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SCIENCE AND TECHNOLOGY IN THE UNITED STATES TODAY

Mr. Carlton Ward

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Reviewed by: Colonel J. H. M. Smith, USAF, 13 November 1962

INDUSTRIAL COLLEGE OF THE ARMED FORCES

WASHINGTON, D. C.

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Science and Technology in the United States Today

21 August 1962

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Reviewed by: Col J. H. McSmith Date: 13 Nov 1962

Reporter: Albert C. Helder

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21 August 1962

ADMIRAL ROSE: Gentlemen; it's not often that a school such as ours has the pleasure and has evoked the loyalty of an individual to come back 19 times. I think he must be brave. But, this is an introduction that has always been a great pleasure for me to make. As you know from reading Mr. Ward's biography, he is the Chairman of our Board of Advisors and he is officially retired; therefore he is busier than he ever was in his life. I'm sure he'll tell you something about what he is doing now.

"Science and Technology in the United States Today." This is probably as big a challenge as we'll have; a field in which Americans do a great deal, and I think, have a right to be very proud. However, I won't make the speech; I'll turn it over to Mr. Ward.

MR. WARD: Thank you, Admiral Rose.

Freshmen:

I understand you passed your first two courses yesterday. But today is an endurance course. It makes me think of old Jimmy Durante - this is going to be different. In the first place, I hope that what we are going to examine together today will be the groundwork for raising a great variety of questions that you can then try to answer as your course develops through the year. I would like to give you an advance outline by which I would like to explore this gargantuan subject with you, and I'm going to start by trying to define what we mean by science and

technology because these are phrases that are commonly used and often misunderstood. I'll try to give you examples so that we'll get over semantic difficulties as far as a speaker can.

In the second part of the talk I would like to trace some - to me - obvious events in world history where science and technology over the thousands of years have played the dominant role irrespective of the way history has described these events, often in terms of mere personalities, of kings, emperors and leaders rather than the underlying forces that made them actually puppets on the stage of history; very important puppets, to be sure, but nevertheless tools of history rather than the authors of history.

Now, to many of you who may be authorities in this field I may be talking heresy. I know in this audience there are men who know more about most every phase of what I'm going to say than I do, but I'm really talking to the rest of you in each case. The answer period will show up the score, I'm sure.

The third part of the talk I want to give you some figures. I want to go at this more like an engineer would go at it, since that once upon a time was my calling, and let you then try to distill out of these exhibits some of the conclusions for yourself which I may express, and which, in this land of ours thank God, you are free to disagree with. I'm told by the management that we'll have short breaks in between, and so this will, I hope, appear a little less like an endurance contest than it otherwise would.

Now, last year I used a little story which I have never used since and I'd forgotten until I had re-read my notes; but I think it applies today. Two French

academicians who were to give lectures before the academy were talking about the problems of lecturers. One of them said to the other, "What do you find the most difficult experience in lecturing to a group like this?" His answer was, "Before I get through with my subject they start looking at their wrist watches." The other fellow said, "Oh that's not so bad; it's when they start holding them up to their ears to see if they're running." So, I shall watch your wrist watches. Well, now without any further ado, let's start on our subject, and see what we're talking about in science and technology.

I think I've already told you that there are many interpretations and they can't all be correct as to what we mean by these oft-used phrases. Let's start with science. Now, first I want to emphasize that as I see it, science and technology are two totally different things; closely associated; one without the other quite sterile; but quite different. I know that as recently - to me as recently; perhaps not to you - as the end of World War II, one of the hot subjects in the Pentagon was, "Should we use scientists in the DoD, and if so, how?" The war had shown that scientists had a very important role in national survival. But they were queer sort of fellows and one thought of them much as one thought of the work done in the "Manhattan District;" much of the abracadabra that sciences uses which is gibberish to the average person, but so meaningful to them. And the question was, "How would we military people who are not scientists use these experts, and how could we communicate with them?" Now, I lived through this period because at that time I was a manufacturer of technological equipment and weapons systems, all of which involved scientists.

I also knew of the troubles within the Manhattan District which stemmed largely from the fact that scientists in bringing forth this new era of atomic energy were frequently doing engineering tasks, and not too well. And so, the management of the project decided that it was necessary to bring in engineers to make part of the team. Pretty soon, troubles arose - communications between the scientists and engineers; problems. And so, after considerable confusion and soul searching the management decided it needed a catalyst and they said, "Perhaps we can find an answer to this problem, since engineers are not scientists and not acceptable to the scientists, and the scientists are not doing proper engineering, we will catch some young engineers. And we will catch some young engineers who have gone into research laboratories where they are daily working with scientists, and perhaps they will take on some of the protective coloration of scientists. So, among them one told me this story. They went to the Standard Oil Development Company in California where some very advanced research was done and they captured this young engineer who was working with the Ph.D.s and who had advanced degrees in engineering and who seemed to get along with them all right, and they sent him out to the Argonne Laboratories of which he knew nothing; he didn't even know where they were - to be interviewed. The story he tells is this.

He entered the portals and gave his name. Shortly a very tired-looking scientist appeared and handed him the usual questionnaire of about the usual six sheets and triplicate copies, and asked him to fill it out. He labored over this for quite awhile. He was a very sincere person, and being a good engineer he

was being very literal. At the end was a question, "What are your hobbies?" Well, he thought this was a funny thing; he didn't know what he was being interviewed for anyway; and he counted for awhile and finally he wrote down, "I like the outdoors; I ski in the Sierras. I live in California; I go fishing." And after he had finished the usual things there was a little space left and he stood there biting his pencil. The scientist said, "Are you having any trouble?" "Well, yes," he said, "I don't know what to put down next because I belong to 'The Society of Amateur Magicians,' and I don't know whether this would be called the proper answer to the question." The scientist jumped up and his eyes lit up and he said, "You're what we're looking for." And he was hired. Now, that chap was Dr. Lee Olinger who later worked on some nuclear projects and finally tought nuclear science although he really was an engineer.

Well, now, you see I've illustrated by an example some of the early problems. Today you're problems are different. If I may be permitted my own personal opinion, there are too many scientists in your DoD. You're using them in places where,really, military judgments are fully as important if not more important than the exact techniques of scientific investigation. I believe that some of the difficulties occurring in conflicts over weapons systems can be illustrated due to this very fact. I recently ran across a very interesting illustration. You may know that no one understands gravity. Newton first stated the mathematical laws of the behavior of gravity, but he never explained gravity nor did he understand it. And if you'll read his correspondence at that time you'll see that he felt strongly that no one understood gravity. This is true today, and obviously in

the space age gravity becomes very vital. And so, there is an attack being made on what is gravity.

In talking with certain scientists recently they said that you can now know that gravity is somewhat like radiation. It has a wave-length. It therefore can be propagated through space much as we call normal radiation. Its order of magnitude, of course, is very small compared to most radiation energies. Now, all of this leads to an effort to find out what anti-gravity might be. And there are very serious studies being made by the scientists in the field of anti-gravity. I don't have to tell you how important it would be if there is such a thing, and if it can be explained and adapted. And so, a distinguished scientist in Cambridge addressed a letter to the President of the United States last year - in April, I think it was - and said that another distinguished colleague of his, a Professor Hauk in Pretoria, South Africa, had done some extremely interesting work on anti-gravity and he felt that he ought to be brought here and the work should be carried forward. Now, you know what happens to letters that go to the President; they never get to him, to begin with, and the second thing is they go through the secretariat. The correspondence record is extremely interesting; it went from Tinker to Evers to Chance. And it arrived by Chance at a certain gentleman in the DoD. The gentleman in the DoD was not a scientist so he referred it to a committee of scientists. The committee of scientists met and one year later ground out the answer. The answer was, "Write the gentleman a polite letter and tell him we're not interested."

Now, I hope this seems significant to you all, because the great discoveries

in science have been largely the product of screwballs - people who thought different; people who attacked seemingly ordinary commonplace things, and then discovered extremely interesting explanations. This is the way science operates. This is not the way the DoD operates as most of you would quickly tell me, I am sure. Yet, the DoD is probably more in debt to science than any single segment of the American scene.

Now, what am I saying? I'm saying that scientists are far removed from technology. And scientists, in turn, fall into categories. We have the theoretical scientist who seldom works with anything but pencils and paper, and mathematical language. And as you know, the mathematical language is the only language invented by man that has no semantic ambiguities. It means the same thing to a Chinese as it means to an American. So, these scientists who are theoretical scientists oftentimes are at logger-heads with the applied scientists. This, again, occurred in the Manhattan District. This is a useful place from which to select examples.

The example I'm going to discuss is, "Who discovered first the critical mass, the basis of all your atomic weapons? Who discovered it first? Was it the theoretical scientist who used the so-called diffusion mathematical formula and calculated it? Or was it the chap who started putting little pieces together and started measurements?" This argument raged among scientists. This was not a simple afternoon debate. This was a party line between the theoreticians and the applied scientists. And it illustrates for you that there are here differences of philosophy. Actually, no one knows, I think, even today, who won that

argument, because the theoretician worked out formuli - and you have all dealt with formuli and you know that a formula expressed algebraically is meaningless until you can actually put in the quantitative coefficients. Well, the quantitative coefficients are claimed to have been measured by the applied scientist and furnished to the theoretical scientist so that his formula worked, and not the other way around, that his formula forecast the result and the applied scientist built it.

Now, I've illustrated a point and this point I'd like to have you think very seriously on because, if anything, this is a weakness in the DoD. You gentlemen have to deal with hardware; you have to use it; you're really engineers; you're military engineers in the true definition. And you're quite remote from the early process of how it was conceived. Very few of you would realize that nuclear energy, nuclear science, began in 1890 with old Dr. Hertz who first formulated and discovered radiation as you know it today; followed by Roentgen in '95 with his X-rays; followed by Defferell with radiation from minerals; followed by the Curies who separated them and defined them; followed by Max Planck the theoretician - the mathematician who first put down the formula that shows the behavior of nuclear materials to be statistical and to be indeterminate, specifically in any given event. In other words, it is forbidden for any man ever to see an electron. Yet, he has to deal with electrons and know their behavior. Max Planck put down the mathematics that express all of this and made it possible for Einstein in 1905 to work out the $E = mc^2$ which is, after all, the basis of your power in weaponry and atomic power; and this was followed by Rutherford discovering the nucleus of an atom. Thompson had discovered the electron back

in '96. Then came Bohr, the Dane, who worked out the anatomy of a molecule.

You see, there's nothing here that you can put to work. No military man got stirred up over all of this. In 1932, isotopes were first discovered and the first cyclotron was built. Again no military applications. And in the late '30s Enrico Fermi worked out the new elements - the trans-uranic elements - that lie beyond those found in nature. Again no startling reaction. Then, it was an accident in a cyclotron in Germany that showed the possibility of nuclear power. It was so unexplained at the time that the Germans, then at war with Poland, released the information, and it was on that slender thread that we got started on the atom bomb.

Now look at the long course of events between the theoretical science and anything at all having to do with nuclear engineering. You can see - I hope you can see - some of the differences that I am trying to outline for you.

Well, now, if you pass forward from what I call basic science or fundamental research, or pure science - you hear all these terms; they're not exact; they describe the image that I am presenting - and then you go through applied science; now you begin to border on hardware. It's a great temptation for me not to wander a bit because this is a fascinating subject.

The Greeks who coded much of early science, and did it very skillfully, had measured the size of the earth, its curvature; the Egyptians had done it; the Babylonians had done it; everyone knew the world was round; until a great man called Aristotle appeared on the scene. He flattened the earth out very quickly. He decided - being a humanist - and I am not decrying humanists because all of

us are humanists - he decided that man was the central point in the universe and so he quickly reversed all the early astronomy and knowledge of the earth, and he made man living on a flat plain with the heavens set up there as a kind of personal ornament which revolved around him. Then the astronomer Tolemi in about 400 came along and he observed the heavens very accurately and recorded all his astronomy, but the power of the Aristotelian approach was so great that he continued, in spite of his observations, to record the heavens revolving around the earth. It wasn't until Copernicus on his death-bed - a monk - discovered by looking out of his tower window, in what is now East Prussia, that this was not fact; that in all certainty we were doing the revolving. But being afraid to publish this as a monk of the church it was on his death-bed that a fellow monk wrung from him permission to publish the revolutionabus after he died. Thus there leaked out for the first time the break-through on the Aristotelian hold on science which had held it back 1,500 years. Now, why did it do that? Because the Christian religion came into being. It was entirely humanist and it was important to the religious leaders of the time that man, in his relation to church history and dogma, be the center of the universe. And so, Gallileo came on the scene and got arrested for building a telescope and proving that Copernicus was right. This was the first great battle between religion and science.

Religion lost; we'll spare the details. Now religion and science live amicably side by side and religion will accept the fact that in all probability there are a vast number of earths like ours in this vast outer space, and if so, they have high populations like ours; of higher order, let us say. They need not be exactly like

ours because there are certain accidents in our evolution and their accidents may not be entirely parallel; but intelligent. And so, there are scientists today - and these are the pure scientists, now - who are fashioning radio communication with stars that man can never reach, and repeating this in hopes that some intelligent radiation will come back. Well, when you stop to think that even the nearest star takes three years for a message to reach it, and hence, three years to return, they have to wait six years before they will find out whether they are going to get an answer. So, they'd better have good health.

I mention this because this is the area of science that lies beyond the day to day and separates it from these fellows, the technologists. Now let's talk of them for a moment.

The technologist has to learn his science because he's applying it. But having learned this science he has to learn something else. He has to learn what has been misappropriately called "Social Science." I say misappropriately because social scientists are names that are given to a group who study, sometimes including history, and if there is anything unscientific, probably history is the best example. Its given this name because in the administration in universities there are three groups of subjects - which is most unfortunate, I might add - the humanities, the social sciences and the sciences, which include the technologists. The result is that professors line up and fight as bloody battles as Army, Navy and Air Force. And there can be no bloodier.

Now, social sciences get their name because they use some of the mathematical approaches of statistical mathematics and the like which are purely scientific.

But you apply it to unscientific material. In other words, as soon as I apply statistics to men my statistics become pretty loose. And some of the statistics that I am going to give you are these kind of statistics. I challenge you to look at these exhibits for yourselves and to probe them, and to decide what your conclusion is going to be, and whether it coincides with the one that I will present to you. I hope whenever you see a statistical exhibit of any kind you will not take it at face value but you will question its substance. Do remember, and I will point out to you some of the assumptions and suppositions that enter into these statistics.

You will get lecturers here during the year who will emphasize some of these points. Be on your guard to me and to others. Well, then, having dealt off the social scientists somewhat improperly, I want to put them back in their place. They have the most difficult role because it is not measurable. Remember that lord Kelvin defined science in a very simple and understandable way. He said, "If you cannot measure it, it is not scientific." Now, along with this goes another very important example which I'd like to bring out, because this lies close to your problem.

Why is it that nuclear energy, the most potent energy that man has discovered in the universe was undiscovered until so many thousands of years after he had learned to use thermal energies - water-power, mechanical energies, and the like. Why? One pound, under $E = mc^2$ produces 11 billion 400 million kilowatt hours of energy. One pound of coal, if you can call that chemical energy, produces one and a third. Now, take the ratio of one and a third to 11 billion 400 million and you'll say it's absurd we didn't know this thing existed. Well, the

reason no one knew it existed, although the sun was sitting up there calmly furnishing us all this nuclear energy through some 5 billion years, was because we had no means of measuring; we had no equipment.

I used the example last year that if you had a five-ton iron ball on the stage and you were heating it, and you heated it from room temperature until it was ready to melt - which is quite a bit of heat - the ball should be heavier under $E = mc^2$; and a five-ton ball would be. How much heavier? About 20 milligrams. And since a 4¢ letter, which is supposed to weigh an ounce, represents 30 grams, a milligram, as you can see, being a thousandth of a gram, is a thirty-thousandth of a letter. And so, this five-ton mass weighs twenty thirty thousandths of one letter more than five tons. And where would you find a scale that would measure that. Therefore, all through the ages this very obvious force - the greatest force in nature - escaped man, because under lord Kelvin's definition no one could measure it.

Now, you see one of the outstanding easy methods of defining science. Here is where the social sciences break down. They do use statistical mathematics, but they have the average man; the constant dollar; the gross national product; all figments of mathematical imagination. There is no average man in this audience I'm looking toward. I've never had a constant dollar. And, gross national product, as you will be told, is made up of a series of assumptions which go through the computing machines and come out as an exact figure, which it isn't.

For instance, there's a figure in there for your wife. Do you want to put a gross national product value on your wife? One wife buys the cake-mix at the

shopping mart; the other one actually beats the eggs and flour together and does twice as much work and produces a similar cake. Does one do more work than the other in the gross national product? The answer is yes. How do you get it into the figure? You don't. She sweeps the house, maybe. She may go to work. If she goes to work she's in the gross national product a couple of times.

Now, if you go to Russia - and we're always talking about our rate of growth compared to Russia - you'll find some of the most astounding inaccuracies. First, a tractor factory. All right. The product - the tractor - goes into the gross national product. But the tractor gets its transmission from a factory over here. The transmission part of it goes into the gross national product. How many times is it in the gross national product? And what happens about the mine down there that produced the metal that went into the transmission whose figures as the production of steel, as the case may be, or copper or brass or whatever it is, goes into the gross national product? How many times does this leap-frog go into the gross national product?

If you have one company that goes all the way up from the mine to the finished product you'll see your figures come out somewhat differently under the statistical concept. These are merely the difficulties of the social scientists in trying to get measures that are useful in measuring national power. But, much of the ink that is spilled over whether our rate of growth is or is not greater than Russia's is stemmed from a number of assumptions that underly those comparisons. One of them is, "Well, they're in the early stages of the Civil War; we are now very sophisticated. They're up on the steep slope of the curve where

you can make large improvements with fairly understandable techniques. We're down on the sophisticated end of the curve where it takes some super-sophistication to make large improvements. You can go on and debate and debate. And depending upon your school tie - mine is the Industrial College this morning - I will tell you that you can produce whatever answer you wish. And since the Kremlin wishes to awe the rest of the world by bluff and bluster, it obviously presents its very best feet forward.

Now, this, then, is the problem of social science. This is why I wanted today to point out to you that many of my examples from the social sciences should be challenged because of underlying assumptions. You remember that old, old war statement that went the rounds when social scientists in the form of economists began to infiltrate all branches of the government as scientists now do. It was new then. A very distinguished social scientist economist came down to Washington and served. And he kept checking with his fellows in these different departments. He found out that he became more bewildered as he went around checking with them. And he was the fellow who, in a lecture said, "If you put these statisticians and social scientists end to end they would reach no conclusion." This became one of the by-words of that particular period.

Now, this is true. Just like under the second Roosevelt dynasty - Franklin D. - we cut the throats of pigs and plowed the crops under, under the very strange theory that the law of supply and demand had gone sour somewhere and was no longer applicable. The law of supply and demand went out of fashion and was not tought for awhile in the colleges, but it's now sneaking back and is becoming a

little bit respectable in some quarters. You can't do this with the law of gravitation. It's here. It has been here ever since Newton first formulated it and the mathematics still apply. But bright soul in the audience knowing more than I will say, "Oh, but Einstein changed that." Yes, he did. But he changed it like the milligrams on the five-ton ball because he had better methods of measurement. He showed that a refinement can be stated in the Newtonian laws of gravitation. But it's so refined that most of us who are not that refined failed to deal with it or even understand it. However, it is there. Nevertheless, it did not invalidate the Newtonian laws of gravitation. And the point I want to make here is to leave in your mind one essential fundamental difference between science and all other bodies of human knowledge. Science is exact. Science is verifiable by experiment. You postulate, you theorize, and you go out and confirm by experiments. And if the experiments, under all sorts of imagined conditions, and times, and countries, prove your postulation, you accept it then as a law, but not until then.

Now, you cannot do this in history; you can't do it in economics; you can't do it in any other body of human culture. This is not to say that science is superior to other cultures. It merely is to set forth in your minds the differences, and they are very sharp. This is why scientists think differently and have to think differently. They cannot take liberties with their subject.

Most every other culture, whether it be modern art which has taken the most extreme liberties that I can possibly cite; or any formalized study can take certain liberties. Toynbee tortured history into a series of cycles. It took

some doing. But history really isn't in cycles as Mr. Toynbee has it. Yet, there is a cycle effect in history. This is due to human instabilities. And you will see it in military affairs as well. You will see first great resistance, then finally capitulation to a sound idea, and then everybody gets on board and the confounded thing becomes the answer to everything. And it's just as wrong in the latter phase as it was in the earlier phase. This is an element of human nature. It applies to scientific application but not to science.

So, we are now in the field of the technologist. He has got to learn to take the work of the experimental scientist and then fashion it for the useful purposes of man. This sets him into the realm of being a social scientist. Because, as soon as you introduce into an algebraic formula a transcendental unmeasurable function the whole formula becomes transcendental and unmeasurable, and the man is the unmeasurable element.

I'll give you an example. A typical problem for an engineer might be the one of building a bridge. You can say that this is a scientific exercise because, (a) we know the properties of the materials we are going to build; (b) we know the underlying mathematics of the design of the stresses in this bridge. Therefore, we can fashion, we say, an exact structure. All right, you can. But now I ask you the $64 question. How large is it to be? How many lanes of traffic? Is this a scientific question? The answer is no, because the engineer knows his bridge has got to pay off. He has to finance it. And to finance it it has to be viable and useful for 40 or 50 years. This means in building this bridge he has to guess what the traffic is going to be 40 or 50 years hence.

How many of you, turning the clock back 50 years to the year 1913 to the old Stevens Duryee automobiles, could ever imagine 75 million of these death traps going up and down our roads? This is the engineer's problem and this is why he is not a scientist. He has to apply to the useful purposes of man, intuitive judgments. And a scientist should not use this faculty of intuitive judgments as an engineer has to use them quantitatively. He can have all the intuitive judgments he wants as to how the universe works, but he has to then measure it and find out if it does. The engineer cannot measure the traffic 50 years hence. This separates these two professions. And you in the military have confused these two. You have used these people improperly. You've used engineers for scientific work and you've used scientists for engineering work. You will always pay a price when you do that.

Well, then, so much for what we are now talking about today - science and technology - because we are now talking about the team.

The second section; what can we see in history on our examination of this broad subject? Well, let's take some easy ones. Greece. Now, Greece is referred to in most of the colleges as the "Golden Age." It's even said that the philosophers of Greece have stated the great truths and that today these are essentially the great truths. There is great truth in that statement. So, it is often referred to, then, as the height of culture, and Greece is represented as the Golden Age. Is it? Let's look at it as the engineer looks at it and see what is Greece.

Its entire economy was founded on slavery. Aristotle's great contribution to

science was that no philosopher - because that's what they called scientists - should work with his hands; that's for slaves. So, he did away overnight with all experimental verification. He sat down and dreamt up biology. His biology is fantastic; it's so unreal; so unlike nature. He was a lousy scientist. Actually, he was a great man. In humanism no one has surpassed some of his sublime thoughts and philosophies. But in science he was terrible. This is because these two areas of man's mental activities lie along different techniques and parameters.

Greece, then, had this great core of distinguished thinkers who lived on the backs of slaves statistically. It is said it took from 18 to 28 slaves to support one philosopher in ancient Greece. This is the statistics idea of dividing all the slaves by all the philosophers idea. I don't hold this for any one, you understand.

Now, whenever the economy of Greece started downhill, what did they do? They fought a war; that was the only way to get more slaves. If you gentlemen were interested in the days of Greece as to whom your next enemy was going to be you had merely to look and see where there was a lot of population that you could grab onto easily, fight a minimum war, and there you were. But you will remember, now, that whereas Plato was supposed to be the author of democracy, if you read him you'll find that his democracy was based upon some amazing concepts, one of them being that only 10% of the Greeks were entitled to vote. These were people who had property and were educated. Now, the minute you say that a certain part of the population is entitled to do something because, you've got to set up a commission to settle the because. This meant that you had to set up a jury of your peers in Greece to decide whether you vote, or whether I vote

and you don't vote. Is this democracy? Well, that's Plato's democracy.

Now, it was an advanced concept in ancient Greece; far beyond anything that existed, to be sure. But let's not put it out of context; let's not fool the little boys in prep school into thinking that this was the Golden Age. It was a great age, but it was very perishable. Greece never became a great country in the sense of a world power. It couldn't even get along with its sister cities. Athens and Sparta were always at war with one another and so were the other Greek cities, and so were the neighboring countries.

Who, then, became the great power of that age? Rome. All right; let's look at Rome. Rome never had the culture of Greece. They didn't have a Fraxetilles as a sculptor. They did some nice statuary, but it was largely a copy of the Greek systems. Let's look at Rome; 960 years of being the great power in the world. How did they do it? They did it by engineering; nothing but engineering. It wasn't Julius Caeser; it wasn't Emperor Augustus; it wasn't Romulus and Remus; it was engineering. And how did they do it? They were the first of the great civilizations to discover how to make a city of a million people and not have plagues; how to bring in fresh water, pipe it into individual houses, bill the customers monthly by the water they used; they formulated Roman law, learned how to build highways, developed methods of communication; were really good engineers on bridge building to make their highways and bridge structures, and viaducts; they learned how to build an arch. They Greeks never had an arch; they had flat stones. They were not engineers.

If any of you ever go to England, go up on the Roman Wall and look at some

of their forts. And see how they even learned how to mine metals in that very primitive, barbaric country as it was, and how they fashioned pure led and then used the flat stones with the most ingenious led joints to make water cisterns and reservoirs; bathhouses - and look at one of their forts and see the organization of the fort; see the Commandant's house; see the Quartermaster's house; see the storehouses; see the latrines; see the recreation areas; and see the degree of really sophisticated civilization that the Romans had learned through the practice of engineering arts. It is most impressive.

And so Rome remained for 960 years the great power of the world. Well, now let's skip along to a period that was equally impressive in history and see if we can put a tag on that. And I'll talk about the industrial revolution in England, making a very large jump.

When Newkoman fashioned the first steam engine he was really the first man on any reasonable scale - because the Greeks had done it; Hero of Alexander made the first turbine as far as we know, for pumping water into his house - but anyway, Newkoman made a practical engine and used it for pumping mine water out of deep mines, thereby bringing out a supply of coal which became the energy source that founded the industrial revolution. And the coal, plus the Newkoman steam engine, plus the later developments in the art of manufacturing metals and engines; Robert Fulton, James Watt and the rest, all of these people came along and they were engineers. They took this new discovery of a natural force - thermal energy - and machinery quickly came into being, such as the spinning mule and the jenny. Pretty soon a vast textile industry grew up in England and

pretty soon England was an exporting nation. And soon through the working of economic law it began to penetrate all the trade routes of the world. Here was a little bit of an island kingdom with a population of a handful of millions becoming the great power of the era, and maintaining the pax Britannica for 100 years, and extending its empire throughout the world to where the sun never set on the English Empire.

It was engineering. It wasn't the kings of England and their eight wives, or anybody else; it was straight technology and engineering founded on the natural forces of nature.

So, we now come to World War I. What happened? A very industrious and ingenious group of people - the Germans - had harnessed chemistry. They built a great synthetic chemical industry out of French and English science. Many people do not look backward to see again the time cycle from fundamental science to application. But there it was. And the French and English chemists who had done the bulk of the basic work furnished the Germans with a stand from which they then built this great synthetic chemical industry. This little nation of, perhaps, 65 million people at that time, in a country where there were no natural resources except forests, coal and a little iron, threatened the peace of the world. How could a country of as few people as that threaten the peace of the entire world? Ask yourself this question. First, how did they have the nerve to do it? Second, how did they have the power to think they had the nerve to do it? Nothing but science and technology; not another thing. Ingenious and active as those people are, they had learned to harness certain forces in nature, and fashioned materials

and technologies, and they came up with a series of weapons systems that they thought gave them the ability to threaten the world. And they jolly well near did it. Worse than that, they did it again, and again it was science and technology.

It was the German submarines; it was the German Panzers; it was the German stukas. Think of it; you gentlemen know these weapons systems better than I. I was in a mission in France during the application of these German systems and I saw France curl up and die. And believe me, I saw technology firsthand; once to the tune of 30 bombs that hit the building I was in. I saw some German technology.

Now, gentlemen, don't think it is rulers; don't think it is political scientists; don't think it is economists; the economy follows the fruits of science and technology. It is the product of science and technology. It is not the author. It doesn't dictate science and technology.

Madison Avenue, the great advertising throne, does not create goods; it distributes them. It can't distribute nothing. Something produces. And that great production machine is aided and abetted by merchandising techniques. But don't ever think for a minute, or fall the victim to the printer's ink that flows out of that canyon that it is advertising that is creating this. It is science and technology.

Here Germany has threatened the world twice and come within an ace of attaining its objectives.

Now lets turn to another example - Japan. There's a little island; many of you have been there. Only 15% of its land is even arable. It got all its culture from China. Now, remember the Romans got their culture from Greece. But culture didn't make Greece great. And so, Japan got its culture from China.

Seething millions of people who were sophisticated when they said we were barbarians; who were astronomers in the Year One; who fashioned gun-powder; these were ingenious people, sophisticated people. And the little island of Japan made a monkey out of them. It walked in and took Manchuria. It, of course, belittled the Russian Navy earlier, in 1905, I guess it was. This little island of Japan with very few resour ces but fine technology, nearly conquered the whole Far East Hemisphere. It threatened us, the greatest production nation in the world.

Gentlemen, these are my examples. I am re-writing history for you today. I've left out all mention of kings, emperors, czars, mikados, etc., because they're puppets. These gentlemen only reflect the forces over which they preside by a form of elected organization or assumed organization. They don't create it. Their power and their might can only be that of their supporting forces. And the supporting forces are not things you pluck off trees. Agriculture is one of the best examples of technology.

There in Russia there are 55% of all the population trying to grow food, and the rest of the population living on meager diets, while in the United States 7% of our population has flooded the world with agricultural products. That's technology.

Now, I think the time has arrived where we'd better examine some of the statistics on which, perhaps, we have based some of these rather sweeping conclusions.

Thank you.

Now, gentlemen, we'll do the hard part. May I have the first slide? Gentlemen, the method by which science progresses is research and development. We'll start off now by seeing what is happening in the United States to research and development. Let's look at this curve first. Here you see United States research and development expenses in billions of dollars. You see it's almost up to the 15 billion mark. Gentlemen, that's a major industry. That involves one million people. Take that out of your work force and figure it; one million people. But notice how recent it is. There is 1954. Look at it then; one-third of what it is today. This is the response of a nation under technological attack. And you who have read the papers within the last week and seen the outflow of propaganda from Russia on her outer-space achievements, which are very great, very wonderful technological developments, recognize that this is the battle-front today.

With all the earnestness at my command let me say to you this is how the Russians figure they are going to win. They're not going to throw their bombs at you in my opinion. Nobody would win that as all of you know, and before the end of your year you'll be making studies in that area and they'll simply show you how ridiculous such a course of action would be. Do remember that through the course of history the men who declared war - these are the rulers - always figured that if they lost the war they'd come out with a whole skin. Remember the Kaiser in World War I lived in luxury the rest of his life over in Holland. Hitler built the wonderful Berchtesgaden and all these protective areas, and thought he was going to survive even if he lost. No one would survive this one that we're talking about.

The Russians are materialistic, cold, factual people - their rulers - and they are definitely out to lick us. And as I will show you in the course of the day, and if there is one thing I can leave with you, it's the method by which they are doing this.

Now, here is our response. This is the amount of government research, and this is the so-called private research. As you see, this is money in private research, because later on you're going to find out that most of the research is done in this segment even though the money comes out of that segment. Over here you see there's a break down of this. These are government funds which, as you see, run up to about 6 billions of dollars. This is the work that goes into industrial laboratories - 6 billion. And this is the private fund of about 5 billion. So, you now come out with a figure of about 11 or 12 billions which are done in private industrial laboratories. Down here you have government laboratories and you see a little over 1/4 billion. Down here you have the universities, and here it's a little less than a billion.

Now, let me re-emphasize, gentlemen; this is the most important; far more than that. Although, this is the part that you're most conscious of the weapons system that you are about to use or hope to be about to use, down here are weapons systems that you haven't even heard about yet. Down there are scientific development you haven't heard of. Now, the lag time in there can be very large in some cases.

All right. Let's look here at the distribution of the federal dollar. Research and development - now, this is federal. This isn't the total America; this is

federal. You will see the profit organizations do 63% of the spending with federal funds. The federal government does 22¢ in its own laboratories. Educational institutions 11¢, and the so-called non-profit institutes, 4¢. Here you notice the growth from 1940. Remember, gentlemen, you were at war here or were about to be at war. How many of you would know - most of you are not old enough to - that the total research in America was $300 million in 1939? $300 million; and we were about to be challenged technologically. The whole product of World War II brought us only to a billion two, which is peanuts under the $15 billion of today. This is World War II with all of the great developments of that period.

Now notice what happens with the "bring the boys home by Christmas" technique of the politicians. We demobilized our research and development. I could show you my scars. I went before Congress on this thing. Admiral Lonnquest who is here in the audience will recognize that the NIDMA Project was born out of the testimony that I gave in Congress during this demobilization to try and preserve a high tempo of research and development. I was merely a spokesman for the aircraft industry at the time.

Look what has happened since. Here is the lull before Korea; here's the post-Korea action. You see we were almost coasting again. The United States learns, but learns slowly. We were learning over again the lesson here that we had to learn here, and so now we're taking off, and now what I'm afraid is, what I told you earlier; all these human events are like pendulums; we may be swinging excessively here. I know that in the field of Health, Education and Welfare anybody with any kind of an idea can get money. It's flowing out of their ears.

They just don't know how to place it out. And this is the pendulum at HEW. Of course, there was a period where we had dimes for medical research in polio, etc, but now we really have to go. Where is the work to be done? The Rockefeller Institutes and the New England Institutes for medical research are in the minority. You don't have the areas to spend all this money, so somebody's a bit foolish we think. All right. This is the most striking and marvelous example of a nation's response to technological challenge in a technological age. And here are the sinews of our defense in our response.

This is spending for research and development in '60-'61 in colleges, universities and research institutes. This is what I call the most important part. This is the seed from which everything grows. Where did the money come from? The federal government 65%; industry 32%; 3% from the educational institutions. And you wouldn't expect money to come out of them. They're out passing the hat to get money to run their show. Here is where it's spent: 75 - industry; the federal government 50; 10% - there's the significant figure - 3% of the dough, but 10% of the expenses. And that's the area where all of this work originates. Now, again you'll notice this is based upon a $14 billion par. This includes commercial funds as well as government.

Now, this is the one that has to do with basic research only. Here again the federal government furnishes 58%, industry 24%, colleges and universities 12%; others 6%. Let me warn you, this is a statistic. I'd hate to be the man who had to determine whether what I was doing was basic or applied. In most cases it's both. So, how does the government get these figures? He gets them by the

questionnaire route. How many of you have filled out questionnaires and found questions that you really can't answer except in half a dozen different ways? And what do you end by doing? You finally say, "Well, I've got to get this thing off by tonight's mail," and so you put down an answer. And a lot of these things are estimates - judgments - these are not exact things. This is social science; this isn't science. So, remember now, even if you wished questions wonder about it; is it true? What is safe? What isn't? I don't believe for one minute that industry does 24% of basic research. I think Madison Avenue tells you they do. Because it's a kind of a game. You belong to the finest club if you can show that you've got people who can do that in industry. It gives you a kind of public welfare slant and a lot of other things. It makes all of your later on work come out and look as though you did a really great job for the United States of America. I think there is a certain amount of hokum in this. I don't think there's any up here.

Now look. Colleges and universities really doing 44%; industry supposed to be doing 29%; and government labs 19%. Where's the expense? I question that just as I question that. You may question it all if you like. All right. Here is the research and development expenditures as a percent of federal budget expenditures. Gentlemen, you all know of this extraordinary group of men called the Congress, and you recognize that the money has to come from them. When I show you a curve that looks like this I am showing you how Congress responds to a national challenge. This isn't easy. It's a kind of rocky road to Dublin here. Actually, the man who made up that chart - I had one last year that had a big gap in it right here. What caused that gap? The fact that we changed our definition. We put

prototypes in now under research and development expenditures. The minute we put prototypes in the whole curve changed. So, if you were to go back one year in the National Science Foundation's annual report on this subject you would find a different curve in here. And you'd be entitled to say, "Who is giving me the strength?" Well, the point is that they've changed the method of gathering the statistics in the definition of whether the prototype is part of the research and development over all activity and what constitutes a prototype.

Now, Admiral Lonnquest was in Naval Air for a great many years. It's pretty hard to know when is a prototype not a prototype, and it's pretty hard to know after you've got a production stream of airplanes coming through and you heavily modify one for a new weapons system's adaptation, whether that falls on this curve or not. I'll lay odds it doesn't. I'll lay odds it's buried in the production figures, because I used to negotiate those contracts. And so, this is not exact, but you can accept it as to the generality of its conclusion, which is, the Congress is thoroughly alert to the role of research and development. But let me warn you it is not at all alert to basic research.

You'll have an awful time getting money out of a Congressman who says, "What am I going to get for this money?" You tell him you're darned if you know and neither does the man who wants the money know; he merely wants to examine something he doesn't understand. The Congressman is examining things he doesn't understand all 365 days of the year.

All right. Now, here is the federal obligation for conduct of research and development of science, and note this totals all agencies. These are three separate

years, and this, obviously, is the last year. And notice, this is federal money again, so it's only 9 1/2 billion. I say "only" - I haven't got that much myself. Now, here is the Department of Defense. It's the first time I've seen it ever take a step backward; I don't fully understand it myself. It dropped from six billion six to six two. Here is the Space Agency. This is now going full steam under Parkinson's Law. You will see an enormous percentage increment here 66 2/3% increment in one year, and if we go beyond this year you'll find an even worse one, or bigger one. Although, it happens now the Pentagon since Vostocks III and IV is beginning to question whether it did the right thing putting so many eggs in the national basket. And I'm not referring to the ruler of Egypt either.

Here is the Atomic Engery Commission. Parkinson is still working hard there although it's difficult for him because many of the weapons needs have been satisfied and they're having trouble. Dr. Seaborg out at Oak Ridge, the Chairman of this commission - here's a good example of Parkinson's Law at work. The Chairman is Dr. Glenn Seaborg, a Noblel scientist. I think I can be pardoned for saying that I don't think he's the right man for Chairman. The reason is because he is a scientist. He's a scientist right down to the soles of his feet, and a wonderful one. But the AEC is a gigantic business complex.

Let's see what I mean. I think it was in April when he said that the laboratories at the Atomic Energy Commission were so ably staffed with such a great national resource that they ought to serve the broad national needs of research and not be limited to the purposes of the Atomic Energy Act. This means without Congress' approval on laying of budgets, etc. etc., the AEC would like to have a

free hunting license wherever it might choose to go. So, what did he do. One of its most eager beavers is Dr. Weinburg at Oak Ridge. He has never been too happy with any form of restraint. So, he decided when the ANP program was cancelled and he had a surplus number of scientists and engineers, instead of fulfilling the stated purpose of the Commission, which was to throw into the industrial sector of our economy as much as possible and get out from under competition with private industry, let us see what he did. He prowled around - having good intelligence - and found out that there was plenty of money over in the Department of Interior for water desalinization.

Now, five very fine research groups in America had been conducting research into water desalinization. Several of the fruits of their findings are now being built in prototype plants both on the Gulf and out in California. But he saw this loose money shaking around in the pockets of the Interior, and it's a kind of "Holy Cow" up in Congress because we're facing a water shortage for the first time in the history of this country in certain areas. So, Congressmen being Congressmen, are doing the usual trading that goes on under these conditions, and the water-short areas are getting a lot of political support. The result of all this is that Weinburg says, "Gee, here's a horse that we can ride." So, he goes over to Interior without Congressional approval and gets a transfer of funds not envisioned in the AEC Act. You can read it to your heart's content; you won't this in there; just the reverse. So, now he has started on a program of water desalinization and he is employing all the people who would normally be available to go on weapons work for you all in other areas. And the empire goes on.

These are the three big sharers, or the four; NASA, Atomic Energy and Defense. This is on a different scale, so don't get fooled by this. Education and Welfare is growing up, as I told you a little bit earlier, and today you can see Parkinson here; he's running. Here is $510 million. And this half million dollars is getting up into the magnitude that we started with up here, three quarters of a billion. Pretty soon we're going to have to move this one up here and put it on that scale.

Now, down here is Agriculture which you think does quite a bit of research, and it does, but it's only $154 million. I don't know what they did here; they went back a little piece.

Here is the Department of the Interior which covers all the mines, the minerals, wood resources, water resources and the like.

Here is the National Science Foundation which is supposed to be the stimulant for basic research. It's playing with peanuts in this league - $110 million. That has grown up in two years from $68 million, which is what you saw reflected in the curve of the response of Congress and also the money spent in educational institutions. This is a very vital element, but it's in a different league.

Down here is the Department of Commerce which hardly even belongs to this ball team, with only $47 million. And so, those, then, are the areas of segments of national monies that go into research.

Here is the federal obligation for research and development by character of work. And again, this is what I want to emphasize in showing you this chart. See this fuzzy little area here. Percentage wise that is the one that's growing rapidly,

and actually, that is supposed to represent the growth of our understanding of the need for basic research. I'd question the accuracy of the figures, but nevertheless I'm delighted at the trend. This was the reason for really including this particular chart. I don't think anybody can actually separate development from applied science. Anybody who has worked with bread-board models in these various technical industries that comprise your support and back-up would recognize that these are areas that shade; there is no line. Even when you fill out a questionnaire you have to kind of take a mental knife and draw a line somewhere; it doesn't actually exist.

All right. Now, here's the U. S. Government investment in the Atomic Energy Program. First, I want to point out that next year in our budget I think we're supposed to spend $3 billion 800 million for outer space development. Let's assume that this figure is somewhat right and let's do the first approximation on it and call it 4 billion to make it easier. Let's also do the first approximation on the cost of the atom bomb's development which was considered to be the most expensive development in the history of mankind. The atom bomb cost slightly over $2 billion. We are spending on space alone next year roughly $4 billion. This will help you. I can't deal with these huge figures unless I can put some sort of translation into something I understand. I understand when you tell me that we're going to spend twice as much on outer space next year than we spent on all the work we did through five years in developing the atom bomb. I understand that.

When people say, "We should be doing more" - I don't know how many of you read the editorials in Aviation Week - Mr. Holzer, I believe - it seems that his labor of love is to point out every week how we're not spending enough money. I

think he believes all this too. And his arguments are very appealing. But I suspect that he never took economics in college; I don't really know.

Here is the Fiscal Year '60 and here is '61, and there is Parkinson's Law in the AEC in the sense of construction and plant and equipment ledger. They have, roughly, $7 1/2 billion worth of plant - laboratories, if you like. Here is their annual operating cost and there again we see this interesting phenomena of a slight regression. I don't know whether Mr. Parkinson is taking a vacation here, or exactly what has happened. It will be interesting next year to find out. But you do see what happens with any new independent office in the United States Government. It grows.

Now, here I want to show you the new one. Ted, you and I for years dealt with the NACA and you were on it. And you see what peanuts you were playing with. This is the space age, when they took you over and the NACA went out of existence and the NASA came in in 1959.

Now, when you think of all the fundamental work and early applied science in the whole development of aircraft that was done with this, and this is what we're now doing to develop space, I hope again you can have some mental picture of what we mean.

This is total investment in plant and equipment. Now, NACA did pretty well for itself in plant and equipment. They had some wonderful laboratories like the Lewis Laboratory out in Cleveland, the Langley Field Laboratory, the famous Moffett Field in California; they were really some pumpkins in spite of the fact that the cost of operating didn't loom quite as important in proportion. Now you

see what we're doing at Canaveral, Point Magoo, and other way-stations. And this is only starting.

When I was down at Canaveral not long ago we arrived four days after Glenn had gone and come back from orbit. It was set up just as it had been for controlling the flight and it was extremely interesting to observe. When we got through with that and the whole line of launch pads, any one of which could have launched Colonel Glenn, we went out to the new Saturn launch which will be the first test for Apollo. There sat a structure 27 stories high with two passenger elevators, one freight elevator, and the second saturn motor was just being landed at Canaveral. It took a special ship to bring it down the river tributaries from Huntsville, and it took a special pier built out into the shallow waters of the inland waterway there to unload it. It also took a special railway to carry the thing up to the launch pad. The railway must have had a gauge of 15 feet.

Well, we stood there and we were being briefed. And you couldn't keep your eyes off the top of this towering structure, trying to visualize the forces that were involved. Well, the booster of the Series C-1 or 2, I guess it was, a million three hundred thousand pounds. Now, we thought that the Russians were topping off at about 860,000 pounds thrust, but they had more than that for this job they did last week. So, we can say the Saturn, if, when, and as, is on the order of what the Russians have been playing with for some little time now, and here is this gigantic system.

After it was all done and he spoke about this enormous jump from say 380,000 pound thrust in the type of thing Glenn was in, or in that neighborhood, all the way

up to one million, three hundred thousand, ultimately a million five, and the enormous size of this thing, your mind was staggered a little bit. Then I was foolish enough to say to this gent, "Where are you going to do the Nova?" Well, gentlemen, the Nova has 12 million pounds of thrust. And if you need 27 stories high to do a million five, a special railway, boat and pier, I don't know what you're going to do for the Nova except that the Nova is going to be assembled on the lot, I guess, out of these huge multiple engines which we're experimenting now with solid fuels and which have crossed sections of the fuel-burning areas as large as eight and ten feet. You can imagine burning uniformly an explosive ten feet across and having it burn uniformly and behave itself all the way up. This is quite a little piece of work.

But, Uncle Sam has had to turn around and buy land twice as large in acreage as the whole of Cape Canaveral, and he figures the first shot will cost billions of dollars. Well, this is where we seem to be headed.

Now I'll show you a very unhappy statistic. In 1939 a family earning $10,000 a year paid taxes of $269. These were 1939 dollars and they lived very happily. So, we'll now find out what we're going to do today. We'd have to earn $26,476 to pay the taxes of $5,603 in place of $269, and this is this non-inflation that we hear so much about. Now remember, it's in your statistics. When you make comparisons, if they're not in the so-called constant dollar just remember this thing here. When I said the atom bomb cost $2 billion and our single budget next year has $4 billion for outer space I suspect the effort is about the same. But one was a five-year effort and the other is a single year effort. So, it's still a five to one

comparison. But I warn you, this you must look to in all the figures you survey. Don't fall into a trap with all this ridiculous nonsense that comes out of political oratory that we have inflation under control. There it is.

Now, this is a very unpopular exhibit, and when the labor people come before you they're going to get awful angry if you throw this at them. This is steel industry employment costs in the United States and certain foreign countries. These are the steel-making Western countries: Luxembourg, Belgium, France, West Germany, the United Kingdom, Italy, Netherlands, Japan, and the dear old U. S. Let's see what the wages were in 1952; 98¢, 82¢, 72¢, 62¢, 69¢, 64¢, 63¢, 53¢, 32¢ - a good steel-making nation $2.32. How would you like to go out and compete in world markets with this against people whose steel plants are more modern, built largely with Marshall Plan funds and American credit, very many of them built with equipment from the United States that is more modern? This is where Roger Blough was unable to present his case. This is what he was talking about. He wasn't talking about a loan; he was talking about the fact that there is not enough throw-off of cash in our steel figures today to build the mills to keep up with these countries whom we have financed into very advanced technology.

Now let's see by 1960 what happened. Oh yes, Luxembourg got a little inflation, didn't it? Belgium got a little inflation. France got some inflation in spite of the fact that it's supposed to be the country that De Gaulle keeps iron-fisted heel on on wagering.

Here is West Germany beginning to be very labor union conscious. Here is the United Kingdom, which was labor union conscious before we were and before

Germany was, and look where it's lagging. This is because England is trying to survive in a world where her own balance of payments was getting badly out of control. This is the cause of the labor unrest in England. Here's Italy. Imagine; we always thought of Italy as a low-cost labor country. Look where it's speeding up, a 30% increase here. Here's the Netherlands. And here's old Japan. Look at the United States. We're not going to be left behind in any race, by golly.

Now let's see the percentages, foreign, as of the United States. 42,35, 31, 28, 27, 23, 14. And this is what our competition is. Now let's see in 1960. 37, 32, 26, 32, 29, 26, 28. In other words, you can say, roughly, a quarter to a third. The worst of it is, gentlemen, that this has become an annual habit. The public thinks every year that every labor contract must be a more plush one than the one the year before. It is accepting this. This is like accepting your own doom without analysis. Now, I know that you can bring up some very complicated arguments and labor will have them all for you. But the fact remains. All you have to do is look at such things as the export of cotton in the Agriculture Act where we got priced out of world markets, and see where we are today compared to where we used to be. And all you've got to do is to see what's happening to steel exports statistics today in terms of world markets and where we used to be, and you'll see whose arguments are really right and whose are really wrong.

Well, now, gentlemen, we are turning away from the economic statistics of that fundamental nature to manpower statistics. The first thing I want to show you here is the scientists own estimate of what constitutes sophisticated science. There are only two measures that I've ever heard of, one is Nobel Prizes

awarded by a Swedish committee, and the second one is, a number of published papers in the accredited scientific organizations. The latter is just stupendous. The stuff that's pouring out of Russia is like a waterfall.

Let's look, now, at two things. Here in physics we got 13 Nobel Prizes since the war, to 12 for our allies. These are our allies. You can see what would happen over and again to these figures if we were to lose Europe, as at one time was popular thinking in the United States, that the Russian Armies could over-run Europe in six weeks, which, of course, is a bunch of hokum. Anyway, it was a widespread belief. And if it occurred, you can see what would happen; not alone here, but to our subsequent exhibits, to our own military posture in the world. Well, all right. We'll say that the work being done in sophisticated advance science is as great in our allied areas as it is in the United States, and the Soviet looks very small. I think part of the reason that it looks small is because so much of their work is suppressed. So, I would again say, "Question statistics."

Here in chemistry you see the same lesson all over again. Now here is the one that really intrigues me, because I don't see any reason why we've got to keep this one quite so secret. For a while they were boasting about their nerve transplants and a whole lot of fancy surgical techniques. Well, it isn't so rated by a jury of their peers. Here again you see this very interesting balance between Europe and the United States.

Now look at literature. Europe is still preoccupied with the culture of ancient Greece. These are peace awards. You know that the country that isn't strong is working harder for peace than the one that's strong. So, just expect

countries that have no real military strength to be working very hard at peace.

Now, here is a very sad picture. To my mind it is as sad as the labor picture only worse. Here are the bachelor and first science and engineering degrees awarded in the U.S.S.R. - 191,000 in '58, which is the latest we could get. Here is the United States, supposedly its technological competition. Look at the United Kingdom, France and Germany. Gentlemen, the figures are a little more complicated than this, and again, you should do a little analysis.

In the first place, let me answer a question. They are as good as we are in this field. Let's don't be snide about a Russian degree. It is different from ours and it isn't because it's loaded with politics and political theory. It's the fact that is merely more specialized. The Russians graduate an air-conditioning engineer. We don't; we graduate a mechanical engineer. He can do a lot of things in air-conditioning, but their air-conditioning engineer is more highly specialized than our mechanical engineer. He can go to work right away and produce air-conditioning solutions.

Anyway, here is your total over-all picture minus one thing. In Russia they have an institution called the "Technicum." It's really the equivalent of a two-year university. There are as many graduates from technicums in the technological fields as there are from baccalaureates. You must throw into the Russian figure an enormous backing up of technicians whom, in many cases, are junior engineers. We use engineers to a large degree, except in the electronics industry, for technicians.

All right. Now you see over in our allied areas a step down. These people

are equal in every respect as far as quality is concerned. I don't care whether you go to Italy or where, you'll find just as good engineering in Italy as you'll find in the United States. Here are total degrees awarded, and notice the difference. 338 in Russia to 366 in the United States. Look here; look at the percentages. 57% are in science and engineering as against 24%, as against 41%, as against 71%, as against 31%, as against 25%. We are the low man on the totem pole. We're supposed to be a scientific, technological country. We're supposed to be. Why? Well, first of all it's much harder work to be an engineer or scientist than it is to get a liberal degree. And I know plenty of sons of my neighbors, some in my own family to be exact, who elected liberal arts because their room-mates were always going out when they had to stay in and study. One of them switched over after two years of electrical engineering so that he could go out with his buddies.

You don't do that in the U.S.S.R. You go back on the farm or in the factory if you do. This is not good. Now let's see another one. These are degrees per population. Don't think for one moment that Russia is going to be shy of technological or scientific capability. And do remember that the Kremlin can channel funds into these areas whereas we have certain limitations. Now, I don't say that we shouldn't award degrees in a non-science and technological areas, but I would like to say that we're out of balance.

If we want to survive the coming attack - which is a technological attack - and this is part of a conscious policy; Russia has learned why we emerged from a population under England that was forbidden to manufacture in 1776, to the greatest production machine in the world. And Russia started with 80% of its

population serfs. It said to itself, "How do we overcome capitalism?" Their answer was, "education." They started in 1932 and don't think that it's by force and decree; it's by one of the mechanisms which made us great and which we are gradually eliminating - the incentive. Every student is rated in the secondary school system in Russia, and if he shows capability in the underlying basic study leading to science and engineering he is visited by a member of the educational bureau and offered an opportunity to go to a university of his choice with all expenses paid, providing his marks are above a certain level.

Secondly, he will stay in that university as long as his marks are at a certain level.

Thirdly, if he graduates cum laude he will receive a salary increment far beyond his fellows; far beyond doctors of medicine, economists, historians and other educational specialties they permit.

This is incentive at work. So, the student who is the son of a parent who might be anything from a street sweeper to a lathe worker, to a railway employee, or what have you, he sees opening up before him a vista that his family never provided. That incentive is what has promoted this result, from a country that had almost a minimal educational standard.

Now, lastly, there are fewer illiterate people in Soviet Russia than there are in the United States. We have more illiterates. We do not enforce our own laws in some areas of the south and the southwest where we have citizens who have never really had the full measure of their schooling, and some, very little if any. It's tolerated. It's against the law, but it's tolerated. In Russia

it is not tolerated.

This, pictorially, shows you something worse. This was the great push of the G.I. Bill. And for awhile we were graduating more engineers than Russia. This is only engineers; not scientists. A similar curve can be shown for science. Now, this is Russia. Somebody used the crystal ball and said, "Oh, Russia is going to level off at 125,000 grads a year." Here we are. This is our proposed increase under this propaganda you're getting from the national education unions. Boy, are you being propagandized. The shortage of teachers. Do you know that more people went into the teaching profession last year than into any segment of the American economy? There is no shortage of teachers. You can't get people to work as a teacher. They just don't want to work as a teacher; the salary is too low. It's the neatest propaganda that ever came out, and it's in a field that strikes every parents heart. It's like motherhood and sin. Believe me, it's effective.

Well, anyhow, here we are. And there is our competition. Where do you actually think in 10 to 20 years this is going to get us? There's nothing here to correct it. Think about that during your school year.

All right. Here is an analysis. There are the advanced degree holders. Now you're in the graduate school. These are the masters of science and the Ph.D. boys. These are mostly Ph.D.s. Incidentally, in 1955 the Soviet graduated 630 Doctors of Philosophy and Meteorology, and the United States only graduated two. And weather control is one of the great areas that Russia is working on, of extreme military significance.

Well, here are the Ph.D.s. - U. S. Doctorates. Now watch what happens. Here is science. We still have a slight edge on our friends. Here is the engineering result we can show you. It's pitiful. In the engineering colleges last year we had fewer freshmen enrolled than we did the year before. Now, part of the reason for this is that a lot of engineers have been fooled by publicity that outer space is science. You can't get to outer space riding a science horse; you ride an engineering device. But it's portrayed as science. So, the poor deluded freshman with stars in his eyes and outer space as his goal enrolls in physics. He finds he's betting on the wrong horse, but here it is. This is a lack of understanding in our school system or a lack of ability to transmit to boys and girls 15 to 17 years of age the differences that I've tried to point out to you here today between science and engineering. And many of these poor fellows over here are really only designed to be engineers. When I say "only designed," I don't deprecate it, I merely say that have the kind of mind that can make three-dimensional perceptions and intuitive judgments, which is not good in this area here.

Here are social scientists. Here we are and here is Russia. You can't fight Russia with social science; you just can't do it. That's all settled by the Kremlin anyway. This is wonderful. Part of the faculty, a very distinguished faculty of this institution are very able social scientists, and this is extremely important to you and to your instructional process, but this isn't going to be our answer. Those are the gentlemen who, laid end to end reach no conclusion.

Ohio State University did this. I'd never seen it before. I saw it first during a meeting there on military logistics. This is the standard of living in the

United States in the form of silver dollars. They got them out of Las Vegas; that's the only place they have them. At any rate, there is the standard of living since 1920, 1930, '40, '50 and '60. And this is the number of practicing engineers in 1920, '30, '40, '50 and '60. Well, is this difficult to understand? Who makes the standard of living? The engineer. The engineer who takes and makes processes and machinery, and runs the factories; who handles the help. He's the production brain. That's a very interesting chart. I didn't have anything to do with it.

Now, this is a pictograph; the only one that I have and I love it. In 1855, man by his muscles contributed to the production process. He dug the ditches, plowed the fields; he toted the loads. When they were too big for him he got his friend the horse; animal energy. In other words, through the bio-chemical process of protein into energy. There is how we ran our economy. And this, proportionately, was the contribution of power-generating mills - largely water-power mills. This represents 13 hours a day of men toiling. He was on the farm. That was the statistic of 1855 before the Civil War. This thing here is the symbol of the "horn of plenty," and this was his standard of living beside.

Now, 50 years later we began to have some primitive automotive engines. We had some steam engines; quite a few of them, and so the man was doing much less. He was doing the kind of work where you couldn't tote a steam engine on your back. The horses were doing less. You hadn't got general tractorization on the farm, or you didn't have earth-movers and the rest. You were using drag-scrapers attached to horses. I went to college nine years after that and we were taught how to build railroads with drag-scrapers and horses.

All right. Now, here is the machine. And you can see that the machine has grown considerably. So, again we find people working long hours, the same as up here. They haven't improved too much. Really, it's about 12 hours. Now look what happened to the standard of living. Remember now, man works less, animal power less, the standard of living, area-wise, a number of times. This shows you - in economics, now - the picture of production. It just came out of Dupont; I didn't do it.

In 1955 the horse was rapidly vanishing, the man was using less and less of his muscles, the machine had grown to a point where the philosophers (who had never studied engineering and scinece were writing volumes about how man was going to be consumed by that Frankenstein monster, the machine. He was going to be merely a cast-off product of the "Machine Age." You'll even hear people talking about computers doing this to our mathematics, etc. It's just sheer hogwash. It takes men to run all these things. But, the people who never studied these things and who graduated from the humanities or what have you, they speculate; they philosophize. They came up with these astounding conclusions.

Just think where we'd be today if we were in Russia and if those gentlemen had dictated our scientific and technological problems. Look at the standard of living in '55 as against '05 and against the Civil War. Well, the gent who drew this let his fancy out and he suddenly became an engineer, and here's the year 2005. The poor guy; I don't think he even buttons his own pants. He has even got a motor-driven zipper of some sort. The horse is a museum piece. The machine has gobbled him up and now we don't hardly work at all. You've seen

the publicity of the AFL-CIO, starting an immediate drive for the 32-hour week. Look at the standard of living we've got.

Now, these are my own amateurish efforts to understand economics. The engineer can make machinery. He can build processes. But something has to provide the energy to run it. So, I took the total energy generated by our electrical systems in the United States for which there are statistics in the Edison Electric Institute which begin in 1903. I divided the total kilowatt hours produced across the land, by the population. So, I now have the kilowatts that each man, woman and child had serving him in 1905. That curve is the dotted curve. Actually, in the industry the amount of power we consume doubles every ten years. But you see, our population also expands, although per unit of population it doesn't grow that fast. But it does grow very fast. This is the reason for the strength it gives the little man on the chart.

Now, here is the standard of living in the United States over the same period. This was pre-World War I. This is post-World War I and this is the Great Depression following the 1920s period. This was the stimulus of World War II. This was the "bring the boys home by Christmas" effect. This was the catching up. During this period we were making war material instead of consumer goods. So, we were doing a good job of catching up. We caught up and now we're on the normal curve and what do we find? We find we're back on the road now with Kilowatt hours. In other words, the standard of living in the United States can be said to approximate the total electrical energy available divided by the population.

If you will apply that to your enemies you'll come up with some very

interesting conclusions and they will explain a lot in the military sense what is not otherwise clear. As far as I'm concerned, I did this, so I accept it. You may reject it.

This one I didn't do; this was done by the utilities industry. It says that with 1/16 of the world's population we produced 1/3 of the world's power. And this is another way of saying why we're technologically great. This is another reason why we say economically we're strong. It's another reason why we say we can back up our allies. We are the world's great source of economic strength. Now, you'll notice we had a population of 180 million people. The rest of the world had 2 billion 800 million people, and yet look at our share of people and our share of power.

Now let's see electric power; the United States with 186 million installed kilowatts. That's our capability. The rest of the world with 350 million, which includes our allies as well as our enemies. The bulk of that lies with our allies as you'll shortly see. All right, here it is. The United States, our allies in Western Europe, and Canada rich in water power. So, we come up with our team having a war-making capability, as against the U.S.S.R. versus the United States. The European satellites of the U.S.S.R. - and you see how important they are to the U.S.S.R. machine here, just like this is important to us, bearing a somewhat similar relationship. Here is Communist China in 1960, and the so-called Asian satellites.

And we were puzzling over this when these figures first came in. This sounded awfully large for Asian satellites. But the answer lies in North Korea which is rich in power and which is one of the reasons in my opinion why the Communist

World forced that unpalatable decision on us; whatever that 49th Parallel is, or whatever you call it. This is the reason. Look at that as a percentage of total Chinese capability. Nine million out of that ten million is in North Korea. The rest is in North Vietnam, etc.

Well, there, then, is their war-making capability, 1/3 of ours if they don't overrun Europe, in terms of kilowatts.

Now, this is the gross national product which I've already warned you about statistically, in terms of the man-hour of so-called labor. It is in this somewhat unique term the constant $47. So, you can forget, now, my curve of so-called inflation. Just have a look at what's going on in the engineering profession in improving production processes in the United States. We are supposed to be declining in terms of our competition; a fact which I have some difficulty dealing with in my own mind.

This is the increasing value added by manufacturing per million. If you put it in per unit population the curve would be the same. The same thing. The same thing. Again, that shows mechanization. That shows this horror of the labor unions of not long ago. They began to get sophisticated on it; automation. Gentlemen, without automation you can just begin to figure that your children are going to be studying Communism, and not under our system of government either.

Well, here are the sources of energy that we have used to accomplish this miracle that you have seen. Do remember, now, that a country's capability of generating a standard of living and of a war potential, are its capability of supplying energy. Look. Here in 1850 - roughly like that man thing we saw here -

you will see that the bulk of our energy came from some very interesting things. I don't know whether you can all read this. This is wood. This is hard coal. This is soft coal. This is wind - strictly wind. This is water - thank you - and this is wind. This is the horse; animal power, and here you have manpower. You see the man and the horse did here just what they did on that pictograph chart. And you'll see that our sailing boats - we didn't have many steamboats back in 1850 - largely were the article of commerce. So, here you've got water power - New England mills and the like. And here you have the growth of coal - hard and soft. Let's watch this.

Here in 1910 - as early as 1910 - we reached the peak of power generated by coal. The first introduction of oil came in; gas had not yet begun to arrive. You will notice that water power had not changed much; it had diminished from back here and was holding a fairly constant figure here, before we went out for those huge reclamation Tennessee Valley type of things where we harnessed a lot of water power. That is responsible for this so-called growth. Now, here you have natural gas. Here you have the vanishing contribution of man and the horse. Here you have oil and here you have bituminous coal and the vanishing hard coal and wood.

Now then, the sad part of this is that the coal mine is roughly constant; it's not shrinking because the country is growing and the demand for power is greater. So, the total amount of btu's that are coming out of here are probably the same as here, and probably greater than here. The new load is picked up by oil and gas. Those are the three possible fuels, with only 7% left for water power. They make every-

thing that runs your country's economy and makes for your battle posture.

Now, you can apply this to your enemies and see where they rate under a similar analysis. This is the first chart of technology at work. This is a picture furnished by Standard Oil, of a flask of oil - the so-called refinery at night, working away. What does it do? We'll skip all these chemical intermediates and we'll get to the end points. Well, it's the source of resins; it's the source of anti-freezes; it's the source of dacron; it's the source of orlon, dynel, acrilon; it's the source of ethyl fluids; of rayon; of polyethylene; of plasticizers; of detergents; of paints; of explosives; of artificial synthetic rubber; of nylon; of bugles; of lacquers; of fertilizers; explosives again; insecticides; and atoms.

Gentlemen, we are burning this. This is the source of your carbon chemistry which is in its infancy. If you read the annual reports of the great oil companies you will see the stress they're putting onto their growth in these areas. But they are still small in terms of their total output of energy. And the consumption of energy has petroleum. Now, it isn't too difficult to show you that the time will come when you can't do that, and then what are you going to do? This is the estimated energy required, as calculated by, I think it was the Fabian Committee. We're going to burn all the coal and oil we've got by 2050; we're going to use all the water power developed across the land; and it only represents that amount of energy.

And now you see staring you in the face the end of civilization because if this actually were the limitation we would start being barbaric long before 2050. You wouldn't have any of the gadgets in your home. The factories couldn't run in the

way they're run today. Manpower would have to come back. Horses would have to come back. Civilization would turn back. The standard of living would fall rapidly. The workday would increase in spite of the AFL-CIO. This is the dull-looking drab future that would pertain if you were going to continue to rely upon the present state of science and engineering in furnishing the energy which is the basis of all your economics, your standard of living, your war potential, and your position in international affairs.

All right. Now, what is that orange thing there? Well, this is the estimate, and believe me this is looking into a crystal ball that I think is full of crap, but it doesn't matter. This is the estimated capability in terms of energy, of our thorium and our uranium. Now, apart from my purpose it doesn't matter whether this is correct or whether it ought to be up there on the ceiling somewhere, or just where it is. It also is expensive. Supposing that this does carry to the year 2075. What is civilization going to do then?

The cosmologists tell us that the earth has been here some 4 billion 200 million years, as a rough approximation. Man has been here since 1 million 200,000 years ago; we have the remains to prove it. All right. What is man going to do for the next million years and how long will the earth be habitable? Well, according to the cycles of the sun, now recently understood, this will be a climate beneficent to human life for about 5 billion more years before it gets, in the biblical sense, to be fire and brimstone. We know that the sun in its aging process expands and finally fills all the space between the earth and the sun, and we become inside the sun. However, long before the 5 billion years the heat will be

such that any biological life as we know it today will not be possible. Well, for 5 billion years where do we get the energy from when we use up this over here? Well, gentlemen, that's another story, but it is here. It is available. We have not learned the process of using it. If we simply use the heavy water with the tyrian that is in the ocean it will more than provide for us for a vast period running into billions of years. We have not learned to use it, but we're working hard on it.

These are the theoretical scientists and the applied scientists who are working well ahead of any other system today. There are relative forces of energy, one of which is the nuclear energy that comes from the center of the earth. This is the earth's terrestrial heat. Another source is the radiation that comes from the sun which is many times what we need to run our civilization. It happens to come at a low thermal level. We have not learned yet how to harness that thermal level except by studying the plants thoroughly. It is believed that we are close to an understanding of how to use these low temperature energies which are so profligate around the universe.

Now, this is part of the need for basic research, not hooked up with any Senatorial questions - "When are you going to have whatever you're going to do?" These are the problems on a very broad horizon.

Now, this shows you a typical engineering curve. I hope you will memorize a curve like this, if not this one; any other one will do. In the time of Thomas Edison, in 1882, he took 19 pounds of coal to make one unit of electricity; a kilowatt hour. And with engineering improvement - and engineering improvement

means evolution, and it comes about through developing the third stage of the process, basic science - applied science - and development. This came about so that in the years in the first third of the century we were using about six pounds. When I graduated from college they showed me a brand new power plant which was the world's wonder, and it only burned four pounds of coal. Today we use the same unit for about 8,800 btu's which is roughly 2/3 of a good pound of coal.

So, here we are. It has taken all that time, gentlemen, to learn how to do this. And obviously, if we can go from 8,800 btu's per kilowatt hour to 8,000 it will hardly show on that curve, yet it will be 10% better and it will automatically say our coal resources have increased 10%. So, this is big game.

This is the phantom or will-o-the-wisp that nuclear power is chasing. Because, as nuclear power gets better and better, so does this. But it has had a very sobering effect upon the miners and the mine workers in the course of fuels. So, actually, coal is not going up in price.

Now, this is the famous curve by the Atomic Energy Commission of when is nuclear power, as we understand it, going to be an energy source that is competitive. This is a gentleman whom you all know. His pet project is the shipping port. Now, he carries power at 55 kilowatts, with 55 mills per kilowatt hour. Then he went on the lecture platform, as I am doing here, pointing out that atomic energy was not here to stay; it was not practical for competition, economically, with our current method of making power.

He had a little difficulty in climbing off that platform because being an energetic gentlemen and one who speaks frequently, he's been on record so many

times that there isn't anything that can be quickly switched around. The truth of the matter is that he would like now to build a large power plant with what he calls the "season blanket method," and he would like to put it down in some high-cost area like New England. But he still told Congress a few weeks ago that it won't be competitive. And yet, the American Power Industry is building competitive atomic power plants. So, this curve concerns what the AEC is selling. And here in 1970 you will see that atomic power is well within the envelope of the economic cost of power by fossil fuel.

Now, this also cautions you that since much of the debate that you have been subject to, either by people who are anti or pro, occurred in this area, you are using the engineers technique of the crystal ball. It takes five years to design, build and get running, and training help in atomic power. So, whatever you do here, is going to be entered on this curve here. So, at a time when so many people were proving that the early enthusiasm about atomic power was over-stated, they were using figures from here, forgetting that the art was moving as rapidly for that field as it has moved - and I showed you the curve - on coal.

Now, gentlemen, these are the techniques of the engineers. They are evolutionary. They're not revolutionary in the normal sense. They are not like projects; and it pays to understand the engineering application to prophesy. At any rate, plants are being built today, mind you, that have guaranteed fuel costs in 1967 of 6.3 mills, here - well below that curve. And the path of economic atomic power development is exceeding the forecasts of the enthusiastic people in the AEC. And so, the day is not remote. Of course, in England they have built a

huge system, although their costs are up here. Likewise, their coal costs are higher than ours because their seams have run out and they're mining very thin seams with high trash.

This, then, is the kind of things to have in your mind when you're trying to evaluate a technical process. Historically it does not stay still. Let's look at a naval application. There was the first atomic-powered submarine. It steamed a little over 60,000 miles on the first core-loading. Now, the second core-loading was about a 50% improvement and it steamed 95,000 miles. The third core-loading, which is about done, will really be about 190-odd thousand miles. Again the same factor of improvement. The present one being designed is not 200,000. Available for installation in future designs is predicted for 400,000 miles.

Gentlemen, this covers a three to five-year war with a Nazi submarine. This means that no historic war would last long enough for the submarine to use up the fuel. But the point I'm bringing out to you is not to show you how fine the submarines are, but for two reasons. (1) To show you the engineering improvement in the art, how rapid it is, and how foolish it would be for you to be caught by a scientist who says, "Oh, it will only do this," but maybe that's the way it was doing. And who may not understand the engineering process. Or even a timid engineer who is afraid to lay it on the line. You have to use your own judgment in dealing with scientists and engineers, and understand these fundamental curves of processes in order to evaluate whether you are embarking on a correct or incorrect technical decision. These are decisions that you as military men will have to make.

Gentlemen, there is the growth of the aerospace industry. This was World War II and their plane production. This was the "bring the boys home by Christmas" demobilization. This, then, was the post-war development. Sputnik occurred here in '57. So, this was the shot in the arm that Sputnik gave, just as the Vostoks III and IV are going to do in our space science activities within the last two weeks. You will find the same shot in the arm of Congressional liberality due to the Russian accomplishment that you found here, and this will play a big part in the inter-politics in the Pentagon as to who is to do the weapons systems in outer space, and how much. As you know, this has been jockeying around, and a distinguished government bureaucrat the other day said, "We have made a mistake in shipping so much to NASA from the military." But, we've done it, so we have to live with it. Well, I'm not so sure you have to live with those things, and I think you in the military will be the recipients of some reverse gifts before too long in that field.

This shows the enormous expansion in aerospace, but it also shows you the pitiful level of the pre-1940s; the lack of understanding by Congress and the American people, of the kind of a contest that we were going to be involved in within a year or two. I was then running a large aeronautical company, and our experiences in coming to Washington to try to get support and help were just fantastic. You wouldn't believe that our nation could have been so utterly naive.

Now, this is the growth of the electronics industry and I put it on because each of these two things I have shown you are the sole products of science and engineering. They would not be existent today without science and engineering. This is

how your economy moves, progresses and grows. This is not a political theory, this is not an economic theory; this is science and technology. This is what gives you a military posture. This is what will preserve our civilization if, we take heed, now, of some of the danger signs that you've been seeing. Remember, this is the battle front with your major enemy.

Now, this is the vagary of politics plus some awful careful propaganda and salesmanship. Please note that the allocation of Defense Department contracts for research, development, testing and evaluation - this is the egg. The chicken comes out, as you know, with a one to five-year egg. But this is the egg. Look at California. Next comes the great State of New York. Now comes a non-political area called Massachusetts. Now we come to the home of Boeing; new plants in Colorado, around Denver - the Titan, etc. New Jersey, Pennsylvania, Maryland, Utah, Florida (Canaveral), Ohio, Connecticut my home state; all others. And here is California.

Now, gentlemen, if I were running the show over in Russia, and I didn't have to come to the time when I'd have to use my 50-megaton bombs, think what I could do. That's a silly thing; it never ought to be permitted. It never ought to be permitted. It's putting our eggs in one basket. Now, the man who put these figures together is the Under-Secretary of Defense. You in the military fall the victims to propaganda just as we not in the military.

You have been propagandized by the sunshine and the smog of Southern California. Let's look at the trend. This is contract awards; this is production; so don't try to tie these figures up to the others. These are the figures that will

come out of the other in three to five years. All right. Here is the East North Central which is the great Middlewestern belt. You see what it did in World War II - the great Detroit-Chicago complex. Look what it did in the Korean War. Look at it today. This is part of the problems they're meeting. All right. The Middle Atlantic - New York, Pennsylvania and New Jersey - very interesting. But do remember this is an insecure world and this is going to shrink badly. This is a hangover. These are the things we've been learning to make in this area, but the money for new things is not going into this area. You're making a fundamental shift as a military organization in the economic pattern of the United States.

Now let's look at the South Central. Here, boys, you're getting into some hot areas. I forget which party is strong down south. The South Atlantic. Look at this. Here is dear old New England. Here is the Middle Atlantic. Here are the mountains. And here is the Pacific. This, mind you, is production. The other thing I showed you is advanced R&D which will lead the production. This figure is bound to go way up, and these figures are bound to come way down, and we're bound to have a great dislocation in the whole back-up of the military.

This is a picture to show you how some six years ago the Russians looked at basic science. They're not being fooled about basic science and they're putting a tremendous effort on it. This is a proton cyclotron. When it was built it was six times as large as the biggest instrument we had in the United States. And you will see how they dressed it up at a time when they had only 80 square feet for a family to live in in Moscow. And this is not too far from Moscow. But all that love in effect - now, of course they use that as a symbol; they bring these

Africans and Asians in there and show them how advanced their science is. This is a very modern control system; as good as any in the world at that particular time.

I put this on to show you that the Russians without our strong economy do not spare the money on scientific equipment. Now come the challenges. Gentlemen, this is the radiation spectrum. Here is the lower end of radio; the long-wave radio that we've suddenly rediscovered in connection with ASW. Allright. This is the radio spectrum discovered in 1890 by Dr. Hertz. This is called the infra-red area. I want to point out to you in particular this little part here, because until very modern times that was the only radiation anybody knew. This is what you can see with your evolutionary visual process. It's extremely limited. Now, almost everything you get in the way of intelligence from outer space, or from your local surroundings, must come from this area. Of course, you have hearing and touch, but everything with a spatial area except for some hearing influence, comes to you through that narrow band.

And so, military systems were based on adaptations of that narrow band until radio came along and you added this. Now science has discovered - and I'm leaving out ultra-violet, gamma rays and X-rays for the moment - that radiation is far more complicated than we thought. For instance, biologically it has some very peculiar results. If you put radiation to the human body and call it diathermy you can heat up the inside structure of the body without hurting the flesh. In other words, the heat penetrates in a way that is not done by conductivity. This is very interesting. For awhile medicine used this very freely but never

understood it. So, the physicists went to work on this and found out something extraordinary. They found that in addition to this thermal effect it has a biological effect utterly unforeseen. And under very high magnification techniques beyond visual sight, they found that bacteria under proper radiation, which swim indiscriminately and heterogeneously in all directions - up, down, in, out, x, y, z, axes - no pattern - under certain radiation all of them formed processions like elephants in a circus; the head of one and the tail of the other, and they all go in a perfectly straight line. You say, "So what?" So, a great deal, because as they penetrated this mystery they found that different species were excited by different wave-lengths, whether they were bacteria that were harmful, or whether they were your local cells which are benificent.

Now, I've introduced to you a subject - a challenge. This subject is called "molecular biology." The men who will be practicing in this will have to be doctors, biologists, physicists, and chemists - and, electronics engineers; the very same aggregation of talents. For instance, the electric eel; the Navy has an ASW problem. All right. We tried all these wave-lengths here. We can penetrate a certain amount of water with some of this stuff; it was very limited; not enough for a weapons system. You can't do anything with the high frequencies. But there's a fish called the electric eel. The electric eel has a mechanism in its forward end, which is not radar, but which pulses an energetic pulse of an electrical nature - still not defined - has no eyes, and can detect anything in its path; whether it's edible or non-edible; how to navigate.

In order to prove this they took an electric eel and put some vaseline in

some very queer little pores on one side of its head to which there are apparently no nerves attached - although, no one understands it - and, by plugging those pores on one side of its head it swims in circles. If you put it in the other side it swims in reverse. Why? What is the mechanism that that eel uses? How is it a dog can sneak up on a hydrant and he immediately knows the social register for all the canine population of the area. These are things like the homing of pigeons that are no longer going to be accepted as facts of nature; they're going to be explored because they're going to contribute not alone to the knowledge of man and the cure of disease, but weapons systems.

Very little money is available for this type of work, because you can't say what you're going to prove.

Now let's take the back end of that electric eel. The back end of that electric eel - ten feet long - nine feet of it is nothing but an electrical generator. That nine feet generates 600 volts at 1 ampere - 400 impulses a second. That's one horsepower. We have no device in mechanical or electrical engineering that can with so small energy input generate so much electricity. In the secret of that electric eel there lies a new domain in the application of electricity. It can kill a man. It kills fish that it wishes to digest, which it first discovers by an underwater intelligence system that our Navy would give its shirt to understand and apply to anti-submarine warfare.

So, the gentlemen who went to work without any idea of what they were going to do, to find out what radiation did to certain cells other than warm them up, suddenly came on some new areas in science which may be very pertinent.

Now, I haven't the time and I don't intend to carry you through this, but I would like to leave you with the fact that one of the great challenges lying ahead of science and technology is molecular biology. And if you were to read the science digests today you would find there are more papers being published in this area than any single area. There is a tremendous movement ahead in this knowledge of biological behavior. Why do the white cells of the body attack bacteria the minute they invade the body? What is the force that does it? Every doctor knows they do it, but not a single doctor knows why they do it or how they do it.

No doctor has ever understood that they are military organizations and they have their advance units on guard in all the areas of the body where invasions can occur; they have their base of supply in the bone marrow; and they have a system of communication that one one understands; so that when an advance party of white cells is overcome by a heavy invasion of a bad protein - bacteria which is a protein - a living protein - they can communicate with the base of supply and the reserves come pouring down the lymph system or the blood system, add to the fighting capability of the cells, and give your body a chance to resist the disease. Therefore, you are subject every day to the invasion of a whole host of anti-bacteria who never live to make you conscious of their presence.

You're fighting leukocytes, as they call them, defend you from this force. But how? What is the intelligence system? This is only now beginning to be understood. I'd like to leave you in a mild state of shock which I found myself in when I first explored this vast area of science which has laid outside the

area of engineering. Let me answer you, that engineering colleges are now setting up courses in biological engineering because there are many chemical processes that won't work without biological - well, I'll call them yeasts, in some cases, bacteria in other cases, and still others in smaller elements which approach the proteins largely.

And so, these are going to be the basis of chemical processes, and they are going to have to teach this. And, of course, all sewage disposal and anti-water pollution is based on an understanding of this micro-biological field. So, this, then, is one of the challenges. Don't think we've explored them all or know them all.

This radiation end is one of the unusual tools because you're dealing with things so small you can't pick them up. You may remember the famous Hydenburg Principle that no one can ever see an electron. To see it you have to use a radiation wave which we'll call a light wave. And when you do the energy is enough to make it wasn't. So, there is no way of ever seeing an electron. Yet, we've learned to deal with them.

Now, this spectrum which I'm showing you here is almost unexplored relatively. The reason I put it on here is to show you this vast array compended of four pieces, the long-wave; this ridiculous measurement of one-thousandth of an angle; which is down below the limit of any small cell, bacteria, or molecule.

The other challenge which I want to show today is the old-fashioned thing you all studied. Here are a whole group of things; thorium, praseodymium, viademium, polesium, tomarium, europium, gavalinium, persium, petroleum, holmium, terbium, thulium, erbium, and lutecium. And how many courses

describe any one of them? Yet, these are playing a part in outer space. Yet, these give promise of being very valuable in areas of current chemistry.

There are some properties in the neutron field here. This is very useful; this is very useful in atomic reactors. They are not rays; they are called "rayerths" in your book. I mention this because this field of the materials that surrounds us is as yet untapped, and this is one of the backward areas in the United States where we are behind Europe and behind Russia. Our government is busy at work now in subsidizing some of the colleges into very sophisticated training courses for Doctors of Philosophy who will deal in what, for want of a better word, can be called "solid state physics."

This is the area of the direct conversion of energy. If I were to tell you that the utility industry is diverting money and time to the direct conversion of energy without going through steam, or turbines, or engines, and that there are four basic processes under development, such as thermite, onyx, thermoelectric, fuel cells chemicals, etc., these processes were unknown to scientists a decade or so ago. Today they are at work in our advanced laboratories.

Well, now gentlemen, you've been a most suffering, patient audience, and I think it's time for me to knock off, but you ought to have a conclusion. This isn't too good; I wrote it on an airplane that was flying on a very erratic course and I'm not sure I can even read it.

"Political aims, economic capability, military readiness and national potential, will determine our future as individuals and as a nation. Only by a sophisticated and progressive science and technology will our national power be

developed and preserved to a recognized level such that we can remain free to pursue our own destiny."

QUESTION: Sir, I can think of probably a hundred questions to ask because of your very though-provoking presentation. I know that most of them will be asked, but one I have in particular, which has been thought-provoking for me for some time, is the dollar shrinking - though I don't have to worry about my little poor dollar shrinking; I'm sure of that. But, in this regard, as it occurs to you - and it could probably be measured by you, so I'll ask your comment on these facts.

Since 1939 you could do certain things with a dollar, but today you must spend more dollars to do the same thing. On the other hand, today for a very few pennies we can by anti-biotics which will give life to people. Yet, not for love or money could you get those in 1939.

We have equipment today; we have fabrics and materials with greater life. We get a great deal of energy out of a pound of coal. Perhaps the dollar is the wrong unit of measurement for all of this. Maybe a new measurement for the future is some method expressing it through technology which has given us all of this, so that the dollars that we have today - really, we haven't collapsed three times over, which is what the chart would make you think we were going to do.

We have actually progressed a great deal and can buy a lot more with that same dollar.

MR. WARD: Well, that is a statement instead of a question.

QUESTION: I wanted your comment on that because you had placed the

emphasis on the dollar shrinkage and had not mentioned this other element. Yet, through your entire presentation there was a magnificent progress of technology which is cubing its output and will continue to do so in the future.

MR. WARD: That's still a bit of a statement, but let me see if I can contribute something to your discussion. What you say is true. Technology has produced many comforts in life and many new services. However, these do cost money. Take a haircut. I just had one; I hope it's a good one. It cost $2.00. When I got out of college it cost 25¢ to get a haircut. I don't need any more haircuts, so, you can roughly say that in the case of the haircut the inflationary factor has been one of four. On the other hand you raise the question that we have more available to us. But it has to be bought. These things are on the market - that you mentioned. They are the creations of technology, but you don't get them free. What that chart showed was, that a family has to earn today $26,500 to have the same purchasing power. Now, whether you spend it for the same things is not the point. You have your choice. This is a free country, in a manner of speaking.

So, you could buy some of the things you enumerated, in place of the things you used to buy. You can't have both. In a way it is a correct concept to call that an inflationary comparison. You can easily ask, "Are there as many people today earning $26,500 as there were people proportionately earning $10,000 in 1939. This will raise a very interesting question, because this shows how the tide of economics has swept proportionate elements of the population. This would be a very interesting study. I don't have that answer.

I think of me as an individual or a unit. Me as a unit, I have to have $26,500

to supply the same amount of services and goods, even though they're different goods, as I did in 1939. Let's show you how they differ. My wife and I live simply. We don't have a servant. But we do; it's electricity. It washes our dishes, grinds our garbage, mixes up our cake, runs the vacuum sweeper; it's our servant. It is said that for 1¢ we can buy ten Greek slaves. How does that come about?

One horsepower is a well-known unit. You can translate it in terms of electrical energy and you know what it costs to buy one horsepower. Now, a human being can only exert continuously, a twentieth of a horsepower. So, if I wanted to buy the work of ten slaves I would have to buy continuously a half of a horsepower for 1¢.

So, using your idea now, we've had deflation since the time of the Greeks. That is not quite true. We have more wants. Remember the old economics?

In the old economics one of the fundamental principles was, there was no boundary to human wants. They called needs and wants, two terms. They all said it didn't matter what people earned, their wants would expand with their earnings. So, there was no ceiling on wants. This is classical economics. This is involved in your question. I merely say it takes $26,500 for me to buy as much as I used to buy with ten, and if I bought the same things I could have the same things I used to buy for ten. Now, if I don't elect that, that's my choice.

QUESTION: Sir, in view of your earlier comment referring to the scientists in the Pentagon, would you care to make a comment concerning what the present organization is and what change you might make to that organization with reference to their position in the Pentagon; if there is any comment?

MR. WARD: The firing squad is around the corner. I would not ask a

committee of scientists to tell me whether to go ahead with a weapons system. You make that choice. Make them argue before you the pros and cons as they see them. Then turn around with your basic knowledge and decide whether you're going to back them or whether you're going to use the engineer's viewpoint with the crystal ball.

I'm sure Bull Halsey never called in a scientist when he started off to chase the Japanese decoy fleet up in the north. We are asking scientists to actually operate weapons systems analogies. There is a great hidden danger. It's like the man who puts data in a computer and the computer comes out and gives him a typed answer. He knows that the computer doesn't know how to make any mathematical mistakes, and he says, "This is it." But he forgets maybe what he put in that computer involved some pre-assumptions. It's no better than his pre-assumptions.

Now, this is what I want to tell you. A scientist, because of his training, has great confidence in his approach toward tackling a problem. Furthermore, he never has to apply years; this is someone else. Now, he won't be the man who stands on the quarter-deck when the enemy projectile mows him down. You will. Or you'll be in the airplane when the flak hits you.

So, I say you're the man to make these decisions. Don't become charmed with the intellectual capabilities of the scientist in his field. Yes, it's far beyond your field; it's far beyond mine. And in his field I wouldn't challenge him. But I wouldn't let him make my decisions in my field.

Am I being clear? Is this your answer? Because you are using him in

committees that are giving you the answers - military answers - of application of weapons and development of weapons systems, which I'm not sure, the project's brains with all its great brain-trust, can really properly advise me on. I think they're terribly exciting. You can put the problem into them, read it out, and find out what their assumptions are, and then decide how much weight to give it. Don't accept it as the law. I'm afraid that there's a lot of acceptance that they're a kind of a law.

QUESTION: I would like you to express an opinion on the slow biological evolution of man the animal in relation to the magnitude of the technological advances that are being made. Is man going to be able as an animal to stay up with it?

MR. WARD: I'm Darwin now. For the first time the process of genetic inheritance has been laid on the table in scientific trends. And I don't mean by the Menderian Law and the observed reactions of Darwin himself. For instance, there is contained within each cell a structure. The structure is essentially that of a nucleus which, in turn, has a structure. In the structure of the nucleus is a thing called a chromosome, along which lies a genetic chain, first guessed at by Morgan in California in '17 - way back there. He never saw it. It wasn't until we had the advantage of the electron microscope and very advanced tools - again lord Kelvin coming into play - that this thing was proved to be such.

It has been by a remarkable applying of science that this thing, too small to see with the naked eye, has been removed from its associated structure and has been analyzed. It has been found that it is a great spiral molecule with arms

sticking out. At the end of each arm is a chemical radical. One of them is blue eyes. Another is big bones. Another one is aggressiveness, etc. Now wait a minute; I'll take that back. They don't know that you can inherit an emotional trait. They only know you can inherit structure. This remains for the future.

But anyway, here are these things sticking out like arms. It's like that present publicity you're seeing on the so-called chemical which was put out as a drug which is causing these deformed children. That drug has the capability of attaching itself to this DNB - it's called - deoxyribonucleic molecule - and imparting a defect.

Now, the process of evolution apparently consists of the fact that there are literally - I was going to say millions; I don't know how many; combinations in this spiral molecule. And it takes the male and female to come together. And you have recessive and you have dominant characteristics. The inter-play of these two chemical forces on this complex molecule becomes the inheritance of the child. That simple mechanism - as it seems - a molecule possessing about a million atoms, contains all of the information needed to procure the final child; stature, type, size, color of hair, eyes, muscles; it grows everything - the venous system, the lymphatic system, the heart - all of these organs.

There is in that minute thing all of this intelligence. Now, any chemical occurrence to that spiral molecule produces a variance. It can produce a bad variance like the recent occurrence in the papers. But it can also produce a good one. It has been said that 1 out of 8,000 births normally contains a variant, and that out of this, evolution has processed.

But now these gentlemen working in molecular biology have taken this device and put it to work. One area is fruit flys - those little black things that buzz around the fruit on your table. They're called drosophila. Now, those little drosophila are handy because you can have a whole lot of generations rapidly so you can see the effect of a long evolutionary train, which you can't do with humans. They take these drosophila and they radiate them. Now, you can radiate these things to the point where you'll knock one of these chemicals off this spiral molecule, and when you do you change the species. So, they have grown drosophila that have two sets of wings; drosophila that have red eyes, which no drosophila in life has; queer structural variants. Some of these are so valuable that they're kept in great vaults They are considered precious because they contain years of genetic work in producing these strains.

Now, this is merely to say to you that the elements of the mechanism of evolution are beginning to be understood scientifically. The theory of the people working in molecular biology is that the time is sometime not too far off when humans can be bred with superior characteristics. There's much more to the story than I am giving you, but in the time, that's about all we'll have.

QUESTION: You have offered a replacement for coal in our dwindling resources. Would you care to comment on the possible replacement for metal deposits?

MR. WARD: I'm pausing because that's a difficult question. It just hasn't been done. As you know, in an atomic reactor you can change one metal into another. You can change substances into different elements in the table. Whether

this would be practical in the sense that you're addressing yourself is a question that hasn't been economically solved. The real future for a quite measurable time lies in another area which your department is fundamentally concerned with.

For instance, the amount of uranium useful for an atomic reactor, as used in that computation, was based upon recoverable uranium. Yes, all of the granites in New England have uranium in them, and thorium, to about 15 grams per ton. Well, 15 grams per ton, if you can get it out, is an awful lot of energy. Remember, now, that 1 pound is 500 grams, and in theory that would be about 10,000 useful British thermal units. If you divide up the 500 you have 200,000, which is the equivalent to saying 20,000 pounds or 5 tons of coal.

So, in every ton of New England granite you've got 5 tons of coal. That is, if you counted in those figures. But there is no economic way of extracting that. If you grind up the rock and then leach it as you do in extracting uranium ore you would find that the cost would be more than the yield.

The big problem for metal extraction is that there is a tremendous amount in the earth; more than civilization could possibly use in any foreseeable period of time. But it lies in uneconomic deposits. Just like, out on the Wyoming Plateau there is in the sand in very large areas, recoverable uranium. Now, if that uranium is below, say, three or four pounds per ton, it wouldn't pay to touch it, with the present art. But the art of mineral dressing is one of the backward arts. It is still the old-fashioned engineering of cut and try. You have the modern attack on that process is lagging. Where is the money for it?

We're getting enough of our needed metals at prices the market will take, so,

the money doesn't flow into this research. This is an area for your department because there will come a day when it is important. When it is, these techniques are now lacking and the cost of metal would be very high. And this would exercise a damping effect on the use of these metals.

Now, you have one other item. There are so many metals in the earth we're not using advisedly, and more than that, solid state physics - which I did not try to touch on here today - give the clue. We now find that a single crystal of copper has properties that copper, as we understand it in the market, does not possess. It's fantastic. A single crystal of steel, the same thing. Single crystals of aluminum, the same thing. These involve purities in parts per billion - or impurities in parts per billion. This is now possible. But this was not possible.

So that, metallurgy is one of the challenging areas which I could have thrown out in this conclusion of my remarks.

I haven't answered your question of converting metals from one to the other, because this can be done in theory, but at present it's economically unreachable. Far better, we go along the line of finding out how to extract these widely dispersed metals of which there are vast amounts in the earth.

CAPTAIN BOGLEY: Mr. Ward, I'm sorry that we've run out of time. We are deeply indebted to you for being with us this morning and giving us this stimulating and thought-provoking presentation. On behalf of the Commandant and the college I thank you very much.

MR. WARD: Gentlemen; just let me add a final comment. I would urge you not to take anything I have said on face value. These are my personal conclusions;

some, perhaps, a little dangerous, but you should arrive at similar conclusions for yourself. The purpose of this talk was not to give you a series of answers; it was to give you a methodology. Raise questions. Try to find out the best source of quantitative information - the scientists' approach, if you like - and then out of that you will come to answers that will satisfy you as the year progresses.