They developed the administrative mechanisms, which Greece had never done.

Now let's look back at Greece again. It had all this great philosophy and this so-called democracy of Plato. So-called? Why? Because he defined that only 10 percent of the Greeks probably ever could be able to vote. To him the definition of a voter was a man who possessed property and was properly educated. How would that go today in Africa as democracy? It was a form of democracy, in advance of its time, but it was not democracy in the true sense.

Greece, which brought forth these great ideas, which spawned great ideas, got a lot more credit than it deserved. The Romans came along then, looked at Greece, and said, "Look. Why, Athens can't even get along with Sparta." The cities of Geeece fought each other. Let's examine why they fought.

The basis of any civilization is the engineering use of energy. If you want Ward's definition of history, the rise and fall of countries depends upon the

sources of energy and the intelligent use of energy. The Romans were the first to begin to understand the sources of energy and to use it intelligently. As they did, they subjugated practicaly the known Western world and they ruled it through that long, long period, looking at Greece, who, in order to get enough energy to run their little city civilization, had to do it by fighting wars to get slaves. The statistics of Greece show that it took between 20 and 30 slaves to support one so-called philosopher, thinker, teacher, what have you.

How do you like the civilization that is founded on that principle, as the Golden Age of Man? Slavery, human slavery. Every time their economy ran down hill they started another war to get more slaves. That's why Greece perished, in spite of the great literature and art, which one must say was a tremendous accomplishment. I am not here to play down Greece, but I am here to kind of jar you into what makes a world power.

Now let's skip rapidly, because time goes rapidly. I want to take another great chapter in world history to show you what engineering did to world power. The invention of the steam engine probably goes back into antiquity. The early references that one sees often are to our hero, Alexander, of Alexandria, who made a turbine to pump water for his bath. That was a heat engine. Through the ages very little thermal energy was ever used. Wind was used, yes, windmills. Animal power was used, rotating buckets for fertilizing the elevated areas of the Nile country, and so forth. But there was little use of thermal energy. Coal was known. Coal is known from antiquity, and even oil.

So here were all the sources, but nobody was smart enough to see how to use them, until a practical engineer named Newcomen came along, because they wanted to go down deeper in the mines and had to pump water to do it, and had to do this by

hand power, which is not very practical. So Newcomen built the first pumping engine for a mine, which was a steam engine, in 1736, I think. That's quite a ways back. That was followed, as you know, by a series of developments. Now, nobody knew how to make steam engines. They didn't have tools to bore around cylinders. They didn't have the means. All these things had to be created, and, by the time of James Watt, who developed the first condensing engine, steam engines had come in.

What did that do? No ruler in England did this. No political leader did this. No social art did this. That caused England to take industry out of the home, the guilds, and put it into factories, and the industrial revolution was on. That little island kingdom, with a handful of inhabitants, a million, spread its power over the civilized world like ancient Rome, through engineering. They manufactured a surplus of products. They shipped the products. Where trade goes the flag goes, and the sun never set on the British Empire. That little island kingdom, with a fraction of the people on the continent, became the world's greatest power and maintained it for 100 years. Who did it? The Prime Minister? Parliament? The Kings? Not on your life. Engineering, the application of the natural forces and materials of nature to the uses of man, which is a broad definition of engineering.

Of course science has to go hand in hand. If it hadn't been for the scientists who worked out the theories behind the steam engines, you wouldn't have had the high degree of refinement. You certainly would never have had electricity. So, as this factory system was built up, England became this vast power.

Now, don't think that there weren't thinkers in other countries looking at all this, and saying, "Holy Smoke! We ought to get aboard this gravy train. How can

we do it?" So now we have another nation of doers. A poor country, with a relatively small percentage of the world population, built up a threat to world power and started World War I, a tiny country in terms of world population. Germany, harnessing the new knowledge of chemistry fashioned by Frenchmen, largely, and Englishmen, largely, not by Germans, took this body of scientific knowledge. Gentlemen, here again is the line between science and engineering, boiling right up to the top of the stew. The Germans took the French and English chemistry and developed the art and science of synthetic chemistry. When they did this they were able to manufacture, out of raw materials that they could readily get, the sinews of national power. They developed the greatest chemical industry the world had ever seen. This was behind the German power--explosives, weapon systems, metallurgical products, and a viable economy that allowed that big bombast, Kaiser Whilhelm Der Grosser, to threaten the world and bring on World War I, and to darn near win it.

Let's take another. Over in the Pacific, there is a little island, Japan. Most everybody lives on 10 percent of the land, because the rest of it is untillable, mountainous, unsuitable. Next to it was that great, spawning world population of China, millions more people, and theoretically more power. Were they? No. They were philosophers. They were sort of Chinese Greeks. The highest attainment of the gentlemen Mandarin of China was to be able to write poetry upon all occasions.

Through an accident, a very amusing accident, this was the means by which China got a universal language. A student at Cornell, Hu Tzee, one of the greatest Chinamen of our time, became an ambassador to this country, and was the head of large universities in China and adviser to the Taiwan government. He was a student and he and a pal decided in a break in the curriculum to get a couple Chinese

girls to come and spend a week end. They were going to go canoeing on Lake Cayuga, which is at times a very interesting little body of water. They didn't get too far from the dock and the canoe turned over. There were some Chinese floundering around and swimming, and eventually they all got ashore. Well, now, any educated Chinaman at this point has got to write a poem about it. That is essential in Chinese culture. So Hu Tzee wrote a poem. But he couldn't find any cultural words for canoe and Lake Cayuga and Cornell University, and a few other things. So he proceeded to write it in what might have said could be coolie language. When this poem was published, all hell broke loose. Classicists in China beat their breasts, tore their hair. Articles appeared from the Chinese literature saying this was a debasement of Chinese culture by a student.

Now, I won't carry it through the steps, but it impressed iself on Hu Tzee. Everybody could read his poem. Only the Mandarins could have read it in the classic Chinese. So he set about revising the Chinese language and he invented the method by which China communicates today.

All right, I've given you a funny example, to show you accidents of history. But, remember, now, Japan was not concerned. Japan borrowed her language from Korea. She borrowed her mathematics from Korea. She was an uncivilized area of barbarians when Korea was a fine, cultured nation. The only defeat she ever took in a major war was by Korea. So the Japanese had great respect for the Koreans. Like the Romans, they said, "These guys are so good we'd better borrow their stuff." So this became the basis of Japanese culture. The Japanese then looked Westward to Perry and the Dutch and all the early contacts, and said, "Those guys have got something." They borrowed all this just like the Romans borrowed from the Greeks. The first thing we knew they came out with the Kanaka Memorial, where Japan was

going to run all of the Pacific area, with a fraction of the population--less than Indonesia. Think of it. Less than Indonesia, and with a newer culture than Indonesia. How? Was it the rulers of Japan? Was it the Mikado who did this? Was it their so-called Parliament that did this: Was it the politicians who did this? Was it their social scientists who did this? No. It was the fact that they built up an engineering background for national power, which led them to threaten the world at an appropriate time, they thought.

What overcame it? A greater engineering background, right here.

Now, gentlemen, the role of engineering is a fantastic role in history, but it isn't taught this way in schools. But it should be taught in the military colleges, because it is your sinews. You couldn't wage a campaign, you couldn't be a national power, without first a very sophisticated, scientific, engineering weapon system and an enormous logistical supply. That can only come out of engineering, not out of politics.

So, in the subject that you are looking at today, don't try to think too much along the line of the political interference with science and engineering. Think of the interference of science and engineering with politics.

I have been on this platform at a time when one of the hot subjects was: What should be the role of the scientist in the Pentagon? Now you are all through with that. You go away beyond it. You did some funny things with it, too. We are going to talk briefly today on what should his role be, in, let us say, our opinion, because this is an opinion. Your staff here has asked me to discuss the question whether there should be a secretary for science. I'll deal with that now, because it captivates me. No. In my opinion, definitely no. Why? We are living in a period, one of these human, emotional periods, in which many of our

reactions are emotional--not logical, emotional. For a while science was so neglected that a physicist was a shrinking professor, averaging about $6,000 a year, tops. I remember this. I am old enough to have seen history in a very brief moment and through some very interesting times. It was the atomic bomb that pulled this guy out of his ivory tower and made him a person to the public. The gentlemen who spill ink over paper began to describe him. He became someone. All of a sudden he went from obscurity almost to ecclesiastical superiority. In the course of this, without understanding the process, he became a direction to which the eye would turn on almost any problem.

This is human affairs. You can liken many human affairs to physical systems. This is the physical system simplified by a pendulum. It was pushed away too far. Problems of segregation today can be likened to a pendulum. President Kennedy told us in the White House the other day at a meeting that half his time is on this subject. He said, "Now we are facing bloodshed. You have seen bloodshed. This was only a few weeks ago. Each month it grows worse." And he said, "Now we are reaping the result of over 100 years of not having given these people a fair chance. Now, in order to correct this, we may even have to put ourselves in the position of favoring them." If you don't think this has spread through the labor unions and is causing one hell of a reaction, which one can't predict, you don't know.

It is the pendulum at work in human affairs. So the pendulum worked for scientists. All of a sudden they came out of obscurity and came over here, and they have the answers to everything. This mistake was made in the Pentagon and everywhere else. Business made it.

Now, of course, I am here to point out the enormous role of science, not to

degrade scientists. I don't want to see scientists making political policy unless they train themselves for politics. Ex-Governor Dewey gave one of the greatest lectures on what it takes to become a politician that I have ever heard. Believe me, it is just as hard work as being a scientist or anything else. If you think you can run for Congress and be a politician overnight, you are going to have some very unpleasant surprises. This is an art.

So, when you ask the scientist to be a politician, you are not exactly doing him a favor. So, I say no secretary of a Cabinet post for science. It is a staff position. It is important that it be regarded as a staff position and not an end position.

Now, all the Cabinet positions, by and large, have an end product. Interior deals with minerals and reclamation, and all sorts of things. Defense certainly deals with things. Even Justice deals with things--people, jails, the enforcement of things. But the scientist doesn't have an end product. You can't accept a formula as an end product. That is his end product. So he should be high in your councils, but as staff. Once you get a department of science and a secretary, and you have Parkinson's law at work, this can run away. It can become an end in itself,

I lived through the era when, having graduated as an engineer, the engineering professional magazines kept beating on the drum, "Engineers must get out of their drawing offices and take part in the life of their communities." We don't have any in Congress, and we are always dealing with engineering matters. What do we do? We do some ridiculous things.

Well, this is true of scientists. They need to get out of their laboratories and get into the human life stream. But, when they do, they are no longer practicing

as scientists. And they are going to have to learn the hard way, the way everyone learns. So I say no to that question which was put in my assignment for today. Ward's opinion. You are all entitled to any opinion you like. You can all draw it from what ever sources of information you like.

Gentlemen, I am watching that confounded clock. I have hardly done with two things. I have defined for you the role of science as I see it, why science is different from any other body of knowledge, and the fact that you call things scientific because you use some scientific disciplines in connection with them, which doesn't make them scientific.

I fully admit that modern economics deals with statistical mathematics in a very sophisticated way, but this is like the statistician crossing the river. It doesn't make the end product scientific. The result of this is that the President's economic advisers told him that this year was going to be a year of somewhat declining activity for the country, and the best he could hope for was a decline in the first six months, with a slight leveling off in the last six months. And what do we see? We are going like a windmill in a full blast of wind, and we are going with our normal factor of increased activities. Were they right? No. Why weren't they right? If it's a science, they can't be wrong, because science has laws.

You must all remember that, during a certain Administration of this Government that lasted a very long time, the law of supply and demand was suspended. In fact, it was made a bit odious. So we slit the throats of pigs and we plowed crops under in order to accomplish a certain result which was contrary to the law of supply and demand. Did we get it? No.

Only now is the law of supply and demand being taught again in respectable

schools. It wasn't taught for a while. You can't do this with Newton's laws of motion. You can't take his description of gravity and teach the laws and then suspend them. Yet, I will probably have someone rise to say, "Didn't Einstein prove that they weren't accurate?" My answer is yes. They were accurate within the limits of the measurement at the time they were formulated, and they are still accurate within those limits. All Einstein showed was that in refinement, such as with the 5-ton ball, you do not apply them with precision. That couldn't come about until the methods were available to show that this variant occurs and how, and why. So the laws of Newton stand today as macroscopic laws, and the laws of Einstein applied to gravitation as microscopic laws. They are all still laws.

This is the difference, then, between science and the so-called laws of the social scientists, which are really statements of principle and which apparently can be attacked from time to time, since there are no such things as constant dollars, constant men, typical men, typical anything, in that great, difficult subject with which they deal. My hat is off to the men who try it.

Now, while the President's advisers are telling him that deficits are not important, there is another group or school of economists who are saying that's hogwash, that you can't escape what they consider to be the laws of traditional finance, that you can't run a family in that way, and that a government in a sense is a family, and it is hogwash to pretend it isn't because it is made up of multiple families.

Yet Mr. Heller, the Chairman of the President's Council, addressed us on this subject with vehement and pious language. Not one of us believed a word he was saying.

You don't do that in the sciences, gentlemen. Now, I have many more examples to try to take you through, to show you that science and technology are important to you as military men. The role of science and technology should loom large in your appraisal of your opposition. The sources of energy and the use of energy are means by which you can measure national power. The statistics for these are reasonably accurate--they are not accurate. No one measures the power of a tractor on a farm and puts it into a national hopper so that it comes out as a statistic.

I'll give you an example of what this means--the use of engineering and power. I was on Quemoy this fall. General Wob was briefing us, and when he got through showing the million and a quarter Chinese troops on the mainland to keep his force from landing there and stirring up trouble, when he showed us how he commanded these two great deep-water ports which denied them to the Chinese mainland, and what he was doing to upset their economy, what he was doing propaganda-wise to make a monkey out of the things that came out of Peking, he built up such a case that, had it ever been presented to the American public at the time of the Presidential candidates' debate in the last election, it would have made quite absurd the whole debate. Of course, that was his purpose in the briefing. He said, "For Heaven's sake, take this back home and give some of the people the facts on this, to get them away from the idea that these are two little bits of real estate that are unimportant to your strategy in the Pacific and to the Chinese Nationalst strategy in the Pacific, and recognize what this is doing and the role it is playing."

Having done all that, there were a lot of byproducts. He showed us the 46,000 civilians who live on that little 8-mile island, all going about their

business, plowing their fields, and every other day dodging the shells. He ran movies for us showing how the Chinese children got out of their little primary classes in kindergarten and went down into the holes in the ground when the shelling would begin, and how they all turned it into a game. The boys would pull the girls' pigtails and slap them on the fanny and push them around. They make a joyous kind of game out of it. They don't see anything very horrible in it. When a house gets knocked over, everybody turns to and rebuilds the house.

Now, this goes on. There are 46,000 people. On the mainland there are over 1700 major-caliber cannons, 8 landing fields, modern Migs, a million and a quarter people. Think of it, only 40,000 soldiers on Quemoy living underground, so that they can't be interfered with by enemy fire. They have some very good counterfire of their own and a very high morale.

My point is: What about the civilians? At the time that America was involved with the first great battle of Quemoy and the Sidewinder was unveiled by the Chinese National Air Force, trained by our people, it knocked eight of the Migs out of the skies for every loss of a Chinese Nat plane. This put such a fear into the Chinese Air Force, which no longer can get supplies from Russia and therefore does not want to waste its material, that it doesn't bomb by air the island that is only 2,000 yards off the mainland. Think of it--2,000 yards. Incredible, isn't it? So the result is, they shell the island. All right, many of you know these things.

But, what about the civilian population? At the time of that battle our problem was that the Navy could not take in the supply ships beyond the limit of international waters. At that time the Chinese were bombing from the air, and were pulling out all the stops. And the island was not prepared for what it had to undertake, nor were the fortifications completed. In fact, it was somewhat

vulnerable. So there was a great deal of loss. One of the problems was, "How are we going to feed 46,000 civilians and 40,000 troops, and get these supplies in when we can't convoy them to the beach?"

Now let's look at what the situation is today. General Woo said that American agriculture moved in on the island and converted it from a one-crop agriculture to a six-crop agriculture and diversified. They brought in technology. They brought in agricultural engineering—fertilizer systems, soil systems, tractors, harvesting equipment—with an amazing result. The 46,000 civilians feed themselves, feed the 40,000 troops, and have to export their surplusts to the mainland Taiwan.

This is the product of mechanization, engineering in agriculture. You all know that American agriculture today uses fewer people every year and generates bigger surpluses every year. We're down to 7 percent of the American population now engaged in farming as against between 45 and 55 percent in your enemy's country, Russia.

When you talk about manpower, you've got to apply some very interesting factors to your manpower calculations. They do not have the manpower available for the things you have the manpower available for. We have a mass-production economy and they are only beginning to attain a mass-production economy.

These things are engineering factors. If you do not bring them into your political evaluations, you are missing the boat.

I think it's time for coffee.

MR. WARD: Now, the second part of this endurance contest-that we are all enjoying--question mark--together is to subject you to statistical exhibits from which you can draw some conclusions of your own. To confuse the picture, I'll give you some of mine as we proceed.

I think, without any further ado, we'll turn to the first slide. I don't like busy slides. This happens to be a busy slide because it has so many lessons on it. Let's turn to this side first because it's easy to see. First let me say to you that the role of R&D is the role that is the servant of science and of engineering. Here is where they come together, on a sort of mutual boundary.

What is a boundary? There are many definitions. There is a new one in the Government, incidentally, which I am not going to give you. To my mind it is the product of an overactive imagination. The simple definition is: You have a basic research phase, you have an applied research phase, you have a development phase, and if you want to add your military side you have an evaluation phase. These are four simple steps in the whole project.

Statistically, the men who put these things together have an impossible job. However, they are the best statistical exhibits I can give you. The lesson which they show you is correct, even though the arithmetic may be somewhat distorted by the assumptions that lie behind the statistics.

Over here you see an extraordinary phenomenon. In this brief period from 1954 to, let's say, 1964, or actually a little less, you find that the total research has gone from $5 billion to $15 billion. Now, there isn't anything in our national economy that moves this fast. This is alone. This is a phenomenon. This is merely a recognition of this role of science and engineering in our

economic posture, in our overall world position.

There is an emotional content in this, and the emotions are beginning to set in motion counter emotions which you will now see on the Hill. These are congressional explorations into the "holy land" of requests for money for research. There have been abuses. Now, you can't possibly deal with sums of money like $15 billion and not have abuses. Government agencies abuse this. They try to stuff money down your neck when you don't want it, at times. They get money stuffed down their neck when they don't want it, at times.

These are all products of emotion. The emotional wave is, by the example of the pendulum, beginning to subside and counter emotions are beginning to appear. Is this question on my assignment justifiable? What should be the portion of the national effort that is devoted to this servant of science and engineering? Now, I think you all recognize that a ducked answer is impossible. The whole subject is too complicated, but, nevertheless, attention has to be given to it. We have to have some conclusions about it. In other words, it is not going to go on forever, because, mathematically, if it did, there would be an infinite income, and there is no such thing.

Please notice the role that government sponsored money plays versus private sponsored money in this immediate picture of the current 10-year period. Let's turn to this one. Here is a curve at the bottom. It shows the amount of money that comes from private funds into laboratories other than government laboratories. As you see, it doesn't look like much. Actually, it is about two-thirds or three-quarters of a billion dollars. That's quite a bit of money. Up here you see university, a government fund, which is the next one, and this gets up to about a billion dollars. Largely, the basic exploration, the basic

thinking, is done by this money, not this money above.

Don't get taken down the primrose path by the advertising fraternity, which tries to show that each company that it is sponsoring in the press or the media is doing a vast amount of specific basic research. They don't. Very few do basic research but, because it is a little more holy than applied research, they like to have the kudos that goes with it.

Now, here you have private funds, total. It's this item here, and you will see that it is a considerable amount, between $4 and $5 billion. But here is the big fellow, the government funds, over here. This is predominant, of course. You add all of these together and you come to this figure over here, $15 billion.

So this is the makeup. Then, remember in your mind that the Government is the predominant agency, and that basic science is not merely money but the vital root source in terms of effort.

That's the general picture of the last 10 years.

(Slide) Now, I had to put this in to show you where you come from. You see, I'm an oldtimer. I was in the Ordnance Department in World War I, in Watervliet. Before that I was in the machine-tool business, where we made the very machines that made the cannons. I went all through World War II as an airplane manufacturer, or an engine manufacturer for aircraft. Prior to World War II, through this period here, I was running Pratt & Whitney Aircraft Company, the engine company.

So I have been a merchant of death all through this period in here, according to Pearson and Allen, and other newspaper writers. This is a Senator who passed a law that required that we license everything we did if we did it for any object outside the United States. I mention this because the political

philosophy of the United States at that time was anti-weaponry. We were against weapons, against military effort. You gentlemen suffered in other ways, but we in the industry, if we hadn't been a kind of idealistic, almost irresponsible group, would never have made you ready for World War II.

At one point here, a Secretary of the Army--you had Army and Navy in those days--withheld all the money for research except $19 million--that was the total amount that the Army and Air Force had at that time--and this all went to one manufacturer. He called me down and gave me hell. He said, "You fellows up there are stubborn." So, I said, "Colonel Lindbergh has just come back from Germany"--he was a pilot and he was made a colonel--"and he tells us that German aircraft is superior to American aircraft, and the reason is that their liquid-cooled motors have a small frontal area and hence more resistance, and they get better speed." He can set himself up as an engineer, but he is off the farm. None of that was true, except the fact that Colonel Lindbergh went and was taken in by Colonel Udett of the German Air Force and sold a bill of goods. He went to Madison Square Garden and told us we should never fight Germany because they would win the war.

I am not making fun of Colonel Lindbergh. He was one of the greatest pilots and did more for aviation than any man I can think of. But remember, now, he is in the role of an engineering and military expert. Somebody made him a colonel. You don't make a colonel by putting those chickens on his shoulder. That is not the way a colonel is made. He made the mistake that maybe all of us make in one of a variety of ways of talking knowledgeably about something we do not know much about because we have a reputation in some other field. Just remember that when you go to a Chamber of Commerce luncheon and hear something.

So here we were, merchants of death. I want to remind you of the fact that on this chart the total money in the United States, statistically, that went into research in the whole country, including all the government bureaus, and they included NACA, was $300 million, and we were facing the period of World War II. But politically we were blind to World War II. The politics of the time were to assume that America would not be embroiled.

You are not interested in this. It's history. So the industries that were going to serve you so well in World War II were starving. You had politicians with no knowledge of science and technology making idiotic decisions based upon men who were not authorities and disregarding all the authorities who had spent a lifetime in industry.

These are the lessons you want to watch out for if you are ever procurement officers. Don't fall victim to the siren songs of people with big names who become experts in areas that, frankly, they have never trained themselves for, and disregard what you might be inclined to say are the self-serving statements of people who have spent a lifetime doing those things. This is an easy thing to fall into, and it isn't alone confined to military procurement. This is where a lot of your wasted funds go.

All right. This doesn't look like much to you, maybe. But just remember that in 1939, about here on this chart, the total amount of research was $300 million, and at the peak of World War II it was just barely $2 billion. That's 600 percent increase--600 percent increase. This is what had to develop all your electronic gear, all your new weapon systems, dig out your ships, and do all kinds of things you had never heard about in the prewar period, and without which you would have been sunk.

I have just read an article in the Institute of Naval Proceedings, quoting from Admiral Donitz, and he thought he had us, with his submarine warfare. Twice he thought he had us, first when he launched the campaign. And then we had the countermeasures that were effective. Then he had the snorkel, and then he had us again. And again he was defeated. He finally is quoted, after having first said "We have the weapons to win this war out of German science and technology," as saying, "It was superior science that licked us."

Now, here is a quotation from a practical man of your profession as to the role of science in war.

Well, now then, this $2 billion, which I'll call it, was well spent. But you see the political effect in the postwar period, when we were bringing the boys home for Christmas. That was a complete debunking of the military effort. We had finished the war then, and Russia was our ally, many people said. At that point I was testifying in Washington to help to establish a climate in a senatorial committee to continue R&D, knowing there wouldn't be any money for procurement, hoping to Heaven that they wouldn't dismantle the R&D teams that would take years to assemble. They are not just a collection of experts. They have personalities. Sometimes they clash. If you've got a team of experts that clash all the time you haven't got anything. It takes an awful lot of weeding out to find a team that can work together.

With this development from here a new concept had come into R&D. Originally, in the Thomas Edison period, one man worked in a laboratory with a couple of technical assistants and machinists, and he brought you out something. But, all of a sudden, in 1903 the United States discovered that research had gone beyond that

and that there were no such men of omniscience and we needed a team, and the team was made up of men with different knowledge and disciplines. When they discovered that, research in the modern fashion was born, and that was in the year 1903. I didn't put it on this chart, because it wouldn't even appear. Back in this period you could hardly find it.

This is where you have come in less than one man's lifetime. I remember these things. I remember as a boy this original Langmuir Laboratory at GE. It was called the House of Magic. That was the position of R&D in that period.

Now you notice this tremendous effect of a war in seeking knowledge in science and engineering. Gentlemen, if you don't have the resources to do that, you will never win a war. You can't win a war without the ability to do what that curve is telling you.

Now look at what happened. I will show you in another curve what happened between government policy and private policy. This was the impetus of Korea. Again we got lulled, and sent the Marines over with terrible equipment and even clothing to fight a war in a very brutal land. We were not ready. Then all of a sudden again the wise boys who came to Washington to help the Givernment of that picture said, "Holy smoke! You don't even have a good anti-tank weapon for these chaps." So the bazooka had to be quickly thrown together and shoved over there, and a lot of other things.

So this is the Korean War. Notice carefully. This is World War II. If I had the time I would have shown you what World War I did. When World War I ended we had no real research in a true sense in the military establishment or in the United States. We were still using leather and horses, and all that kind of business.

Now, we suddenly discovered that Germany had it, and we suddenly discovered that we were depending on Germany for the raw chemicals that made our military posture workable. Overnight we had to turn people to work, professors and people. We had to scrounge them out, wherever we could get them, and get enough together to show what research could do to win a war.

This is a repetition of World War I on its proper scale. And this is a repetition of Korea. Some people say that governments never learn anything, that they just go on making the same old mistakes because there are different people in government. I disagree. Some people even call history a social science. I think that's the biggest piece of hogwash I ever heard.

People do learn. Governments learn. Of course they learn. We learned something here that we had unlearned here, and we also learned the same lesson back here. But twice we unlearned it. But we didn't the third time. That accounts for this and the emotional content which I think will set in counterforces.

(Slide) You are charged with the responsibility of questioning everything I tell you. The only thing you must agree with me on is the sources which you can find on all of these charts and where they come from. They are subject to whatever limitation you find the source might be ascribed to have.

Now look at this on a different sort of chart level. Here are the billions of dollars again. This shows two things. There is the government sponsored research all by itself. This is the commercial research, all by itself--free money. This is unpolitically tainted money; this is politically tainted money.

All right. You add this thing here to that, and you come out there, even though the curve as it's broken shows it. I want to show you what happened by

bringing the boys home by Christmas. There's the political money. They hadn't learned a damn thing. They didn't realize that your safety hung on this. They were willing to disarm the United States in the face of what some people could certainly read in the Russian intentions. That's a colossal political crime that you see here, an unbelievable political crime, in the light of any point in history, of a knowledge of science, of knowledge of the role of our need in national security.

So, all right. As conditions got rotten over here with the Korean situation, then the politicians recognized that Russia was an enemy and that China was an enemy, and this thing went into motion. Then, by the law of the pendulum, they gave the pendulum an awful kick and it swung away over, and off they went to the races. They are still in the races.

Now let's see what private thinking did--not political thinking. There was no deep dismounting of research effort at the period when the Government cut its research effort down to about 40 percent. Private industry did not. While this curve looks kind of sleepy down at the bottom because it is on this enormous chart, you must remember that in that particular period the economy was not an $88 billion dollar gross national product economy. These dollars are in no sense the dollars of today. Industry had to cough them up. Industry had learned a lesson, so it kept along until finally you reach this period of today and they catch the fever and go hogwide.

If you look up here you will see something. Here's distribution of the Federal dollars in research. This is Federal dollars for the fiscal year 1962. So-called profit organizations get 63 cents of every dollar. In other words, the work is done there. Educational institutions took 13 cents out of every dollar.

That in my opinion is the most important segment. "Other" means nonprofit labs or small-profit lab organizations. They took 4 cents. The Federal Government takes 20 cents. That includes every single laboratory in the Federal Government system.

So you see this is still a private-enterprise tainted economy. This is the degree to which it is affected, with private enterprise.

(Slide) Here is the spending for R&D--colleges, universities, research institutions, and other nonprofit. I want you to see this, because this says where the money comes from. You will notice there is 3 percent from the nonprofit institutions; from industry 32 percent; from the Federal Government 65 percent. Uncle Sugar gives 65 percent.

All right. Now let's see who does it. Twelve percent is done by the fellows who put up 3 percent. These are the nonprofit boys. They don't have 12 percent. Here is the Federal Government doing 14 percent out of 65 percent funds. Here is the big load that industry does. This again shows you the private sector and the role it plays.

(Slide) Here is spending for basic research. This you should challenge. I defy any statistician to be accurate in gathering figures as to what is basic and what is applied research. It can only be approximate, so you must, with me, question the specifics of this chart but not as a general lesson. Spending for basic research in the 1961-62 period and where the money comes from. Federal Government, 57 percent. They are not nearly so generous with their funds on basic research. Industry is more generous than they were on applied research. This is a very strange thing. Colleges and universities, and, well, other nonprofit institutions, 7 percent. Colleges, people with no profit, out of the tin cup, begging your

support for their alumni drives, have to cough up this slice. All right, other nonprofit institutions--this is where it is spent--10 percent, instead of 7. This would be Arthur D. Little, the Battell Memorial Institute, the Illinois Institute, Leland Stanford, and what not.

Now here's the colleges and universities. Leland Stanford Research Institute is different from Leland Stanford University. There's quite a difference. Colleges and universities doing 47 percent. They are the only people who can do really the out-of-the-blue-yonder basic research. I don't believe industry does any 27 percent. I think their advertising writers say they do that, but I don't believe it. Federal Government does 16 percent. Maybe.

All right. Then you see now the role that universities play. I can tell you that that's the heart of the whole thing.

(Slide) Research and development expenditures as a percent of the total Federal budget expenditures. Gentlemen, this is terrific. As recently as 1940 and the period of the World War, you will notice that 1 percent or less of the Federal budget for 1945, a little over 1 percent, was expended. Now you will notice what happens in the Federal budget as a percentage. Look at that. When you talk about a $90 billion budget and somebody says to you, "Holy smoke! 13 percent goes into R&D," that should sink in. Science has invated politics here in a big way in acquainting them with the role of R&D in national power.

If I could rest at this point and time would run out, I could say, "Gentlemen, there is my sermon." Even politicians recognize that R&D and science, these being the handmaidens of science and engineering, are national defense, national interest. You see there is no turning back yet. Some day they will have to.

(Slide) All right. Here's the Federal again. Remember, this is not total.

This is Federal. Here's the fiscal year. I have put this chart on for one major reason. This littls area here represents the basic. I want you to see that the basic support, support for basic research, is growing faster than for total research or than for development or applied research.

Now, Vannevar Busch said after World War II, "We have used 50 years of science in 5 years of war. We'd better get busy now and catch up." This was an extremely significant statement, not at all necessarily appreciated or heeded at the time. It is only now really assuming practical proportions. Here it comes with the recognition that after all it is what we do in basic research that is the factor for what we can do in engineering, which is development. The engineers' role in this picture is not in that field. That's the science field. The engineers' role in that picture is not in applied science, although they get in there a little bit by infiltration. And the scientists' role is not in development. That is purely an engineer's role.

As you see from this chart, this is a small percentage of that overall process.

(Slide) Here's your government agencies. This is Federal still. This is total for all. Department of Defense--that ought to surprise you a little. The Department of Defense percentage-wise is not really growing in R&D. Where is it growing? Well, look at dear old NASA--400 percent in 3 years. Last year's budget was $3.5 billion or some fancy figure out here. One time they talked of leveling off at $5 billion. Holy smokes! I'd hate to buy a ticket to the moon on that sort of economy.

Now, this picture here indicates that NASA has suddenly come up with political reality. The head of NASA has said to Congress, "Our next budget will not be any

higher than the present one, the present one being $3.5 billion. You see where it comes from in the last 3 years. You see a phenomenon.

All right. Here's atomic energy, now becoming old hat. You can't even get space in a magazine for atomic energy any more. It's old stuff. It has been complicated by Parkinson's law, in one way or another.

Dr. Glenn Seaborg, who has been one of our best Chairmen of the Commission, and who is a wonderful scientist, in meeting his craft. something that caused a political repercussion. He said, "You know, our laboratories are now so big and well manned and staffed that we ought to attack any kind of national problem for which we have the facilities." If you can't see dynamite in that statement, you are not as smart as I think you are going to be in this course.

Well, why should that expand? Fortunately, they set up about a year ago what they call a Department of Industrial Participation. The purpose of that department was to try to get out of the Commission things which the Commission was doing in its own laboratories but which industry could do as well or better.

I don't want to entertain you with this kind of problem but you ought to know the characteristics of some of these problems. Private enterprise is now building power plants at a very high rate of expansion, running into billions of dollars, to create electrical power out of atomic sources. And of course it is soon going to generate atomic ashes. These atomic ashes have to go back for reprocessing. You have to extract out of the ashes the unburned coal--to use a simile. Then you have to put that back, and it's hot, and lethal, radiationally hot. It's a very difficult thing.

So of course the Commission had built laboratories for itself in the early days, when there was nothing but weaponry to waste materials, and submarine

propulsion materials, and the like. Now all of a sudden there is going to be a civil component. Now, a choice was immediately presented to the Government: Must this be done as a government enterprise, or should it now move out into civil enterprise? The civil people in the Edison Electric Institute say, "Give to the Government this public power and that's death." It means subsidies like TVA, from which there would be no taxes. They borrow their money at rates lower than the Government can borrow it. All kinds of things are hidden from the poor old Tennessee farmer who benefits by it and thinks it's wonderful.

These things are politically full of appeal. So there is a very major matter of public policy involved in what you see here as to whether this will level off and turn down. The first plant for treating these atomic ashes is now under construction in northern New York State, due to Cliff Furnace, who used to be here in Washington, and Governor Rockefeller, who is backing him in the politics that can be used. That plant will start off at higher costs than the Government can do it for. Here's where the trouble lies. Why should the Government surrender from its own laboratories operations which it says it can do cheaper than private industry? Not, this may or may not be so, because government accounting is a sort of a department of fairyland in accounting which private industry doesn't have access to, and sometimes it raises an eyebrow here and there.

Now, many times factors are left out of government accounting, such as the cost of capital. Of course it doesn't cost under some of their systems as they review it. Now, these are vital figures. If you compare two apples in a barrel, all you've got to know is that they are apples, and that one isn't a pear. So this is involved. These systems are very complicated. And there is much logic on the side of people in the Government who say they can't afford to have private

industry do it. Look at what we are doing it for.

If private industry starts like putting in a wedge, very small, it is going to grow into atomic power, and its initial work load is small. You all know enough about mathematics to know that when costs come down the volume goes up. When the Government is doing a big job, with all the Navy boats and other things, and has its own reactors, then obviously it ought to do it cheaper than private industry. If that's the case it ought to always do it. We will never come to the point where initial private effort can compete with the public effort.

This is tough. This is tough for people who sell it. They have to go to Congress and explain why they gave a private group something to do at a higher cost than their own costs show. There are people in Congress who are straight socialists and say, "This is simply ridiculous. Under socialism you don't waste all this money." It's a nice problem.

Well, here is Education and Welfare. This is a phenomenon. It's sort of trying to imitate this one (NASA). There has come to be sufficient abuse that Congress is raising some very large eyebrows at a problem which Congress created. NIH and particularly HEW was forced to take more funds for research than it came to Congress and asked for. Having been forced to do this by what I unfairly call the do-gooders in the committees that handled that, it now tries to shove this money out. I mean this. They'll pressure you to take some of this money. They have to get rid of it. It's hot money.

Congress has discovered all this because it has taken a look at the national budget of $16 billion and has said, "This thing has gone upstairs pretty fast. When do we call a halt in this thing?" So of course now this thing is getting the pendulum treatment.

Here is old Agriculture tripping along. It looks pedestrian alongside of these things. Here is Interior. She may look pedestrian, but percentage-wise she isn't. If we have the present policy of Interior indefinitely, this will be quite a thing.

All right. Here is Science Foundation. That's a very interesting one. That was the body called into action by the Government to advise the Government in the role of scientists advising the Government. This is all right. The idea of that is sound, as opposed to a Secretary of Science. This is the kind of medium that should fulfill the role of a secretary of science in large measure.

Now, of course, there is another mechanism coming up that is on assignment, and that is the so-called Science Advisory Committee to Congress, so that Congress will have a Jerry Wiesner Committee, so that, when Jerry Wiesner comes before a Congress Committee they are not left sitting there flatfooted. They will have some people of their own who can say, "Well, look, Jerry. We don't quite agree with you on this particular point. Here is what our scientists say." They have not had that advantage. They've tried the ad hoc method, and now they are seriously considering a standing committee of science advisers to Congress.

I think this has some merit.

All right. Here is the Department of Commerce--peanuts. They are sellers of peanuts.

Those are the main agencies of government. That is the division you find in our R&D.

(Slide) We turn to manpower. Who does these things in R&D? What are the national resources in this area? Here is the most difficult thing to handle. First off, how do you decide who? The scientists themselves mull over this all

the time. They have this problem.

There are two methods I have heard discussed in a seminar at Harvard, with international scientists present, as well. One was that you will decide by the number of Nobel laureates you will find, and the other was by the number of accredited public scientific papers setting forth new knowledge in journals that are recognized as scientific, as opposed to popular.

I don't know of anyone who has the statistic for the latter, or I would have had it for you. We discussed that here with the staff and decided it was too monumental a thing to try to get. I have only for you where we stand in science/on this chart of Nobel prize-winners.

I'll turn first to this. We got 12. There's our principal competition. Here is all others. I want you to notice all others. As big as we are don't get the idea that has pervaded in some quarters of America that we are outstanding in the world in this area of advanced science. We are not. Europe is. I can use the carrier as an example in engineering. The steam catapult is British. The landing system is British. The canter deck is British. Yet when we look at their Navy it is a miniscule Navy alongside of ours. That's an engineering development.

But I could name examples in science, such as the development of radar. It started in an Anacostia laboratory of the Navy down here but it never got anywhere until Sir Watson Watts did the job in England and enabled them to win the Battle of Britain in the air. There are plenty of examples. There's the development of ships and all sort of counter magnetic mines, and so on. These things come out of other science and we have great respect for it.

Let us remember now, when you start to measure world power and you have that old problem which I hope is now down the drain, that Russia could overrun

Europe in six weeks with her massive army, that was hogwash, of course. I am sure you recognize it as hogwash more today than it was at the time. That was a theory and when you threw the weight of European facilities on top of Russian facilities you found we didn't look too hot. But of course there were a lot of jokers in that, one of which is: Can you make people do things, who aren't on your side really but who have just been overrun by your force of arms? I don't think you can, but you can get something out of it.

All right. Here's chemistry. We have 10; the Soviets have 1; others have 13. You see there is more strength than we have.

Here's medicine and biology. Of course you recognize now the limits of statistics. Nineteen to zero. Eighty percent of the Russian doctors are ladies. I don't mean that ladies aren't as good doctors as men. What this means in Soviet terms is that they will not put the love, affection, and money on medical science that they will put on survival science. So that the medical profession is nothing like supported in Russia. This is the reason why women have rushed in to fill the vacuum, because in essence they can do better in medicine, which pays infinitely less to a Russian practitioner than to a physicist or a chemist. So the men stick there and the ladies go into medicine.

All right. There is others again. We are doing pretty well in that spot. Now, here is literature. Here's old ancient Greece down here again. This has never been quite a preoccupation in a land of mass production even of books. It has been in the European cultural center where the kudos for a literary man is infinitely higher than the kudos for a literary man in the United States. Here if he is on the best seller list, he's wonderful. But he never has quite the position in our society that he has there, and that has something to do with this figure.

Well, here is peace. Maybe these are the boys I went to Arden House on two sessions with. I don't know whether I hope that is true or not. But anyway, here it is. The demand for peace is greater in the lands that are not going to be the principal contestants. I think you can easily figure that one out for yourselves.

(Slide) Here is science and engineering graduates. Believe me, this has pulled the rug out from under me in previous lectures, because somebody in the statistical department has revised the idea of gathering statistics. This has taken a turn that nobody can quite explain.

So this is the best we can get now from the National Science Foundation. It comes from a variety of sources. There are the USSR citizens with bachelor of science degrees as engineers or lawyers. You will notice that this figure is comfortably over ours as to the percent of them. It has been so for a long period of time, with the result that the figures that I used to see show that there are as many scientists and engineers in Russia as we have here. When you think that they had to start from almost nothing, this means that they have poured them out like mad in order to get onto the same plateau on which we live.

The sad part of it is, we are beginning to lose. Here is total degrees awarded and you see we've got them blanketed there all right, but these are the non-sciences. These are the social boys, social studies, humanitarians, and various studies which are largely the core of our liberal arts curriculum in this country. I am going to show you more on this subject shortly.

Now, looking down quickly at the United Kingdom, France, Germany, and Italy, as other areas that you would examine, I would like to show you science and engineering degrees per million population. Just follow that. Look at Italy. Look at Germany, with the great scientific Germans.

Now, like all statistics, give this a very skeptical eye, because in Russia they have a thing called a two-year college which supplants their degree-holding colleges, and the system is as large as the entire four-year degree curriculum. These people are very well educated technicians. We have no comparable mechanism in this country in size. It's miniscule. So that the Russian scientific effort in a way, I think, is in one sense more efficient than ours, in the sense that they supply a very competent degree-holder with excellent technical assistance through two-year colleges. In this country we have four-year engineers and even advanced degree holders doing doing clerical work, with blueprints, records, desk work, and what have you. This does not involve drawing on their total abilities and training in these fields.

Here was one of the great charges during the war against Southern California, the hoarding of engineering resources, and so forth. I think it was true. That was the way we always got ready for the next order. This is still the way.

This is where you have to think behind some of the figures and how they are utilized. I think they've got some enormous wastes in Russia by the very nature of their system, but we have ours, too. You can't be too literal, but this does show two things: Russia's preoccupation with the factors of survival, science and engineering, in terms of total education--this figure here--and our lack of preoccupation with the causes of our strength and survival. This is a serious thing in education. This has got them all worried.

You will notice countries like the United Kingdom, France, Germany, and Italy. All of them are above us in terms of their educational processes. This is not good.

(Slide) This curve is not right. This is our mistake here. This is the

crystal-ball department. It doesn't look like that. It does look as though it is going to look like that. I have just come from some engineering institutions. We discussed this question, and we find that the number of freshman candidates for engineering is decreasing in this country, not increasing. You see the wide gap. We don't know, of course, the bachelors, either. We do know that this is true. And we do know that this is true. We also know that that is true. The number of engineers produced has been declining.

Again, like all statistics, you've got to think in terms of what it means, how we get them, and do they apply. Let me say that the press, which influences our thought so greatly, has treated outer space shots as science achievements. They're engineering achievements. The scientists couldn't build those things. That's an engineering art. Of course it gets into science. It wouldn't be built without the basic science to draw from, but the actual achievement of launching, building, recording what these outer space developments have come to be, is an engineering achievement. The papers call it a science achievement.

So youth goes to university with stars in their eyes and want to be scientists, when actually their aptitudes, for which they were measured, would indicate that that is the last thing they ought to be. They don't have that kind of mind. They are boys who should do things. They are boys that can make quick and intuitive judgments. They belong in engineering.

Now, this has got the educational profession absolutely stymied. They don't quite know how to unwind this thing--the power of the press, the emotional reaction. The result is that science has swelled and engineering has declined, and the fallouts, the dropouts, are really shameful, because, after the boy starts he finds it is not what he thought and he drops out. He very often goes into

liberal arts. Very seldom does a science major drop back into engineering, because it's a harder curriculum. The engineering schools demand more work from their students than the science departments and the liberal arts demand. So it's a much harder curriculum, and youth being human sometimes avoids hard work. This is in part a reason for not having a high enrollment in the engineering discipline.

The engineering disciplines are getting tougher. Because of the great rush of new scientists, the poor engineers have to take an awful lot of para-mathematics which was formerly the realm of only the scientists. To do that they have to drop out of engineering courses. This has led to another problem, that a lot of engineering students never know what engineering is until their junior year. They don't do any. All they are doing is amass a scientific background from which they can be engineers. They don't take to science. They are not scientists. So they say, "The heck with it," and they hop out. And they are lost.

So engineering colleges have a problem: How do we tell a freshman what an engineer is, when he can't be an engineer for some years yet? I merely leave you with some of the great questions in education that will have to be met and somehow or other worked out in a pattern to solve this otherwise rather terrifying statistic.

(Slide) Now here comes an area we have carefully not discussed. This is the area of advanced degrees. I think you recognize that here in the United States there is an enormous movement toward advanced degrees. One engineering college of a large size has 82 percent of the students going on to advanced degrees. So you can't talk in terms of baccalaureates.

Now, a paradox has presented itself. Are you going to graduate a boy who

can go to a public utility and become a practicing engineer, or an industrial establishment where he learns how to get out production? Or are you going to graduate a boy so crammed full of physics, chemistry, and mathematics that he doesn't know the tools of his trade? He couldn't make a good blueprint to save his soul. He certainly doesn't understand shop practice. He is geared to a research career in engineering.

So the schools have suddenly faced up to the diachotomy: How can you educate both types of guys? The education has to be different. Both will get engineering degrees. What kind of engineering degrees? So the national engineering bodies are trying to solve that chestnut. It will probably end by two sets of degrees, one a professional degree and the other one a classical degree.

Well, here is another problem.

Here, then, take a look at the Soviets and ourselves. We have more people with higher degrees in the U. S.--these are doctors, mind you--than the Soviets, but not quite so much more that might be comfortable as you might think. In science doctorates they have about caught up with us in doctorates. But in engineering, look at that.

Gentlemen, there is where your backdrop for military might comes from. It does not come from here. It comes from there.

Well, here are what I laughingly refer to as the social arts, the humanities, education, and others. You see. I think sometimes this is the reason for our confusion in economics. We have so many of them. It has been said in viewing statistics that if you laid them all end to end they would reach no conclusion. This is said to illustrate something. While the President's Chairman of the Economic Advisers is telling you the country is growing at 1.8 percent per annum,

An equally fine group of economists tell us that there is no such thing, that it it is doing better, at perhaps 4 percent. Newton's order mostly does not yield up this kind of complex. This is characteristic of that art. I have the greatest sympathy for people who practice it.

But you start from beliefs and assumptions, and my friends in the group of the President's advisers believe that Lord Keynes was right. They believe that Harvard economics which spawned the Keynesian theory is right. But there are other centers of learning that do not. So, if you start from one set of premises you arrive at one set of conclusions. If you start with another, you get another.

Some textbooks will do what the politicians do in a debate. They start off and tell you that we not only live in a mixed economy--this is a technical term--but that there are growing needs of government that lend themselves to the mixed economical process. Now, they don't prove this. They don't point to the countries in Europe that tried it and abandoned it; to the laws of the Medes and the Persians, who had a price for hair cuts, writing letters, units of grain. That's why you often say, "This is as constant as the law of the Medes and the Persians." They abandoned it. The countries fell apart.

All of these great social experiments of the times in history created some very interesting questions. Here we go back in our eternal cycle to the idea that many of these things must be done by government bodies.

Now, of course, I have not covered this properly or thoroughly. There are probably any number of men in this audience who could cover it better. But I am trying to bring home something to you.

Well, then, you learn that Russia does not accord the same role to these disciplines that we do.

(Slide) This was made by Ohio State. I don't know how they did it but it's not too hard to imagine. These piles of coins represent the standard of living in their respective periods, which you can see run from 1920 all the way to 1960. Here it is- Ohio State University.

They also found out and said, "Who creates the standard of living? Is it a professor? No, he grinds out textbooks. Is is the social economist? No, he interprets the flow of trade instincts and tries to predict. Is it the schoolmaster? No, he educates." You go down the line and find who does it. It's the producers. But, how do producers do it? They carry on engineering principles, they use engineering tooling, they use materials fabricated and furnished them by engineers, they use the raw sources of energy created by engineers, distributed by engineers. This is the pattern of your national economy. Everything is founded upon making something--a good or a service. These are elements of social studies. Then the distribution of goods and services is an element of social studies. But they are only a study of something that is going on.

The Romans produced things. The Greeks talked about them. Of course I am not fair to either side when I make a statement like that, but I am trying to crystallize for you what is essentially the dominant feature of civilization.

Now, we have been a do-something country. We inherited vast forests, vast mines, vast, rich agricultural lands, and we were pioneers. So we came over here and we developed. Europe, with thousands of years of lots of population settled along. Out of this rich complex, our first problem was that we didn't have enough labor. That's why all that immigration occurred--the shortage of labor. We went to work and developed engineering methods, processes, and tooling by which we could mass produce. The French invented mass production away back in the

1700's. We harnessed it with old Whitney and the guns, away back in the early 1800's, and it spread like wildfire through America. It led us into automation, where we lead the world. It led us into all these mass production technologies, all results of engineering, not the results of science. Get this clear. Engineers are the doers. They harness science. Scientists are not the doers.

So that the economy of the United States, no matter how you want to figure it, is produced. Economists tell you that, if you take the total output of goods and services in the United States and divide it by the total population--including women, children, cripples, and what have you--you have the standard of living. Well, that's what these figures are. This is the share of the national economy everyone would have if socialism was rampant and we got an equal division. A one-day old baby would get the same slice as a 90-year old man.

Take a look at the number of practicing engineers per unit population and the standard of living per unit of population. Ohio State says that this is the explanation of the American phenomenon.

Now, this is what the Russians have. This is why their preoccupation is so intense with respect to engineering. They first discovered this in 1932 and they modeled their education procedure on this theory. So they have made astounding progress. They say they expand at 8 percent a year, against our miserable 1.8, which certain people say is our rate. They say this, and the Russians say it is because they understand the role of these funny gentlemen up here. This may or may not be true, but that's a very interesting piece of information.

(Slide) This is a quickie. It's too busy to take you all through it. This is something basic--steel wage rates, Luxembourg, Belgium, France, West

Germany, the United Kingdom, Italy, The Netherlands, Japan, and the United States. Where do you think we would be if it wasn't for mass-production engineering in this race? How could we ever beat this race? Now, the sad part of this, gentlemen, is that we have shown these countries how to use our best methods. Furthermore, we provided them with the loans under the Marshall Plan to help them do it. The result is that you suddenly see an exporting country in steel become an importing country of steel at a threat to your local industry and a surplus of production.

Why not? You can buy products effectively made. Why should you pay for those? Now, that has grown in the intervening period to this. This is one of the high rates in this country. The construction industry could compete with it and more, especially with Brotherhood No. 3, with its 6-hour work days and heavy fringe benefits, whose members pull the wires out of anything shipped into New York that wasn't wired in New York. They can beat this.

All right. Let's see what is happening in Europe? A very interesting thing is happening. Japan has doubled its rates. United States has added, roughly, 40 percent. So, with the average of mechanization in Japan not up to the average here, there are some products that we can still deal with, particularly with ocean freight rates, insurance, and delivery costs.

So, economists are pointing to the fact that these countries, by and large, are in the grip of a wage-labor movement which is comparable in some degree to the political wage-labor movement that we are suffering, and have been through, since the inception of the Wagner Act and the various subsidiary acts.

Well, I think that is really enough of that chart. It is interesting, but quite busy.

(Slide) Here you have the U. S. Government investment in the aeronautics and space program. I want you to see what happens as a product of research. There would be no such chart if it were not for scientific research and for engineering development. It couldn't exist. You see it covers a fairly modern period, 1950 to 1963.

This shows the construction of facilities in progress, and this shows those that are now in business--Cape Canaveral and like illustrations. You see it has gone up into very great proportions. That's just the plant. Now look at the cost of the operations. Please note. We had to break that curve because the end of this thing would occur somewhere beyond that wall. Take a look at that.

There's your threat to defense funds, and there is your threat to a great many things. There is the reason that--notice that $3 billion, 6, 7, or 8--Congress is saying to Jim, "When are you going to start cutting down on your requests?" He has to pull in enough to say, "Well, we are not going to increase them next year; we are just going to hold them."

However, for this lecture, the purpose of this is to show you the enormous effect of new research and development in new areas.

(Slide) There's an oldie. That's the atomic energy program. You see it's aging. Here's what it was. I could have shown you a curve in the early days very much like the one you just saw, plotted to a proper scale. As you see, it still goes on by Parkinson's law and building new facilities and slightly increasing its plant. And, as you see, it is still increasing its total payroll. But is its course taking into account the constant inflation which is denied by government authorities but evident to anyone?

I don't know whether they are really increasing this much or not. But

you will notice that it is pretty sizable. Now, when they say, "You've got an excess of weapons, and you've got an excess of uranium, and your stockpiles are overheavy," and private industry say, "We'll carry the ball in the private sector," then what? I think that's a political paradox, gentlemen.

(Slide) All right. I want to show you another characteristic of what you might call research and development but is essentially development. This is an engineer's curve. Back here in 1905, it took about this amount of coal, 6 pounds, to make one kilowatt of energy, the basis of our civilization. When Thomas Edison made his first electrical generating station, it took, as the records show, 19 pounds.

Now, a gentleman whom I am sure you all respect, who wears your service uniform, Admiral Rickover, was caught up in this phenomenon and he didn't interpret it quite right. Let me show you what happens.

Engineering development--now, you might say it has gotten tired and flatted off, but, for every 1/10 that this drops, you've increased the coal resources of the United States 10 percent--billions of tons. It is just as hard to get a 10 percent saving here as it is to get a 10 percent saving up here. In fact, it's harder. It's still going up.

Conventional thermal electrical generation by coal supplies--actually, today, you can build a modern plant with .65 pounds of coal per kilowatt hour, two-thirds of one pound. Supposing someone had said to Tom Edison back here, "Boy, that's a lousy plant you built," what could he have said?

I want to show you that this is a normal characteristic of engineering.

(Slide) here is something out of your own profession. There's the first core for the Nautilus. It went 60,000 miles and then had to be taken out. The

second core went 95,000 miles. A couple years ago the Navy pulled the rug out from under me because the third core, which then had not really exhausted itself, was estimated to go 135,000 miles, instead of which they now say it went 180,000. They say the fourth core is designed for 200,000 and then, calmly, with their tongues in their cheeks, say that it will go 400,000.

Now, if I plotted a curve of the economy of atomic power with these data marks, you would find a very similar phenomenon to what you saw in the coal curve, proving again that these are characteristics of live engineering development applied in a wide variety of cases.

(Slide) This is one of the most unusual things that have ever come to my attention. This was done by two fellows I knew quite well in the Atomic Energy staff, Davis and Roberts. At the time they did it, the press had gone through the pendulum effect. Chairman Strauss, a wonderful man who was Chairman of the Atomic Energy Commission, got so intrigued with this enormous thing, that one pound of uranium would produce 3 million kilowatt hours, whereas one pound of coal produced one, that he did himself a disservice, by jumping to the theory that it would cost only one three-millionth as much, and was so cheap that you couldn't read it on an electrical meter. He came out in a public speech, as Chairman of the Commission, saying that electric power was going to be so cheap that you could not afford to meter it.

Let's observe now that there was a wonderful man, well educated, and very responsible, who was in the field of engineering but he was never trained. Let's not get over too far, out of where we are somewhat at home. We do some funny things. Now I am going to come back to Admiral Rickover, because I know him quite well. He built, or he feels he built, the shipboard plant. Now, the shipboard

plant was the first plant that developed steam on a commercial scale for making electrical power on a commercial scale. He knew it was going to be expensive, because he was doing it. His course, he always maintained, was somewhere in the order of 45 mils per kilowatt. This enabled him to be an authority. So he got up on a platform--many of them, it might have been here--and proved that atomic power could not compete with fossil fuels. He went around the country so lecturing.

Now, the country being our country, and believing that, if a man is a great authority in building a submarine--and of course it's no fact at all--that has remarkable performance and does it well and does it satisfactorily--stands up against all sorts of competition and succeeds in this--he must be terrific, and that makes him an authority in everything. So poor, old Admiral Rickover fought the battle of 45 mils per kilowatt hour and lived to see what Davis and Roberts projected on this curve.

The reason they did this was, as servants of the Atomic Energy Commission, they are charged under the McMahon Act with developing a civil industry in this field. You couldn't develop a civil industry with Admiral Rickover's figures. So they got out a crystal ball--both being engineers, not scientists--and they began to say, "Well, all right. We are familiar with engineering phenomena." Now, I've shown you two engineering phenomena, one for the Nautilus, and one for coal rates, and I'm telling you that this is a fundamental of engineering development. So they constructed out of their knowledge of forward techniques an imaginary economic curve. They did it away back in this period here, when the press was still yowling about the fact that we had been sold down the river by the proponents of atomic energy saying that it was the maiden's answer, when it

wasn't any such thing.

They produced this, saying this is what is going to happen to conventional costs, and this is what is going to happen to atomic costs, under the engineering developmental formula.

The funny part of it is, that curve is absolutely accurate. I don't know where they got their crystal ball. I've been a consultant to atomic power companies in a mild sort of way, and I happen to know that not only the New England Power Station, at Rowe, Massachusetts, which is operating today, is right in this field of cost, but the one they are building at Higginham on the Connecticut River is going to be operating at that cost, right here, a little below the line, by 1967 and 1968.

In other words, it's so close to that curve that it's here. I happen to know that the ones in California, projected by Southern California Edison, by the City of Los Angeles, and by the Pacific Gas and Electric, all lie in this area. This is terrific, gentlemen.

Here is the next group of engineering work, its importance to the economy, and what it does to shape the economy.

(Slide) Now, this is a scientific one. This was made by science. I am fascinated with it. Everything they do is so precise. It always has me absolutely transfigured.

They go back as far as electrical power generation, which became known in Farraday's time in England, away back here. They showed that there was practical electric power generation--meaning Thomas Edison's station in 1882--from which they deduced that it took from--we'll call it 1930--1885 to 1882--as you can see, that's a span of almost 30 years--from the time of discovery to the time of commercial application.

Now we go up the scale. Here's the discovery of radar, about 1922, at the Anacostia lab, although actually this can be disputed. Some scientists made a test run away back here. Kohler Tessner said that he had had electromagnetic wave echoes. He predicted this thing. The boys ran into it in the laboratory, but couldn't get any money out of the Navy Department of that day. But the British were interested in it, and they produced the answer, back here, which was the time of the Battle of Britain, in 1940. The scientists deduced that this was the time from the discovery up to the result and practice, and the time of radar.

You get up here to transistors which were discovered by Ball Labs on this date here, and they find out it was reduced to practice and began to kick our vacuum tubes for certain applications by this time, which, on the scale that you see here, was about 7 or 8 years.

Then we get up to artificial diamonds. This was a General Electric development, up here. However, artificial diamonds had been made in physics labs. This is the commercial development. They deduced this curve. I don't agree with that.

Now we get to super conducting magnets. These are cryogenic magnets. They shuffled it when the principle of superconduction in low temperatures was announced. This gave the way to enormous magnetic fields beyond which we had never had the capacity to produce, and we were producing those magnetic fields for purposes as rapidly as that.

I hope you question the neatness of this, but I don't question the lesson. Fortunately, as I am going to point out to you, at this point it vanishes to zero, which is a way of saying that the day the scientists discover something it is in general economic use. If you go slightly further, you find it gets into economic

use before he discovers it.

(Slide) Gentlemen, there is the growth of industry, spawned out of research. There was the effect of World War II in the electronics industry, per scale. This is the effect of bringing the boys home by Christmas, to scale. This was largely a military program. You know, bench radios didn't amount to much. They hardly appear on this curve.

Here's your Korean War effect. Here's your Sputnik date.

This--notice it started to go to hell in a hack before Korea hit them. Then the money bags loosened up and off we go.

That thing represents the size of a silicon component. All I want you to see there is the effect of war on national policy and what can happen out of the scientific-engineering developments. This is now one of the largest industries in America. It's well over $15 million, one of the largest industries in America, and it grew from pure research.

(Slide) Here is air and aero space. This, of course, is the peak of World War II. It's measured in such funny things as airplane pounds, which I helped to start as a unit.

Here's what we were struggling with when war hit us. We in the industry who were merchants of death were splattered all over with printers' ink. This is what we had to do. This is one of the greatest achievements of a response of an economy to the necessity for survival in all the history of war. It could well be studied. How was it done?

Here's what happened when the war was over. There weren't any more funds for military airplanes. This was when I went before Congress to point out the folly of that idea.

This, then, became the postwar period. Slight sanity beginning to be evident here. Then, the threat of Russia, and the Korean War. Aerospace taking over missiles from manned aircraft. All these are steps on this curve. I haven't time to outline the details of that, but you see the role of military sales, and you see the role of commercial sales. You see that commercial sales are very much a sector of the economy.

Gentlemen, this is the product of science and engineering. There was no such industry until man conquered flight.

(Slide) Here's the gross national product per man hour in the United States. This is an economic curve. It tells you this: Engineering use of tools, processing, and methods, scientific management, and everything thrown in, has produced more goods per man hour--this gets away from money--in the United States and it's still going on.

I want you to notice what our productive capability is per man hour from 1909, or, if you want to come down to more recently, here's the end of World War I. I want you to just in your mind see that we have multiplied a man's efficiency 2½ times . In one man hour a man produces 2½ units, as opposed to what he produced at that time.

This is the strength of America. This is engineering at work, not science at work.

(Slide) Now, this is all done by the use of power. So this curve represents now: What is the relation of power to, again, the famous curve of the standard of living? Well, you see the effect of the wars and the 1930 depression. I can balance these areas where the curve of the standard of living was subdepressed during the thirties but was high during the war periods. Here it is coming out to about

where they both are today. If you look at with your eye and try to smooth out the bumps the way a statistician can do, you will find that the two curves run together. In other words, the standard of living is based on two things--the amount of power and energy that can be used for useful purposes, plus the engineering know-how to perfect the tools that utilize that energy. When you add those two things together you've got national power.

(Slide) Here is the rest of the world. This is our population in terms of the rest of the world. That's our power production in terms of the rest of the world. Gentlemen, that's your strength. Never lose sight of that. This is the power that is available to you and your allies.

(Slide) Here is the whole of Western Europe. Here is the United States. Here is Canada--quite important. There's our team. And here's the enemy. We can snow them under.

(Slide) This is that old chart which is so expressive. In 1855 energy was supplied by men and horses, and little water wheels. This is very little. They worked very long hours, and they produced this standard of living as shown by that symbol. By 1955 look at what happened to the machines. There are steam engines now, because the horse is disappearing. Now the man is taking it easy.

Let's see how his hours have shrunk and see what the standard of living has done. Here's what they predicted for 2005. This is the crystal-ball department. See him? I don't know what he does now. I have been trying to figure. I was with a friend of mine this week in Ithaca, New York, and walked as he went off to work. He walked through the kitchen into a little room. He turned the switch, and there was an electrical shoeshiner. He put his feet under it a couple of times and then walked out the door. I said, "Hey, don't you do anything in the way of

physical effort?" He tried to think of something he did. He hoists himself in and out of his car and in and out of bed. I said, "I know something you do." He asked, "What?" "Well," I said, "you've got to pull up your zipper. We're going to get a motor to do that."

(Slide) There's the way the clock has shrunk. There's the way the standard of living is supposed to react. This is so lavish I'm going to merely say that out of oil comes this enormous array of progress, which is both military and civilian--all of the new plastics, all of the new fibers, all of the new paints, the synthetic rubbers, the insecticides. I can't begin to tell you all the things that come out of oil. So, when you burn it, you don't get it. It's gone forever.

This is a sort of carbon chemistry. If there were any oil representatives present they would cut my throat, because their biggext market at the moment is obviously energy. But, if we burn up our resources in these areas, we restrict our future.

(Slide) This is the old familiar periodic picture. I threw it on here because I have been asked to forecast some of the future in science. Gentlemen, I am abusing you terribly because I am encroaching on the question hour. I must give a word on where the future lies.

If you will look at this and see the number of these elements that you are now using, if you will look at the challenges through the needed new materials, if you will look at these strange things here--viadimium, promethyum, uropeum, gallilaneum turbines--and learn of their unusual properties, you will see some of the frontiers that lie ahead of the people who are interested in materials. Many of these contribute to the solution of outer space problems, which, as

you know, are high stress and high temperature.

I haven't time to explain the challenges, except that I would ask any one of you to go to this chart and pick out the things you are familiar with--iron, chromium, manganese. You will see how few of the total number of the basic materials in nature you really have explored.

(Slide) Now, here is the electromagnetic spectrum. This is the visual part that gives you the bulk of all your knowledge of the world. It's a phony, because there is so much in the world you can't see it with the visual spectrum. This is the reason for so-called radio telescopes which are now bringing in information from the cosmos that had never been available. In ordinary telescopes you depend upon this little band here. This same thing is true in some very interesting fields.

In a public discussion earlier it was asked: What is the role of lasers and masers? This is one of the great breakthroughs. It isn't merely a little gadget that you've heard about in a laboratory. It's the nearest thing to Buck Rogers that we've had. It is said we can bore a hole in the surface of the moon from the earth by using a laser. This is serious. We can transmit untold answers and focus beams that will deatroy. In medicine, they can fasten the retina on your eye when it becomes detached by the use of this phenomenon, without surgery.

So there are some byproducts of this. The point I want to leave you with as to what the future holds is, don't for one minute think that we have exhausted science. As a great scientist told me this week at a university, when I threw this question at him--and he's a physicist--what molecular biology holds for us in the next 24 years will make the birth of atomic energy shrink in comparison.

Just think of it--molecular biology. Most people think of it as genetics. We have discovered now the means by which information is transmitted from parents to offsprings through biology. But we haven't begun to fashion the mechanisms that give you power. How do you get your muscular power out of chops and spinach?

There's a little material called phidenafine triphosphate, which has just been synthesized. It takes the food you eat after oxydization and it becomes the source of electricity that runs your brain--the brain doesn't run on electricity--your nervous sytem and your physical effort.

There are lessons that can be learned in any of these conversions. This is one of the great horizons of engineering and science.

Now, I'm sorry. I have messed up what I intended to do for you, gentlemen. I will just read a couple of these challenges that I put down. The enormous future for raw materials I mentioned in terms of the periodic case. I didn't give you the great future for raw energy. This would be another lecture. You must assume that the materials and energy together comprise everyting--us, sitting in this room, everything in our economy.

The Hoyle theory of cosmology, the constant state theory of the universe versus the big-bang theory of the universe, may sound like tripe to you. But here are the secrets of nature now being probed, now being fought over in very, very advanced areas of science.

Radio astronomy I have touched on. It brings the information from outer space, which is extremely useful.

Lasers and masers--I haven't time to tell you of their many, many promises for the future, and they have only just come into being. Gentlemen, they are no

different than what you did as a child, when you pushed another child in a swing. By standing back and giving it a little push now and then you got it to swing until it was almost all the way around. That's all a laser does with electrons, and that's all a maser does with electronic waves. It's just that oldfashioned principle: Add a little bit to what you've got and you've got a little bit more.

Biogenetics, molecular biology, biophysics, and biochemistry--here is the great area which will startle you, because weapon systems will emerge from this. A form of engineering is emerging from this now--biological engineering. This is being taught in the more advanced engineering schools.

Fusion, plasma, and magneto hydradynamics are three areas that are now being studied on a graduate-school level, and mentioned on an undergraduate level. They provide completely new phenomena, new tools leading to some surprising end uses.

Superconductivity with cryogenics--magnetic forces innumerable times beyond anything that has ever been possible of attainment, and with it the strangest behavior of materials that are old, familiar materials with you, showing the innate solid-state magnetic forces in materials which are commonplace.

High voltage power transmission, in which Russia is leading us because of her economic need, but now we are beginning to catch up.

Direct energy conversion systems. You are all too familiar with that for outer space for me to spend any more time on, except to tell you that it has the public utility industry agog. They can even see, some of them, private little energy conversion systems in each home, which would be the end of central-station distribution, with all its billions of dollars of investment. So, believe me,

they are following this.

Management science, so-called--computer technology--solid state physics.

Now, there are merely some of the areas, gentlemen, that I have been asked to tell you is the future. I know of no boundaries.

I would close by telling you that in my humble opinion the might of America lies in the subject you have addressed yourselves today, plus intelligence by the nonscientists in the employment of these great forces. I have not meant to sell you off of other disciplines and other realms of knowledge, not at all. I respect them greatly and they play an intricate part in our picture, but not the main-spring part which I have tried to impart to you today, and which has been so little taught in the universities, so little recognized in the public, so vital to our future, and in which our competition with Russia is leading us to see a closing gap in education and in effort.

Thank you.

COLONEL BEALL: Mr. Ward is ready for your questions.

QUESTION: What steps are being taken, if any, by scientists and engineers on the problem of weather control?

MR. WARD: Very serious steps. The Travelers Insurance Company has probably one of the most distinguished groups of scientists in this field. Why? In relation to insurance. Accurate weather forecasts concern many of their lines of insurance. Now, it concerns us all, but with them it touches the pocketbook, and this is the way the private enterprise system responds. They have gradually

amassed this unusual collection of scientists who are building their work at a very high level of competence, of course, with meteorology here in Washington, with the Department of Commerce, and with their scientific brethren around the country, also with foreigners, because the Norwegians were the first to bring about a sort of rational theory of weather and raise the question of weather management.

The force in an ordinary storm is so great that it is many times the great Russian blockbuster. So the idea that people had that, well, we'll just drop a bomb or two, at this stage makes no sense. So weather management has to lie along different lines.

I can't tell you. I am not in that field. I only know that it is being intensively worked on and seriously thought of by nongovernment groups as well as government groups.

QUESTION: I've heard it said that the U. S. lacks a body that has knowledge of our technological resources, that we only guess, whereas the Russians do a much better job of management. Can you comment on that?

MR. WARD: That's an awfully good question. Of course I don't possess the knowledge to give you a really fine answer, but I have certain views on the subject. I think that the substance behind your question is correct. I do think the Russians do a better job, and I'll tell you why, because they better understand the role that these people play in their own national party. We take things for granted. We have been such a "have" country over so long that we have accepted a lot of the things that have made us where we are today--great.

Now, the Russians have their reverse problems. You know, I think it was Shakespeare who said, "The uses of adversity are sweet." The Russians have had

adversity. So back in 1932, when we were saying, "Don't give those people tractors, because they haven't anybody who knows anything about mechanics and the peasants will go out and just reduce them to scrap iron, and we'll be wasting resources," the Russians found this out, because this was largely so, and they studied our economy. They studied the world's great powers and they found this role eventually. So then they provided education, and they started with an educational concept which led to these figures that you see here showing heavy action on the science and engineering side of education.

This is only an expression of their political judgment, because the Kremlin is monolithic, as you know better than I. Now, we don't have a monolithic system. We have the choice system. This leads me to believe that our choice system has not at all provided us with this answer.

Life Magazine presented the most dreadful article on engineers. I can't tell you the year it was. It was in the fifties somewhere. They did it using the University of Detroit, I think it was, and making the horrible mistake of reading the general into the specific. What they found out was that 30-odd percent of the students had jobs and the rest didn't. What they didn't know was that the University of Detroit is not a typical college generally, and, secondly, that many students won't take jobs at graduation. They want to take a trip, they want to go on a vacation, and have a last fling, and they won't commit themselves to employers until fall.

So it wasn't a question of no opportunities, which Life depended on. The worst of it was that Life used labor statistics, from the Bureau of Labor Statistics, and the Bureau of Labor Statistics had made a fatal error. They had forgotten the lag between freshmen and seniors; they had omitted from their figures

some very important factors that bear on this decision. This article went all over the United States, and freshman enrollment in colleges everywhere in the United States dropped--showing you the power of the press, and the misuse of the press.

Now, a distinguished educator found the joker in this through obtaining a preprint of this artical, and wrote to the management of Life and said, "Don't publish this. It is not significant and it is not correct." Their answer was, "We can't stop it now. It has already gone to press."

I think the answer to your question is that we don't have adequate knowledge. The Russians do have a more accurate knowledge than we, because they control the system by which students enroll in Russian universities. It's one of incentives. They must make a first choice of engineering or science--not medicine--if they want to have the guarantee by the Soviet government of the best jobs afterwards, with the highest pay. But they must also meet certain educational standards. The whole thing is incentive.

I also address myself to your question to say that the fact that the Russians built such an incentive and apply such an incentive, and give by government fiat such additional importance to the graduates in these areas, is a proof that they understand the importance of these areas.

QUESTION: I have a feeling that, because of the rapidly advancing technology, a good engineer has trouble keeping up to date. Is there something that could be done about information retrieval or making information that is available more accessible?

MR. WARD: Gentlemen, that's a beautiful question. As one of my other hats I am the President and Chairman of the National Research Center, and our

first effort is directed toward that problem. Let's see what that problem looks like. Just about after World War II I first became conscious that, through meetings of the American Association for the Advancement of Science, science was coming out so rapidly that the master scientists--and the man who made the speech was Eugene Wigner of Princeton, one of our top people in this country--were no longer even in touch with all of the breadth of knowledge that came out, nor could they relate it. They couldn't assimilate it. It was too much. It was a wave. It was inundating them.

He said, "I do not understand how science can progress without at least a handful of senior scientists who can weigh the importance of the different fields"--getting back to your question--"to a degree that will encourage proportionate efforts"--in areas that presumably one must address one's self to in this regard.

That was an opening speech to me. I am sure it had been made elsewhere. Since then the scientific and technological periodicals have just droned and droned on your question: How do we communicate, not alone with the poor old engineer who is obsolete in 5 years? Think of it. An engineer graduating in 1945 wouldn't know that there is such a thing as atomic energy. That man today, in less than 20 years, is now in his early forties, and he is now on the senior level of utility and trying to build plants that cost $100 million, based upon principles that he never studied.

There's a typical case of what you are addressing yourselves to. Now, how does this get solved? There are here in Washington five governmental agencies that are sweating over your question. For a while, as my friend in CIA knows, we were very shy on technical intelligence in Europe. I was on the first Hoover Commission and we addressed ourselves to Allan Dulles at the time on the

subject. We came up with one of our principal findings, that the CIA was not doing a good job in medical intelligence or in technical intelligence.

Since then much has happened. We captured all the German documents in the war and a lot of foreign stuff. Then the problem became: How do you disseminate it it? How do you use it?

Well, this is a big subject you've asked about. The nub of it is that we are now getting indigestion from information. The Congressional Library is charged with translating all the rest of the stuff. They just pour it out like Niagara Falls, because they have such an enormous cadre of people, And they are urged to publish it. There as here you get kudos if you write a paper. So, since their whole future depends on how they are measured, this is a measurement.

So out comes this enormous outpouring. Now, a lot of it is awfully good, very high level. We can't afford to ignore it. Some of it is in advance of some things we do. Our scientists do not play down the Russian capabilities in these areas.

All right. How do we get this material out? The scientist gets out of date as quick as does the engineer. Now, today the mechanisms are simple. You go to an annual engineering meeting of your press, or auxiliary press. The same goes for the scientists, with the American Physical Society and the American Chemical Society meetings. The scientist hopes there to digest the titles of the papers, the abstracts, because that's all you get. In those areas that he thinks touch him most nearly he gets the specific paper and he bones up on it.

Now, there's one missing link. That is not enough. He needs to have contact with his peers in education who are constantly doing this, not just at annual meetings, the professors who are teaching. He has to master new techniques,

new mathematics. This isn't so easy.

So scientists today are very choosy. If you are, as I am, located in Connecticut, and you want to hire a great scientist who is at the moment, I'll say, living in South Carolina, which we are overnourishing with funds from research and development--43 percent of our total Federal budget--he looks at Connecticut, and he says, "Yeah, my family would love to be on the Eastern seashore, and all those lovely hills and things you have out there that are green all year round, or most of them. We'll move. I want to know just one thing. Where can I do a little teaching on the side on this level? Where can I sit down with my peers?"

Now, his question concerns your question. He wants to keep up to date. He won't move until we tell him, "Oh, well, the people in your field are at Yale University, or at the University of Connecticut"--or some specific area, because of your problem. It is an unsolved problem.

These agencies in Washington are presently meeting, and they are trying to set up regional centers around the United States where this great Niagara of information can be assembled and then diffused locally to people who can't afford to pay an airline fare to Washington. If you live in the State of Washington, that is really something.

COLONEL BEALL: On behalf of the College, Mr. Ward, thank you for another stimulating morning.

MR. WARD: Gentlemen, I apologize to you. I ran over the time and we sort of played beforehand. I tried to figure out areas that I thought I could drop out, but I am subject to physical laws. My momentum just didn't let me do it.