Naval War College Review

Volume 21
Number 5 *May*

Article 3

1968

United States Science and Technology

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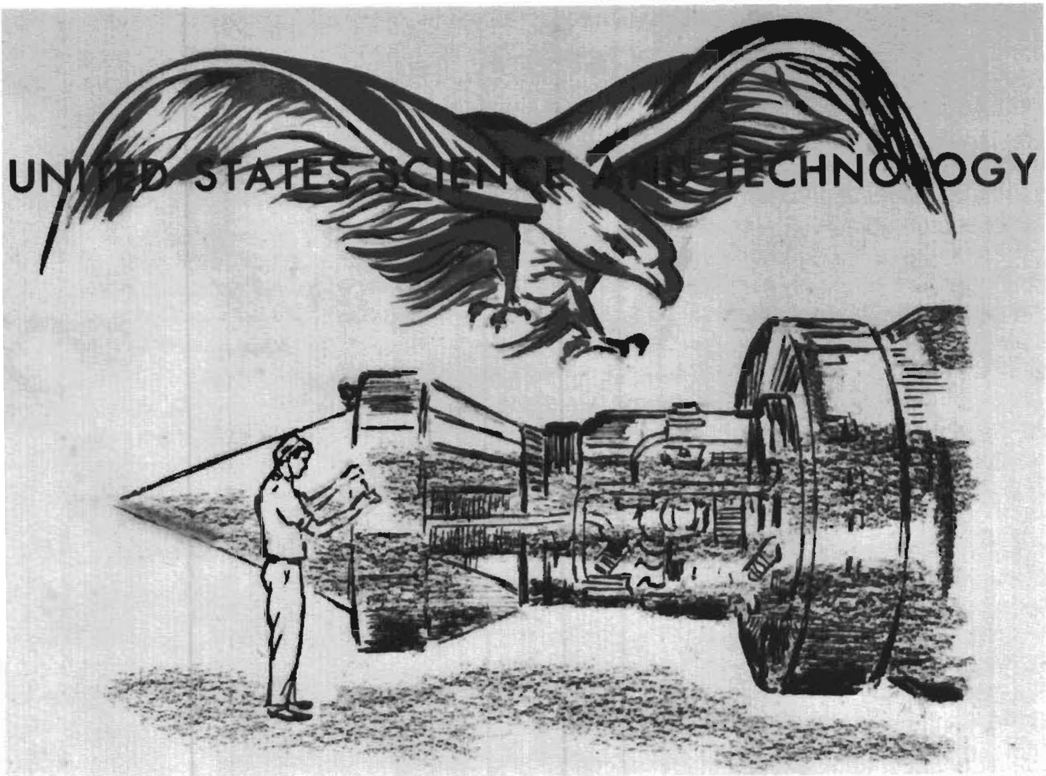


A lecture delivered at the Naval War College

on 12 January 1968

by

J. Carlton Ward, Jr.

Colonel Hartley, Gentlemen, when I come here I recognize I am looking out on a sea of faces representing more knowledge in almost any specific field than I possess myself. The saving virtue is that you all don't know everything. So whereas I may be merely telling some of you something you know better than I, there are others to whom I might be giving something useful.

Now, when you have lived as long as I have, you begin to think of the meaning of all the events that you have either witnessed or been a part of and how to put them together in some sort of a conclusive pattern. Perhaps I have an impossible task today. In the first place, all of you who may have read the scope of the assigned lecture will recognize that any one facet of it could be the subject of not alone a lecture but almost a term study. So we have to do something here in a very sketchy manner without giving you all of the backup information which I believe is essential to make factual conclusions instead of opinions. I have a horror of lecturers who spread platitudes and opinions without presenting to the hearers the factual matter which lies behind their so-called erudition. For example, as you all know, if you were to listen to economists in time you could prove and disprove nearly every one of the so-stated axioms of economics. We are going through such a state now in our national finances where many of the so-called principles of economics on which our Government has operated are proven fallacious, and the result is that the United States is in danger of losing one of her most cherished and valuable elements of national power. I refer to the ability of our finances to serve as the standard for the world and hence allow us, nationally and strategically, to assert our total power in a very positive way.

Now what I would like to do is take you through a little more than 2,000 years of world history as I see them, and the latter part of which I experienced. During the first part, obviously, I was not present. We'll start with Greece and Rome, and those of you who read the series of articles in *Life* magazine within the past year will recognize some of the facts that I may tell you along with others which were not in *Life*.

Now let us begin, for this has to be very quick. So, we start with Greece versus Rome as the opening chapter. And most of you who studied it in your college work, and particularly if you were in liberal arts studies, I suspect must have come away with the idea that Greece probably was not only the high point in man's civilization—the Golden Age of Greece as it was often called—but that Greece was also, overall, a great nation. Well it wasn't a great nation in the terms that we are going to deal with today. It had a rather limited life, and its total power was limited.

The interesting thing is that the people who write history are essentially nontechnological people and therefore are unaware of the role of technology in history, and it is generally not presented to you as students when you are taking history courses. It is only now within the past two decades that universities have recognized that the history of science is a fully accredited course on the university level. This means that at this very late date the role of science and technology is only beginning to be appreciated in educational circles.

And so, today, we are going to delve into it. The reason that Greece was not, overall, a great country in terms of total national power in the way that we mean it here was simply because the Greeks were not very good technologists. They devoted themselves to philosophy as their cornerstone, and along with it they did some mathematics and speculative astronomy which was very useful, but that largely ended the sciences. Aristotle, probably the greatest of the Greek philosophers, had many theories. For example, the Babylonians and Egyptians had measured the curvature of the earth, knew that it was round, but Aristotle, being a humanitarian, flattened the earth into a plane again and insisted that the heavens revolved around man who was the central object of the universe. Now man is not the central object of the universe in the sense that we study it here. He is an agent of the universe. He is a biological accident, almost, of the universe. Biologically it is more than possible we may merely be one of a variety of intelligent beings scattered through outer space, some of whom may, outside of the funny papers, actually be ahead of us by a large margin. However this may be, Aristotle not only prolongated this view of earthly man but then proceeded to develop his views of science which were so frequently wrong. And when he was challenged at times, "Why don't you prove your thesis by an experiment?" his answer was a very strange one. The reason, he said, is that to experiment is the work of the hands, and the work of the hands is a work for slaves. Now, from this authoritative example, and this is all I can say today on this subject, Greece was a nation of thinkers rather than a nation of doers. Alexander the Great's campaign in Asia Minor is described as failing before it reached its objective because he had not provided suitable logistic support.

Now then, why did Rome last nearly a thousand years? The Greeks looked down on the Romans as a sort of peasantry because the Romans worked. They worked in the fields, and they worked with their hands. They were artisans. They were, in fact, also good engineers. And so when Athens could not grow greater than much over 200,000 people simply because it couldn't logistically supply itself, Rome grew to be over a million and a quarter people due to excellent civil engineering. The aqueducts you all know about. Also to be emphasized is the fact, for instance, that the Romans invented more modern structures, including the arch, whereas the Greeks knew of nothing but the use of flat stone; the fact that the Romans built wonderful highways, which the Greeks did not; the fact that the Romans did not use slaves as the motive power for their economy, whereas the Greeks did; the fact that the Romans learned bridgebuilding, as Caesar's commentaries so aptly set forth. These things made Rome a nation of technologists, and the underlying basis for Roman power was its technology. It was not its Caesars. It was not its forums. It was not its system of law which was far ahead of anything in the world at that time. Simply because Roman technology had expanded to a point where the new city of Rome and the expanding Empire required that there be an orderliness and that it be enforced, Roman law was brought in. Roman law did not precede technology. The accomplishments of technology generated the need for Roman law. Technology was the keystone of Roman power, and Roman power was the keystone of all world national power in its day.

We have spent all the time on that phase that we can today, and now we are going to jump right into the 1700's. And let us remember that Great Britain was the last of all the Western European countries to have been civilized by the Romans, and in many ways it probably had the least to offer. Britain had a difficult climate, and perhaps in this climate may lie its subsequent greatness, because the British found that they had outcrops of coal and that coal was a very fine thermal fuel, and so they early mined their coal and thus kept their bodies warm. But as the mines were sunk deeper and the number of easy outcrops were mined out, the mines began to become full of water. They had to be pumped, and the only way the British knew how to pump was with a man at the end of a lever, a very primitive pump, and as the mines got deeper they had men on platforms 15 feet apart vertically, each one pumping to the next one above him. This is a pretty laborious way to mine, so an engineer in England of that period named Newcomen produced the first practical steam engine for pumping. And this was the beginning of Great Britain's enormous power. It didn't come from its Magna Charta. It did not come from its Parliament. It did not come from its political system. It did not come from its liberal studies. It came from engineering. And once it had power in the form of thermal power and the necessary energy sources, it developed the spinning mule, the jenny, and all that plethora of machinery which put it into the modern industrial age. These were all products of technology, and once the British began to make goods under the industrial system, as opposed to the guild system in the home, they produced so much better goods and in such volume that they couldn't consume them all and other nations clamored for them. Nations which, according to the humane studies, were considered further advanced in civilization and were more cultured people. These older, more cultnred nations began to bny British goods. This led Britain to develop an oceangoing shipbuilding indnstry. Then, after it had built a shipbuilding indnstry, it had to bnild a Navy to protect its world commerce becanse the pirates were nearly everywhere. And so Britain's power arose out of its indnstrial revolntion. Its sonrce of national power, as with Rome, was Britian's technology.

It is unfortunate that onr histories cannot more clearly explain the causes for national power and not pnt so much accent on the man who might be head of state because, in many ways, he is a pnppet. He is limited by his own country's economic capability, in tnrn limited by, and determined by, its ability to employ technology. It's very important that the country have a leader, but, believe me, as in a military sense, leaders do not fight battles. They can direct a battle, bnt without the logistic support they would lose. And so the people who provide the logistic snpport make possible a successful leadership. This was what the Greeks apparently did not completely understand. By contrast, the Romans did. In this way Britain became the world's greatest power, and it was said that the sun never set on the British Empire. This lasted throughout Pax Britannica, roughly 300 years.

Well, obviously, other nations envied this position of national power, and the one that did the most about it was the German nation. The Germans, learniug that techuology was the source of power, did something very subtle which we were very late in properly evaluating in this country, and in the rest of the world also. It comes into the heart of the subject of today. The German universities harnessed research into higher education. And, thus, for several decades the German universities became those educational areas where the leading scientists and technologists of the world came for their graduate degrees. Thns, Germany produced many snperior technologists and scientists, and through applied research an impressive technology came into being. Yet Germany did not have vast mineral and raw material resources. She had ample coal and iron, very important; she also had timber; but basically that's it. She did not have a wide assortment of metals, minerals, and raw materials so she developed, largely ont of earlier British and French chemical research, the vast applied chemical industry which depended npon the development of what we know today as the technology of synthetic chemistry. And in this manner Germany supplied itself with synthetic materials which were not native to her own resources. Having done so, she created a technological know-how and a technological power which allowed her to wage World War I.

Now *I* come into the scene. A few years before World War I, I had graduated from my university and found myself in the Army Ordnance Department. I was aghast at what I saw. We had to fight World War I with many of the technological prodncts of Europe, and I can remember reading some of General Pershing's telegrams almost begging, imploring this great country with its vast economic power to give him some guns and cannons. And what were we forced to do? We even took old 7-inch naval guns of about 30 caliber or even 25, I've forgotten which. They were the turret guns from Dewey's old flagship in the Spanish war, *Olympia.* We were told to put those among others on caterpillar mounts and find 7-inch shells, God knows where there were any, and send them over to General Pershing as a stopgap until we could produce more suitable guns of French design. These were the 155 millimeter and the 240's of France and the French 75's. And at that time we were the most powerful economic nation in the world but completely unprepared. As we know, Germany came within an ace of winning that war. Her submarines were far advanced over what the rest of us had. Her technological surprises were many. Time will not permit me to give you a catalog of them. I saw many of them. Many of us thought America had learned something, particularly the central role of applied research and technology. Not so!

Subsequently I was in charge of the Pratt and Whitney aircraft organization in the 1930's. There was only a $19 million fiscal year appropriation for the whole country for the total development of aircraft engines for their research and development. There were then only two major companies, namely Curtiss Wright and Pratt and Whitney. General Motors indicated an interest in their Allison division.

Colonel Lindbergh was called to active duty and sent to Germany to find out the state of German aircraft preparedness. He returned with what seemed like a fantastic story. Dazzled with the technology which he had observed and its progressive employment, he became convinced we could not defeat Germany in the air. Secondly, he was convinced that the in-line, liquid-cooled engine was the only answer to aircraft propulsion. And the two great American companies built nothing but air-cooled radial engines. Whereupon General Arnold, who deserves all the credit in the world for building our Air Force, called me to Washington and said, "You've got to scrap your radial engines and build in-line, water-cooled engines." Such was our naivete at that time! Now, gentlemen, that nearly ruined our aircraft posture in World War II, and the thing that saved us was no less than France, and later England, with whom we negotiated the largest engine order that ever had been placed up to that time. And the two leading companies had no Federal money for research and development. Think of this in the light of today.

So, in World War II we repeated some of the mistakes of World War I, fortunately not all, thank God, and as you all know, it was technology that made it possible to save ourselves and likewise our Allies. To go back, in the 1920's radar was discovered in the Naval Research Laboratory at Anacostia. It was not, at that time, well understood. Radio echoes came back but nobody knew why. The naval scientists at that time asked the Navy Department for $15,000 for the next fiscal year to investigate and explain this strange phenomenon, and their answer officially came back that there was no money for such a purpose. This was our lack of appreciation for the vital role of research and development in the 1930's. Sir Watson-Watt, who was knighted for it in England, grabbed up what we had discovered and fashioned the radar which won the Battle of Britain in the air. You all know the story!

The role of technology had been outstanding. It not only saved Britain in the Battle of Britain. The degaussing of ships was another one of the great developments of this period in technology which saved so much of the shipping. The German submarines were, in many ways at the start, advanced beyond ours, and later on the snorkel was outstanding. The famous sea battle in which the German battleship was hit time and again with torpedoes, shells, and continued to float, fighting until a lucky accidental hit put her out of commission, illustrated German great technological advances in shipbuilding. Likewise the Germans had made significant advances in metallurgy through their vast chemical industries. The Germans were technologically outstanding and demonstrated that their country, with only 65 million people at that time, was almost able to dominate a world of nearly 2 billion, principally by superior technology. So, twice in this century Germany exerted world power through technology. It wasn't the Kaiser, it wasn't their rulers, it wasn't their Reichstag, it was technology.

We've seen now, how technology operated in the West; let's figuratively turn the page and see if it's unique. Ancient China was a civilized nation, as was Greece, only before Greece. It produced fine literature, great arts, great drama, great poetry, all the things that Greece did so well in the Golden Age—such a wonderful contribution to humanity. But China was not a great world power, although it had sprawled over so much of Asia. It began to be chipped away by the Russians. It failed to hold Southeast Asia where it is again trying to probe. It lacked technological power.

In the year 1000, it is said, Japan was a barbarian nation without even a written language. But it later became very conscious of the fact that it was behind the world around it. It battled with Korea, the only great naval battle which it lost until World War II, although it never acknowledged it. The Korean admiral built the first ironclad fighting ship, a remarkable technological advance for those early times. The Japanese appropriated the Korean language as their written language, even though they speak it differently. And they began to be, in modern terms, civilized. When the Dutch came and then Commodore Perry, the Japanese decided that it was necessary to find out why the rest of the world was so far ahead of them. So they sent their younger, brighter people all over the world, who brought back to them the results of technology. And it followed that Japan built a reputation for being a nation of copyists. Well, of course they were copyists. They were catching up. I think you all know today Japan is not a copier, it's a leader in technology. And so as Japan's technology improved, her national power improved. Again, it was not the Mikado, the Shoguns, or the social systems. It was the application of technology. And with that advanced technology the Japanese entered World War II and surprised us with the Zero which was more maneuverable than our own fighters. They had electronic systems which were not copied. And we learned a good many things that Japan had been doing. And what did it do? With a nation of 90 million people it overran a nation of then over 500 million—China, whose technology was backward. Then it gradually took over the whole of its hemisphere until it challenged us and until our technology, by some very fortunate and fortuitous circumstances, turned the tide, and we were able, finally, to finish it off with the greatest of all technological achievements. And that was the atom bomb!

Can we not see in clear perspective—I think I do—that national power has not been because of our unique political systems? It has not been anything except our ability to do and to do better, and this means applied technology. There used to hang in our laboratories when I went to college a little statement, "An engineer is a man who can do for one dollar what any damn fool can do for two dollars." Now the essence there is he's a man who knows how to do things efficiently. He's a doer. A scientist is a thinker, and an engineer is a doer. We should never confuse them. They're not the same creature at all. And yet the term science is often used to embrace engineering technology. You would have little, relatively, if the scientists had to do it. They establish new knowledge, without which engineering would soon wither, and this, of course, is of unfathomable advantage. But they're not doers. The engineer is the doer. And he takes this new knowledge, and he harnesses it for the purposes of man. In the earlier days in the Pentagon they got these two breeds completely confused, and they put scientists deciding engineering projects. This is not their role. The White House is doing it today, making some sad mistakes in the process. And I don't mean to decry the scientists because their role is pivotal, but I'm trying to show that they have limitations when it comes to putting into the final end of the pipeline a system or a product or a process which will enhance economic power and hence the power of the nation.

So Japan proved in the Far East what we had seen demonstrated among nations in the West—that national power is a reflection of technology and is built on the products of technology, on the facts of technology.

Now, let us turn to Russia. The Russian people are a highly intelligent people. Even under the czars there were a great many very distinguished Russians. I don't have to enumerate their scientific developments. You're familiar with them. Some of them are outstanding. But the Russian system didn't encourage it down through the rank and file.

When the Bolsheviks took over they found that they could not compete, using their system of social and economic philosophy, with the hard-boiled economic incentive philosophies which we call free enterprise. And in casting about to see how they could overhaul us, they hit upon the proper solution—education. And in 1932, it is said, they established a state policy for education with the result that there were fewer illiterate people in Russia at the time of World War II than we had in the United States. However, there are other indices to apply to education. I don't have time to give you the result of studies made on Russian education, but this past year the Bureau of Census made a very interesting one. It shows their strengths and their weaknesses in education.

Their strength is the fact that they give more mathematics and science in the levels that we call in this country grammar school and high school, so that all the dropouts have an understanding of the basics of technology, except the severe dropout who falls a victim in the very early years. The result of this is that in their universities the greatest incentives, and I'm using the word properly, go to the graduates in technology. Number one is science and engineering; then lower down, medicine; with social and liberal (humane) studies quite low on the scale. The incentives pertain to the jobs that graduates are allowed to fill, the money that rewards them, the privileges they have from the state—the result of this is that 70 percent of all the graduates of all the leading universities go into science and technology. Their output is far beyond ours in these fields. We graduate a few more students overall—and here's where there is a subtlety to the comparative statistics. We also have more graduate students than does Russia, but the Russians are training more engineers and technologists on the theory of the Russian State that applied technology is national power. And if they're going to vanquish us they're going to have to do it by that means.

The greatest gift that we ever got from the Russians in modern times was Sputnik, because when Sputnik went up the whole of the educational fraternity, as well as the common people, suddenly rubbed their eyes and said, "My God. These people can do very advanced technological scientific work." We knew we could lick them economically, but this was something new. And we looked at our school systems, and what did we find? We found, in the opinion of many, that under the philosophy of liberal Deweyism we were giving so-called progressive education. Well that's a wrong label. It was a peculiarly permissive education. The students could, in many cases, almost select their courses when they were hardly yet dry behind the ears, so they were likely to pick the easy ones. And so while what Russia was doing was giving good, hard educational background, we were doing the reverse. Permissive education often meant, "Never, never discipline a student because he's a personality. He's simply living out his personality." But Sputnik scared the educators, and we began to scrap liberal Deweyism for standard basic subjects. California, which had gone progressive in school systems beyond the rest of the States, being the kind of State it is, willing to experiment, scrapped it.

We must pause to reflect what it means that Russia had discovered the fundamental role of technology. Russia's advance is through technology today. Now that leaves us the United States.

Through an historic set of circumstances we inherited from England and its Continental associates some very skilled artisans who came here because they felt there was a greater opportunity in a new land than they had at home. And these immigrants furnished a very virile population, not diluted, a very, very high-grade population. Even the criminals among them were high-grade criminals. As a colony, England forced us to be a producer of raw materials until after the Revolution. And this was perhaps the real reason for the Revolution. And, of course, when we won we immediately turned to manufacturing, using our own wealth of raw materials. We had the water power at that time and very skilled artisans from Europe. And so, with freedom through the incentives of our economic system, freedom that was not known in the rest of the world, we produced a viable economy that began to cause the world to notice us. It's particularly interesting because the conception which we took from Europe and for which we claim much credit, as we do in so many instances, was mass production. The French were believed to be the authors of mass production in building guns for Napoleon's Army, and we lifted that technique and swiftly produced our own guns in the South using the French philosophy of manufacture. But it worked so well and we were so short of labor that we couldn't do otherwise but spread mass production to every aspect of our productive enterprise. The result of this was that we became the past masters in mass production. And this enormous and economical output was the basis for America's power. It wasn't our continental political system, per se, our superb Constitution, our diplomats, our Congressional members—it was none of these things. It was the fact that we had learned to produce more and better and more efficiently than the rest of the world, with the result that our economic strength pyramided.

But while we were doing this, we neglected our educational system. Up until World War I we were still sending our best people to Germany, and when World War I broke, and again I refer to my personal experience, it was pitiful that we had to rely on Germany to provide for us and that we had to improvise in order to overcome our shortcomings. The first research laboratory, in the modern sense, in this country came into being after 1900, and it was in Schenectady, N.Y., at the General Electric plant which was known as the House of Magic. Dr. Langmuir received the Nobel Prize for the work he did there. It was said to consist of only seven scientists when they started.

Now, let us see a graphic picture of what later happened. The United States really did not discover the pivotal role of research in our higher educational institutions until after World War II. (See figure 1.)

In many ways this graph is incredible; it could be the subject of a full lecture period. Note World War II. Think of it, this was with the whole world getting ready for a new world war. This shows the meager total research done in the United States. It was $300 million in the year 1939 for Government and industry combined, and in the period where our Government had only $19 million for aircraft engines as already stated, it had only a part of $300 million for the whole

Trends in Federal expenditures for research, development, and R&D plant, by agency

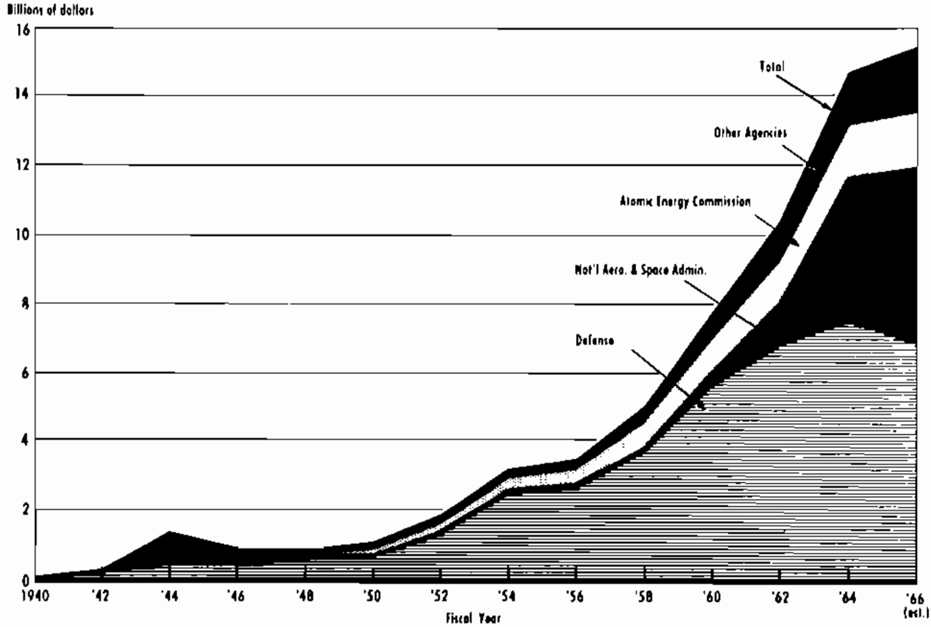


Figure 1 *Source: National Science Foundation*

country.

We thought we had really performed when we got up to a billion and a half, in 1944, all in a war period. This is the contribution the military makes to the civil economy and to our survival. But then we see the "bring the boys back home for Christmas" part of the curve.

Next, we look at the Korean period, and again you will notice the contribution of war to research effort. We suddenly rediscovered the research role. And now notice what subsequently happened. Often it is said a nation never learns. That's not true. A nation does learn. We all saw what happened the first time. And we learned the second time. Thus, we never really "brought the boys home for Christmas" from Korea. And you will notice how we skipped along until Sputnik hit us. And now look at the effect of the greatest gift of Russia to America: Sputnik. The curve rises continuously.

There's a current worry here, a very serious one as of today, that all of a sudden the pressures of the people who don't get research money have influenced our Federal Government to a point where the accent is toward social scientists.

Those of you who have not read General Shriever's address to the Industrial College in September should get in your library and read it. I believe it could well be a part of your course. In any case, it should be part of your course reading and material. He shows that there are three great aspects of weapons research—time, performance, cost—and that up until our present philosophy in the Pentagon, time, meaning do it quickly; evaluation performance, meaning have it function properly, were the things that you looked at first in awarding a research contract. And the last thing you looked at was cost. The present philosophy has reversed this. The first thing you look at now is cost, so perhaps you don't have to do the others. And your weapons systems developments are sadly getting behind. And so the future defense of this country is certainly dangerously shrinking.

The computer is a tool; it shouldn't be a master. It's seemingly been made into a master. The programmers are the most dangerous men in America. Without intending to, they evaluate. Time limitations do not allow us to explore the serious implications involved.

Let us turn now to figure 2. We shall have to be brief here, but as you can see the money value for Federal research and development has remained the same since 1966, which means less research since we have serious inflation, and yet the country is bigger each year. So, really, there is a *decrease* in our capability, not a leveling off. Also note that we are spending less money for increasing our research facilities (plant). That's very sad. Note the funds allotted to development which, of course, is an engineering activity problem. Next we see the applied scientific effort in green where the engineer joins with the applied scientist. At the top we see the funds for basic research. Without the basic research effort we would soon slip far behind. Note that we are not slipping in the basic research. We're slipping in the applied research and development.

Now turn to figure 3. Here we note that the Government dominates the aircraft industry research and development even though the commercial side is growing by mammoth leaps and bounds. But you will see that the amount of money that the companies put in is relatively small. The Government is really putting in the money and therefore directs the research and development. Next, notice the electrical industry. This research and development is largely in electronics. Now note the average for the country. The remaining industrial classifications reflect the fact that Government funds for research and development are less than the funds furnished by the industries themselves.

Note figure 4. Here the thing to

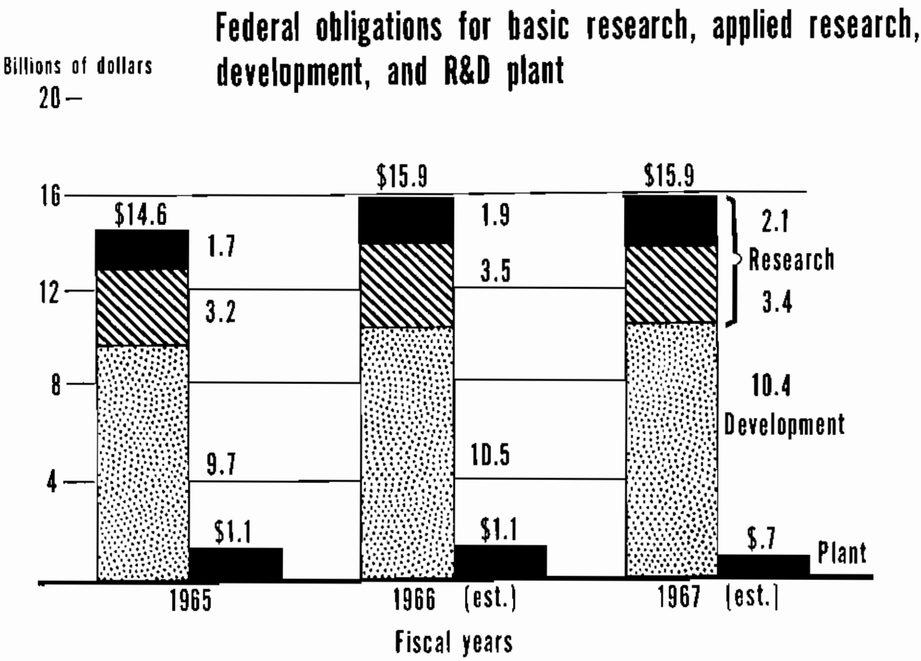


Figure 2

Source: National Science Foundation

COMPANY-FINANCED RESEARCH AND DEVELOPMENT

Percent distribution of funds for R&D performance, by source and industry, 1961

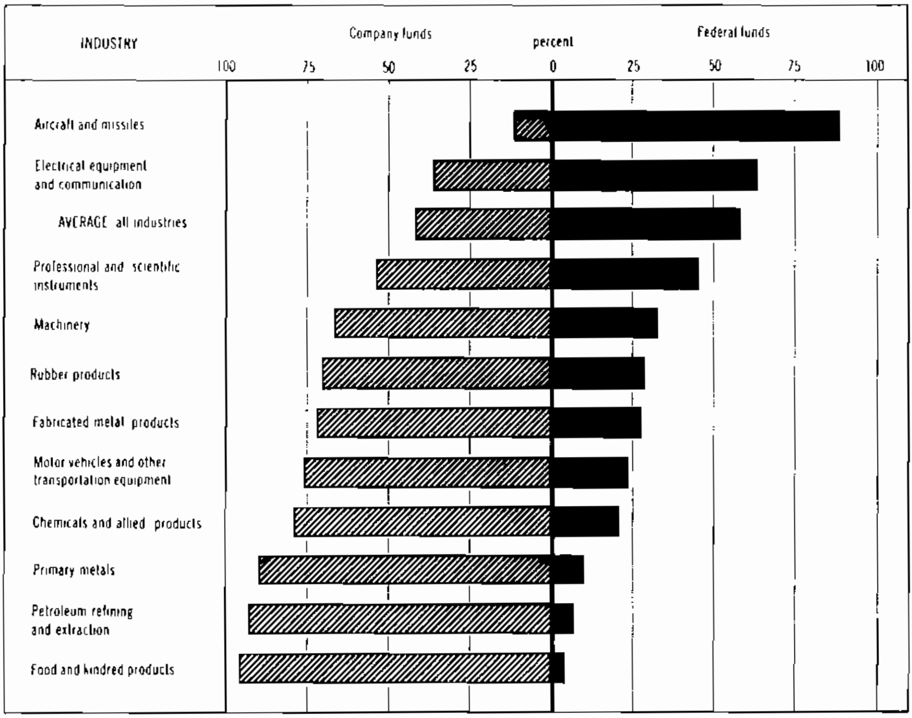


Figure 3 *Source: National Science Foundation*

watch is the percent of the total labor force represented by technology. We also see the total number of people that work in this country. If we don't graduate enough trained workers, and we're not graduating our present needs, we're going to fall sadly behind, because Russia is graduating enough trained workers. Particularly note the relation of manpower in technology to the total labor force. We were very late in discovering that. We have graduate degree-holding engineers doing work that 2-year college graduates could do ably

Manpower in Science and Technology

	1940	1950	1960	1963	1970
	Millions			Est.	Est.
Labor Force	56.2	64.7	73.1	76	86
Manpower in Science and Technology	0.86	1.47	2.37	2.7	4.0
Percent of Labor Force	1.5%	2.2%	3.2%	3.6%	4.7%
	Thousands				
Technicians	300	550	875	1,000	1,600

Figure 4 *Source: National Science Foundation 63-23.*

as technologists, similar to the way the doctors use laboratory technicians and so on. Once again Russia recognized this long before we did, and she has as many graduates in this field of technologists as she does in higher edneation.

Turning to figure 5 we see the figures representing our graduation of engineers and scientists, respectively. We see an alarming growing shortage of engineers and a possible overproduction of scientists. The press, which is largely reflective of graduates of liberal arts, seems to think that the scientists and engineers are the same kind of creature and it generally refers to Apollo as being a great scientific accomplishment. Excuse my emphasis, but it's primarily an engineering accomplishment. The reporters apparently don't understand this, so they keep printing in the press its description as a great scientific accomplishment, and all the young men who go to college who sense the challenge apply to be scientists. It is said we are beginning to have an oversupply of scientists in this country now and a severe undersupply of engineers.

Refer now to figure 6. In my lecture assignment I was asked to comment in some detail regarding the technological manpower considerations, hence the three separate figures. Now here we will see the future estimate, or guesstimate, if you prefer; look at the sad picture it reflects. It shows the severe shortage of engineers in terms of the forecast which, if realized, can be a national disaster. Russian figures by contrast are overwhelming.

Fig. 5—Net supply of new entrants in science and engineering, 1960-69.

Year	Scientists	Engineers
1960	22,200	42,800
1961	23,300	42,100
1962	24,900	42,300
1963	26,900	42,500
1964	29,900	43,800
1965	32,000	44,900
1966	32,300	45,600
1967	35,400	47,000
1968	41,700	49,100
1969	45,400	50,600
Total, 1960-69	313,900	450,700
Annual average	31,400	45,100

Source: National Science Foundation 63-34.

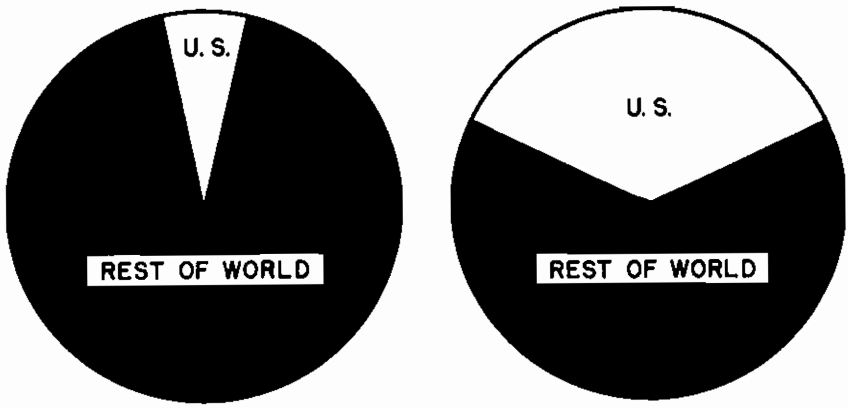
Next, see figure 7. In this lecture I was asked to ontline some principal factors which make us the most powerful nation in the world. This is a very pertinent topic. Here we see the total electrical power in the world. Electrical power is probably the best index of economic strength, and, of course, it is also the product of a conntry's technology. So we see that with one-sixteenth of the people of the world we produce and consume one-third of the electrical power in the world. The atomic scientific and technological triumph is one that fascinates me. Out of the development of the atomic bomb, which at the time was deplored by the liberalists, came the greatest boon to civilization—power, almost unlimited servile power for the future. And, by comparison, the total electrical power consumed throughout the world

Fig. 6—Comparison of projected increases in demand and supply of scientists and engineers, 1960-70.

	Total 1960-70		Annual Average	
Occupation	Increase in demand	Increase in supply	Increase in demand	Increase in supply
Scientists and Engineers	1,012,100	764,600	101,200	76,500
Scientists	294,900	313,900	29,500	31,400
Engineers	717,200	450,700	71,700	45,100

Source: National Science Foundation 63-34.

WITH 1/16 OF THE PEOPLE U.S. HAS 1/3 OF THE POWER



POPULATION

United States	192,120,000 persons
Rest of World	3,027,880,000 persons
World Total	3,220,000,000 persons

ELECTRIC POWER CAPACITY

United States	240,471,000 kilowatts
Rest of World	493,639,000 kilowatts
World Total	734,010,000 kilowatts

Source: U.N. Statistical Office; Bureau of Power, Federal Power Commission

Figure 7

as represented in figure 7 will be less than the electrical power this country will generate in 1980 by atomic power alone. The liberals condemned the atomic bomb perhaps because such people do not recognize the enormous spinoff from military research into the commercial nonmilitary world. Only the Government could afford to finance these out-in-the-blue experiments from which nuclear power developed. Stockholders would refuse to support any officers of an industrial company if they went into research and development for some purpose where risk was so unpredictable and so great. But the Government can, and this should be possible whenever deemed in the national interest, as in the case cited.

Now refer to figure 8. This gives us some idea of the magnitude of the problem we have been discussing. We see here 1960, the total power consumed in the United States now. Then refer to 1980. We at once notice that by 1980 the production of atomic power on the chart is beginning to be appreciable. It hardly shows in 1960 or even today, and yet last year contracts were placed for more atomic power plants in this country than there were for coal, oil, and gas-fired plants by the utilities. Look at 2000, and the estimates of the Atomic Energy Commission are for 50-50 atomic power. If by then we didn't have atomic power, civilization would start moving backwards toward barbarism. Soon we would have to give up our dishwashers and our electric carving knives and all these wonderful things run by electrical energy to serve us.

Figure 9 shows us a limitation of even the greatest informed sources. It shows a series of forecasts, made all within a very short time of each other, dated 1962, 1964, 1966. And we note that in every single instance the Atomic

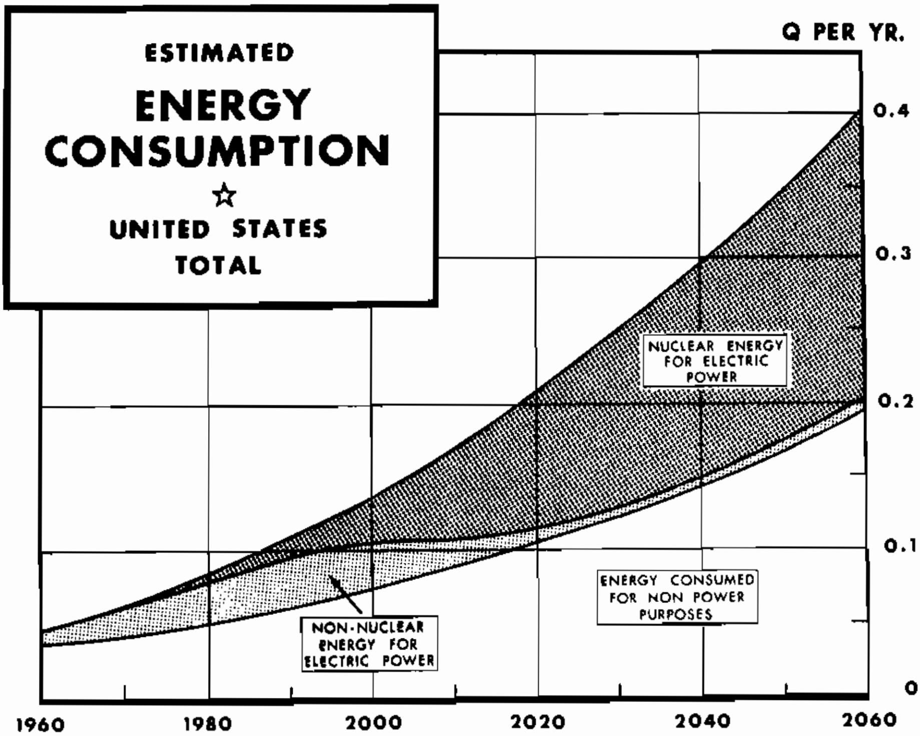
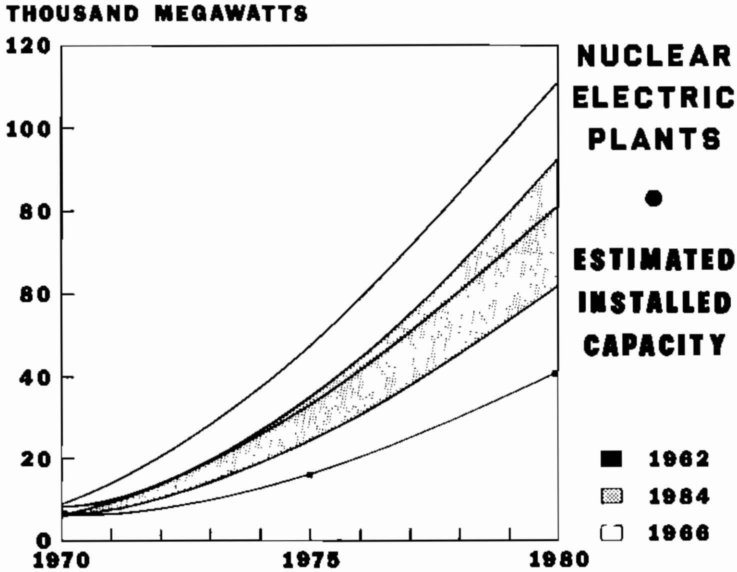


Figure 8 — Source: *Atomic Energy Commission*

Energy Commission, with all its fine knowledge and resources, underestimated the speed with which atomic energy would take over the furnishing of electrical power to run our economy. Actually these figures are still out of date. They show here a maximum of about 115 megawatts, but the new forecast is 150. It seems impossible to keep the forecast up to date! There are many conclusions, all pertinent, which can be inferred from this data and which are vital to the understanding of new technology and its influeuce in the future. This probably illustrates the greatest risk in evaluating the results from radical new weapons systems in the military applications.

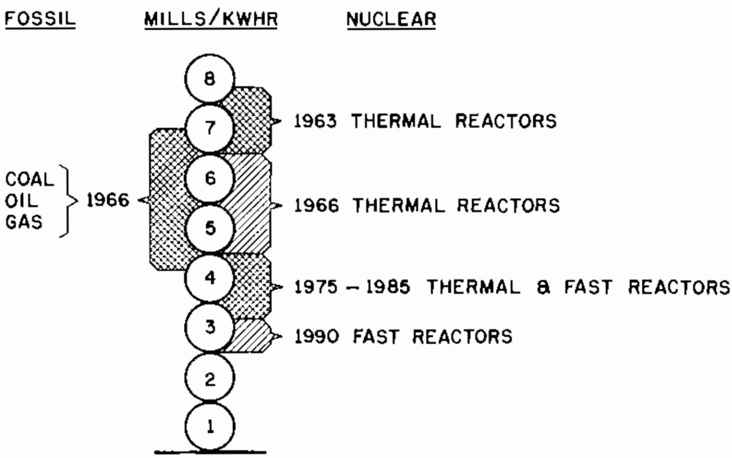
Figure 10 complements our observations on the preceding exhibit in figure 9. One of the arguments a distinguished admiral of the U.S. Navy, who seemingly is not yet ready to retire even after his very great contribution, had to do with economic application of nuclear energy in the electrical utility industry. After his Navy experieuce in nuclear propulsion he courageously encouraged the Shippingport, Pa., plant to be built and demonstrated. It was built to use commercially, aud the power cost was 45 mils per kilowatt hour. This is completely off the graph. So he unfortunately went around the country lecturing that atomic energy would not in our time, if ever, compete with fossil fuel for electric power generation. It was, however, good for submarines. Figure 10 shows how wrong he was. Seven mils per kilowatt hour represented, by 1963, the economics of thermal reactors at that time. Now observe the comparable cost for coal, oil, and gas. Particularly note how rapidly atomic power, through technology, overcame the economics for coal, oil, and gas. Plants are now being planned with an estimated power cost



Source: Atomic Energy Commission estimates

Figure 9

FORECAST OF TOTAL POWER COST



Source: Atomic Energy Commission forecast

Figure 10

of 3 mils total cost of power. Note that as recently as 1963 it was 7 to 8 mils; in 1960 it was 12, and now it is down to 3. Reflect as to what that means to our country! Observe what technology is doing for our national power and for the future, even more importantly so.

Turn now to figure 11. This shows a remarkable post-World War II development. Now the President has not merely the Bureau of the Budget telling him what to do in one ear, but he also has official science advisers and access to the scientific community outside of Government. Unfortunately they are preponderately science advisers. They're not equally engineering advisers. Jerry Wiedner, an outstanding member of the scientific community who was chairman of the President's science advisers, went to Russia, and upon his return he had stardust in his eyes, and he's represented as being for disarmament ever since by agreement with Russia. He found his Russian counterparts to be competent and fine people. Many other distinguished scientists hold similar views, but it is my belief that among the engineering fraternity there will be found far more skepticism. Assuming this is so, the explanation could be that engineers put more emphasis on experience—which with Russia is very, almost universally, sad—and that the scientists are more willing to hypothesize and to rationalize. Note the position of the National Academy of Sciences, which I am happy to say up until now has devoted itself to basic research and done a splendid and much needed job. But, like nearly all Federal bureaus, it is now trying to cover the waterfront. It's getting into engineering and technology but with the scientists having the majority influence at the moment. To me that's the danger in this organizational picture. At the bottom are the Government bureaus, et cetera, in which science and technology play a great part.

It was suggested that we comment on nuclear ship propulsion, but time is running out. It is peculiarly involved amongst many of the organizations illustrated on this chart. Of course, there

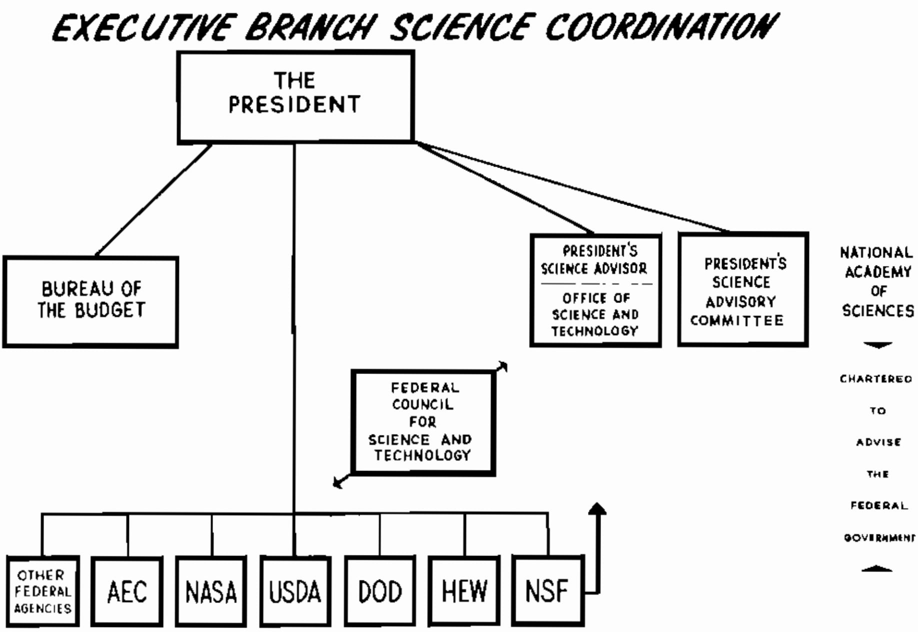


Figure 11 *Source: National Science Foundation, June 1965*

THE TIME BETWEEN CONCEPTION AND APPLICATION OF IDEAS

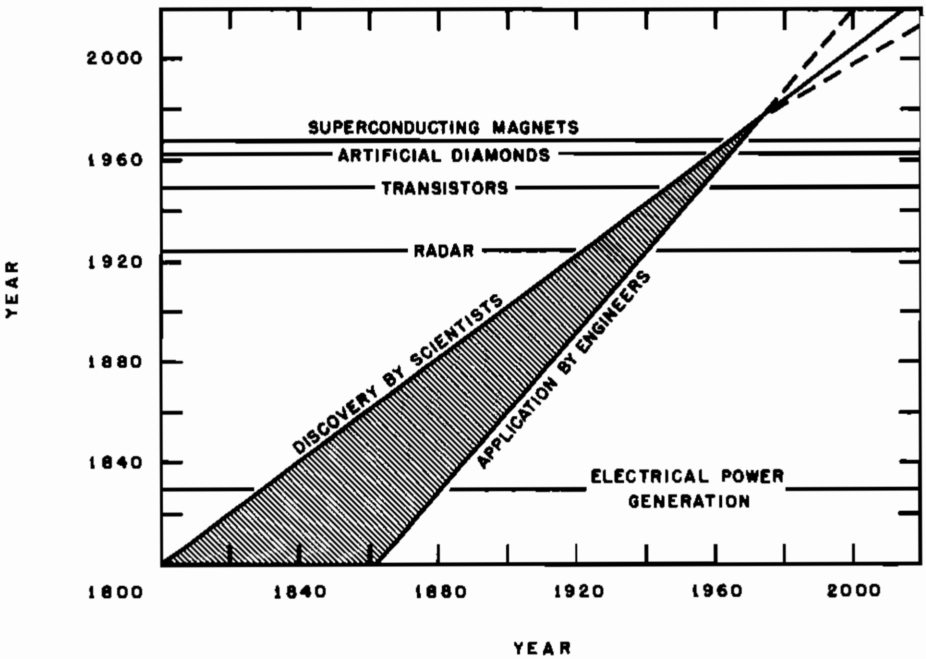


Figure 12 *Source: Franklin Institute, Phila., 5th Coleman Lecture*

must be scientific advice to the President of the United States, who is obviously not a scientist. Similarly, there must be technological advice to the President of the United States. Incidentally, this advice must be provided to the Congress likewise. There seems to be no way to draw a chart like figure 11 for Congress because of its inherent complexity. But we do have scientists called upon from time to time to advise most of the important committees and task forces. Congress is very concerned about the problem for the fact is that this is for the President such a nice chart, and Congress doesn't experience the possibility of such a simple solution. It is my belief that some solution must and will evolve.

Figure 12 may confuse you at first. It is designed to show that it now takes much less time to get a scientific breakthrough or important discovery into the end of the pipeline. About 1830 the original electric motor was demonstrated by Professor Faraday in England, and we see it took quite a period of time, all the way from about 1830 up to Edison in 1882—that's 50-odd years. Later on we notice that when radar was discovered at the Anacostia Naval Laboratory before the date of 1930, it was perfected and used by England by 1940-41. By then the interval had been reduced to about 10 years; this was followed by transistors; that took 6 years. Next we note that artificial diamonds took about 3 years, followed by superconducting magnets which took about a year and a half. These are all typical scientific breakthroughs. The only trouble with the scientist who drew this for a lecture at the Franklin Institute was that he continued the projections upwards too far so we would be applying new discoveries before they were invented. I am certain he was smiling when he did so!

Figure 13 is only one of many that I've selected to illustrate how technology works and where the processes of the computer can and do go wrong, which they certainly did when we built the *John F. Kennedy* which is now in one sense already obsolete. Up here at the top in 1935 you see the cost of a ton-mile transportation by air, roughly 20¢/ton/mile. By 1945 we see the DC-4 of World War II with a cost approximately 13¢/ton/mile. Now we see the super-Constellation of the post-World War period, the year 1950 with a cost of 8¢/ton/mile. Now we see the C-5, a cargo jet, with the cost estimated 4¢/ton/mile. This curve that we are analyzing is typical of about all technological progress. It demonstrates one of the essential characteristics of technology, namely, that it is dynamic and progressive. So, if such a problem is fed into a computer, inherently there must be an evaluation of the rule of technological progress which cannot be solely based on current data. If the computer data processer is not a technologist he is at a real disadvantage. And so where the *John F. Kennedy* was a colossal error was that when they did the data processing for the computer they apparently didn't have the technological know-how to realize that the reactors of that date were not the reactors that would go in that ship.

Figure 14 will be our last exhibit. At the right it represents the growth of our Gross National Product in the United States over 10 years. Technology and population growth are the basic factors. Of course, we're up to over 800 billion now, 3 years later. By comparison, we observe similar figures for Communist Europe with all the satellites. You will recall Khrushchev's boast that the Communists would bury us for their rate of

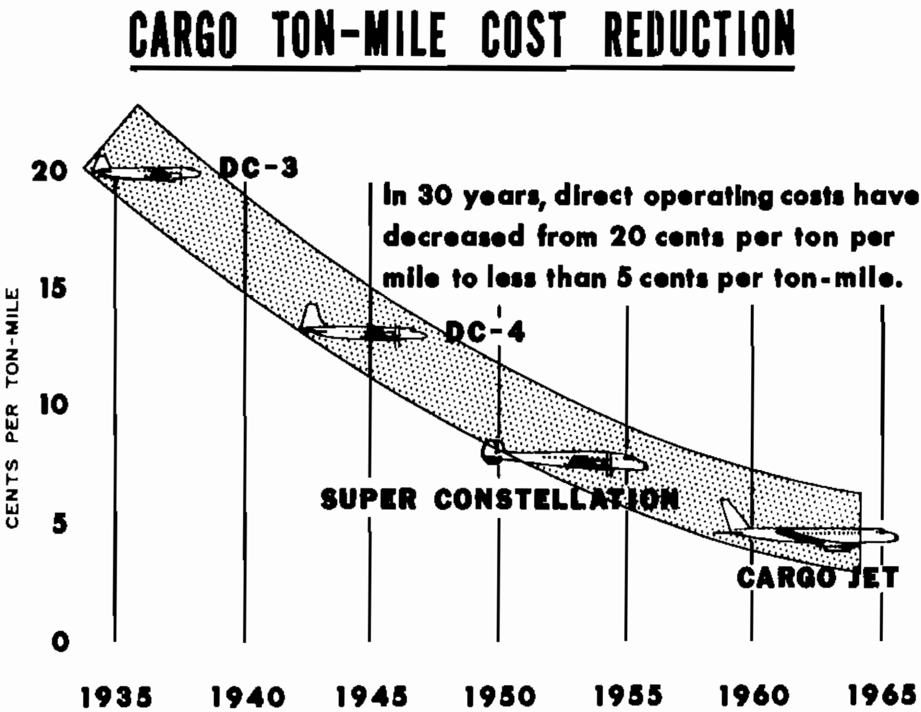


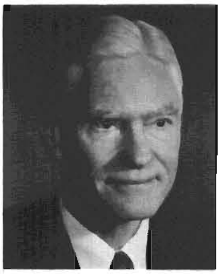
Figure 13 *Source: Aerospace Industries Association of America, Inc., 1964*

growth in Gross National Product was greater than ours percentage wise! But we note the fact that 10 percent of the Russian Gross National Product is not 5 percent of the United States Gross National Product, and he apparently overlooked this fact.

At the left of figure 14 we note the Gross National Product of Western Europe. It is obvious that if Russia were able to enslave their economies through military dominance, we would be in great danger in a world struggle, for it is technologically very advanced. Isolationism could be our Achilles' heel!

And now we return to my added assignment—namely, ship propulsion. When the Nautilus went to sea on the first atomic fuel loading, she cruised 65,000 miles without refueling, a record for all time. Here was a technological breakthrough that had a large contribution to national power attached to it from the military standpoint. When that spent fuel was taken out and a second loading put in, technology (like the air transport example of figure 13) had progressed to a point where the new loading in basically the same engine cruised for 95,000 miles, a 50 percent increase. Then, when that was replaced and the next fuel loading went in, we're still on the technologic progress curve, so the cruising range became 135,000 miles—again the same basic engine. That fuel has been taken out and the new fuel now, as far as I know, is forecast to give between 200,000 and 400,000 cruise miles, and perhaps the hull may not last that long. The point is this: If you are trying to figure out naval ship propulsion in the light of whatever figures you get today from whomever you get them, you're missing the boat, so to speak. At this point I am not getting into things that you know so much better than I do. I refer to the evaluation of the cruise around the world of the *Enterprise* and her supporting nuclear ships which showed that we can cruise around the world without stopping at any port: without stopping and without refueling. It is not necessary in wartime to send a fleet of oilers out which are sitting ducks to any really sophisticated naval enemy; we don't have to establish vulnerable fuel farms. Sometimes I doubt that the computers knew all the many advantages, really. Further than that, we have the excess power to air-condition the ship, so helpful to morale of the crew to fight in tropical waters with a high ambient temperature all around. Likewise there is no need to deny the crew all the shower water they want or need, be-

BIOGRAPHIC SUMMARY



Mr. J. Carlton Ward, Jr., holds a degree in mechanical engineering from Cornell University. In 1914 he became Development Engineer for the International Paper Company. Subsequently he was assistant to the Works Manager, Niles Tool Works Division, Niles-Bement-Pond Co.; Production Engineer, U.S. Ordnance Department, Watervliet, N.Y. Arsenal; Works Manager, Pratt & Whitney Division, Niles-Bement-Pond Co.; Vice President, General Manager, and Director of the Hartford Machine Screw Co.; General Works Manager, General Cable Corp.; and Vice President, Rome Co., Inc. From 1935 to 1940 he was Vice President, General Manager, and Director of Pratt & Whitney Aircraft Division, United Aircraft Corp., and from 1940 to 1948 was President and later Chairman of the Board of the Fairchild Engine and Airplane Corp. Subsequently, he was Chairman of the Board, Thompson Industries, Inc., and President and Director of Vitro Corp. of America. From 1959 to 1961 he was Chairman, Vitro Minerals Corp.; President, Heavy Minerals Corp.; Director, Sheer-Korman Associates, Inc.; Director, Cornell University Aeronautical Laboratory; Chairman, Cornell University Engineering Council; Director, Flight Safety Foundation; and Chairman of the Board of Advisors, Industrial College of the Armed Forces. He was Chairman and President of the Connecticut Center for Research Training and Education from 1964 to 1966.

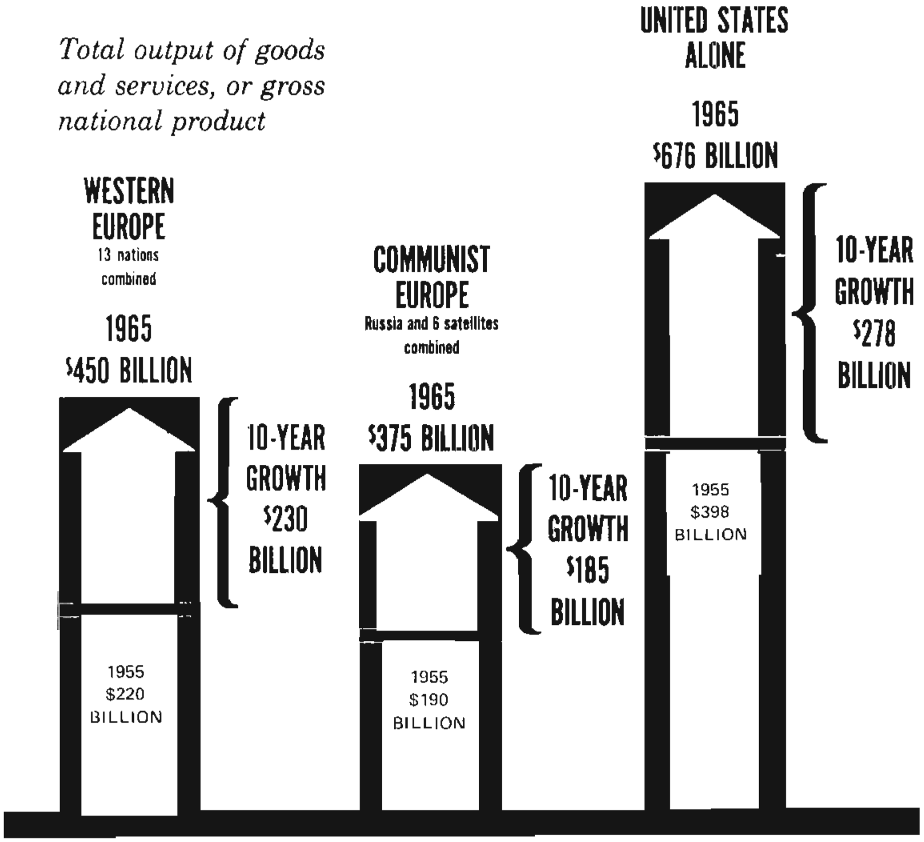


Figure 14

cause there's no limit to the amount of desalination you can have. Let's face it, it's just a different ship. A fighting hour for a nuclear propelled ship is not the same fighting hour for a fuel oil ship. It just isn't the same thing. If you don't understand technology you not only don't understand that, but you cannot see what lies ahead. No rendezvous are needed for refueling with lost combat time. There is now room for aviation gas or stores. Cruise can always be at top speed, if desired; thus there is more combat time per ship.

As to commercial ship propulsion, let's face it, our merchant marine has gone to hell in a handbasket because of our social system of giving labor monopoly power, and the shipowners and shipbuilders can't fight monopoly so they go along with it. The final result is we don't have enough ships, and we have sunk so far down that we're a bad second or third rater. We found this out in Vietnam. We found it out so badly we had to bring out those poor old dying carcasses of Victory ships and what not, very inefficient and costly, and had there been a real Navy against us, wouldn't we have had it. Now shipowners are not stupid people. Sometimes they will go along with a bad cause because they don't think we can win a good one. And so the Isbrandtsen Line, one of our biggest commercial lines, offered to build three nuclear-propelled cargo ships. They showed by figures that they could lick any foreign commercial fleet in voyages over the stated amount. The turnaround time was less, cargo space was greater, the hull design can be different and more efficient, and all of these factors added together would have revitalized our merchant marine. Now comes the sad part of our story. The Navy opposed it. The Atomic Energy Commission wanted it, the Congress Maritime Committee wanted it, almost everybody, including the shipowners, wanted it. And our Navy blocked it. In my opinion, the politics behind this situation are, to say the least, tragically unfortunate as is our national policy which has reduced our merchant marine to relatively a minor role in world commerce.

Ψ

Superiority of material strength is given to a commander gratis. Superior knowledge and superior tactical skill he must himself acquire. Superior morale, superior cooperation, he must himself create.

Admiral Joseph Maxon Reeves, 1872-1948