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REMARKS

by
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Let me say first that I am delighted to be here. I always knew "Greece" and "hospitality" were synonymous terms, but my wife and I are quite overwhelmed by all the kindness extended to us. We both came through Athens shortly before the War on our way back home from duty in China. We had the briefest stop but fell in love with Greece at first sight and ever since we have hoped to come back here some day to see more of your lovely country.

I am only sorry that your invitation to speak arrived at a time when I was so occupied with my regular duties that literally there was not a moment to prepare a proper speech. All I can do is to speak informally.

In casting about for something to say that might interest you, I felt rather at sea. I presume you would like me to talk about my work, yet it is almost entirely in the realm of military matters which may have limited interest to you. You may like to hear some of the larger implications of nuclear energy. These arise from the fact that ours is the first civilization to rest entirely upon fossil fuel energy. All earlier civilizations rested upon energy derived from humans, animals, wind and water -- renewable resources which could be tapped indefinitely. But our civilization consumes quantities of energy that are so enormous that these older sources can supply but a small fraction of our needs.

We live in what historians may some day call the Fossil Fuel Age. Today, coal, oil, and natural gas supply 95% of the world's energy; water power accounts for only 1%; and the labor of men and domestic animals the remaining 4%. This is a startling reversal of corresponding figures for 1850 -- little over a century ago. Then fossil fuels supplied 5% of the world's energy, and men and animals 94%. Five-sixths of all the coal, oil, and

gas consumed since the beginning of the Fossil Fuel Age has been burned up in the last 60 years.

These fuels have been known to man for more than 3,000 years. In parts of China, coal was used for domestic heating and cooking, and natural gas for lighting as early as 1,000 B. C. The Babylonians burned asphalt a thousand years earlier. But these early uses were sporadic and of no economic significance. Fossil Fuels did not become a major source of energy until machines running on coal, gas, or oil were invented. Wood, for example, was the most important fuel until 1880 when it was replaced by coal. Coal, in turn, has only recently been surpassed by oil in the United States.

Once in full swing, fossil fuel consumption has accelerated at phenomenal rates. All the fossil fuels used before 1900 would not last five years at today's rates of consumption.

With high energy consumption goes a high standard of living. Thus the enormous fossil energy which we in the United States control, feeds machines which make each American the master of an army of mechanical slaves. Man's muscle power is rated at 35 watts continuously, or one-twentieth horsepower. Machines now furnish every American industrial worker with energy equivalent to that of 244 men, while at least 2,000 men push his automobile along the road, and his family is supplied with 33 faithful household helpers. Each locomotive engineer controls energy equivalent to that of 100,000 men; each jet pilot, of 700,000 men. I am, of course, more familiar with the energy situation in the United States. However, what I say applies to all countries desiring to improve the standard of living of their people.

Some may think that the cost of acquiring the electrical generating capacity necessary to industrialize is too costly. To this I would reply that the cost of electricity to manufacture an article is but 1% of the total manufacturing cost. Therefore, even if the cost were 2 or 3%, that is, if electricity cost two or three times what it costs today, it would still be very worthwhile. To improve their standard of living nations must industrialize. To industrialize they must have

access to large blocks of electrical power.

The earth is finite! Fossil fuels are not renewable. In this respect our energy base differs from that of all earlier civilizations. They could have maintained their energy supply by careful cultivation. We cannot. Fuel that has been burned is gone forever. Fuel is even more evanescent than metals. Metals, too, are non-renewable resources threatened with ultimate extinction, but something can be salvaged from scrap. Fuel leaves no scrap and there is nothing man can do to rebuild exhausted fossil fuel reserves. They were created by solar energy 500 million years ago and took eons to grow to their present volume.

In ~~the~~ face of the basic fact that fossil fuel reserves are finite, the exact length of time these reserves will last is important in only one respect: the longer they last, the more time do we have to invent ways of living off renewable or substitute energy sources and to adjust our economy to the vast changes which we can expect from such a shift.

Fossil fuels resemble capital in the bank. A prudent and responsible parent will use his capital sparingly in order to pass on to his children as much as possible of his inheritance. A selfish and irresponsible parent will squander it in riotous living and care not one whit how his offspring will fare.

It is predictable that in the relatively near future, fossil fuel costs will begin to rise as the best and most accessible reserves are exhausted, and more effort will be required to obtain the same energy from remaining reserves. It is likely also that liquid fuel synthesized from coal will be more expensive. Can we feel certain that when economically recoverable fossil fuels are gone science will have learned how to maintain a high standard of living on renewable energy sources?

Our present known reserves of fissionable materials are many times as large as our net economically recoverable reserves of coal. Given this fact, it would appear wise to be prepared by developing alternative sources of energy such as nuclear power.

So much for atomic energy as a general purpose supplement to the energy resources upon which modern civilization rests. For propulsion of warships, nuclear power has great additional advantages. This was first evident in the case of submarines. With nuclear propulsion these ships have, for the first time in history, become true submersibles.

The sailing ship, not being limited by fuel, could go anywhere she wished. The steamship, not being limited by weather, could go at any time she wished, but became tied to a chain of coaling stations, colliers or tankers. The nuclear powered ship combines the advantages of the two; she can go anywhere, at any time, and has essentially unlimited cruising radius. We are now building nuclear cores for our naval ships which will enable them to continue operating without refueling for ten years.

We know that we are living in a period of great changes. At times we forget how fast these changes that we now take for granted, have come about. To understand what is happening and will happen in the future it is useful to reflect on the current rate of change.

For instance, our first steam-propelled warship, the DEMOLOGUS, was designed and built by Robert Fulton in 1814, but it was not until the 1880's that our Navy completed conversion from sail to steam.

It has often been said that the steamship revolutionized naval warfare, and so it did. However, as conversion of the world's navies from sail to steam took three quarters of a century, the changes wrought were evolutionary rather than revolutionary, and therefore less drastic in their impact than might have been expected.

Today our Navy is in the midst of another change -- conversion from oil to nuclear power. This change is taking place so rapidly that it is, in truth, a revolution.

Let me give you a brief timetable. The idea of an atomic submarine was conceived in 1949. Four and one-half years later, the land-based prototype of the

propulsion plant for this submarine was operating, and a few months later the NAUTILUS was at sea.

Today the United States has in operation 60 atomic powered submarines. Thirty-seven are the POLARIS type, each of which carries 16 ballistic missiles. The remaining 23 are attack submarines.

When all atomic submarines planned are in operation, the U. S. will have 41 POLARIS submarines, 64 attack submarines, and a small atomic powered submarine designed to explore the ocean bottom.

In addition to these submarines, we have in operation a nuclear task force consisting of the aircraft carrier, ENTERPRISE, the largest and fastest ship in the world, the cruiser, LONG BEACH, and the frigate, BAINBRIDGE. An additional frigate, the TRUXTON, should be in operation by the end of this year.

A few words may be in order about what these atomic ships have been able to accomplish:

First, they have demonstrated their ability to remain submerged for long periods of time.

The NAUTILUS, for example, early in her career steamed from New London, Connecticut to San Diego, California, a distance of 5,000 miles, fully submerged, except for the distance necessary to transit the Panama Canal.

In 1960, the TRITON circumnavigated the world, fully submerged. She followed the route taken by Magellan in 1519. When she finally surfaced, she had been submerged for 83 days and had steamed 36,000 miles.

Our POLARIS submarines normally remain submerged on their patrols for 60 to 70 days. There is no reason why they could not remain on patrol for 120 days if this were necessary.

Our atomic submarines have also explored the Arctic basin extensively. You are familiar with the trans-polar voyage of the NAUTILUS from Pearl Harbor, Hawaii, to Portland, England. During this submerged run of about 8,000 miles she steamed for

1,830 miles under the Arctic Ice. The NAUTILUS then left Portsmouth Harbor, submerged, and did not surface again until she reached New York Harbor, 6 days later.

Before the NAUTILUS' attempt to steam under the North Pole, no submarine had ever gone more than 20 miles under ice. We had no idea what conditions would be found. No one knew accurately what the depths of the water might be, the thickness of the ice, or what currents might exist. There was no assurance that the gyro-compass would work that far North where the force holding the compass in line is so low. As for the magnetic compass, it never works too well in a submarine, built as it is of magnetic materials.

Since this voyage of the NAUTILUS, we have conducted extensive explorations of the Arctic basin. One of our submarines has crossed from the Atlantic to the Pacific through the North-West Passage. This had been the dream of explorers from the time of Hendrik Hudson who, 450 years ago, sailed up the Hudson River in search of this passage.

Our atomic submarines have rendezvoused under the Pole. They have surfaced numerous times through the ice. During one voyage the SEADRAGON steamed 6,000 miles under ice in 31 days, and ~~was~~ surfaced 31 times, most of the surfacings being accomplished by breaking through the ice. On many occasions she encountered ice ridges extending to depths as great as 100 feet, which made it necessary for her to split the distance from the ice to the ocean floor, clearing each by just a few feet.

The SEADRAGON set another record by playing the first baseball game at the North Pole.

The cruises of our submarines have demonstrated the feasibility of year-round operations under the Polar ice. And so another area of our shrinking earth has been opened for exploration and for the use of man.

A few words now about our nuclear surface ships:

In August 1964, the ENTERPRISE, RAINBRIDGE, and LONG BEACH departed the

Mediterranean and set out on a round-the-world cruise, completely free of refueling or logistic support of any kind. This voyage, designated OPERATION SEA ORBIT, took the ships from the Mediterranean to the East Coast of the United States via the Cape of Good Hope and Cape Horn -- a distance of over 30,000 miles. The three ships called at 18 cities in 10 countries during this 60 day voyage. This operation proved conclusively the capability of nuclear-powered surface ships to operate over great distances at high speed, completely free of logistic support.

In October 1965, the ENTERPRISE and the frigate, BAINBRIDGE, left the East Coast of the U. S. for assignment to the South China Sea. During the transit from the East Coast to the South China Sea, they maintained a speed of advance in excess of 20 knots for the entire 16,000 mile trip and arrived on station ready to conduct combat operations. Oil-burning ships attempting to accomplish the same transit in the same time span and conduct similar operations, would have consumed several million gallons of oil enroute. This would have necessitated prepositioning several oilers along the track to refuel them.

On the occasion of the first use of nuclear-powered surface ships in combat, the ENTERPRISE demonstrated her high state of readiness following this long transit, by delivering, on her second day of operations, the highest number of total strikes per day for any aircraft carrier operating off South Vietnam.

I will now tell you about our latest venture -- the Deep Submergence Research Vehicle:

The capability of this manned vehicle will be of an order of magnitude greater than any other developed or planned to date because of the vastly increased endurance made possible by nuclear power. She will be capable of exploring an area five times as great as that of the U. S. The technology gained by development of this vehicle will provide the basis for future nuclear-powered oceanographic research vehicles of still greater versatility and depth capability.

She will be able to steam for periods of time limited only by the amount of

food and supplies carried. This vehicle will be able to perform detailed studies and mapping of the ocean bottom, temperature, currents, and other oceanographic parameters for military, commercial, and scientific uses.

Although development of nuclear propulsion has proceeded at a good speed, one should not conclude that reactor technology is merely a new energy technology, which can be adopted in much the same way as steam replaced sail or diesel oil replaced coal.

If you obtain your energy from human muscle, wind or water, you need almost no technical knowledge. To drive a gang of galley slaves, to manage a windmill or watermill, does not even require literacy. But when you harness the powerful forces of the atom, you constantly face the danger that they may escape man's control. Reactor technology is a complex and difficult technology which makes high demands upon everyone who is even remotely involved with it.

The nuclear power revolution is but one of several developmental projects of similar magnitude; all are concerned with the tremendous effort man is currently exerting to reshape nature. All have, in common, great potentialities for harm if they are not handled by people with the requisite competence.

There is first the requirement that only persons with a high degree of scientific and engineering ability be permitted to handle the powerful natural forces being harnessed by these new development projects.

There is second the requirement that only persons with a high sense of social, ethical and political responsibility be allowed to decide how this new power is to be used. With it man can today do more evil than has ever been possible, barbarous though much of human history has been.

Your country and mine are democracies where the ultimate decision in these matters rests upon each and every one of us. In final analysis, the most important requirement is over-all competence of the public to understand the forces with which we deal and to choose the right men to direct their development and use.

Let me spell out several competencies which are needed when we seek to obtain energy from nuclear fission and apply it to ship propulsion or to generation of power for civilian use. The atom sets its own categorical imperatives; we have no choice but to accept them. Specifically, those require that the engineers in my reactor group must perform at higher levels of engineering competence. It also means that industry must perform at higher levels of managerial and production competence; that officers and men operating nuclear ships, and personnel who operate atomic power central stations must be far more competent technically than their counterparts in conventional ships and plants. What is adequate for routine manufacturing, construction, and operation, is wholly inadequate for the utilization of atomic power.

As is the case whenever man attempts to pioneer beyond established techniques, we in the Naval Nuclear Propulsion group had to learn about the atom even as we were working to develop it for human use. It seems to me this aspect is too often lost sight of when new developmental projects are set up. It should be obvious that when you develop something new you must simultaneously develop new human capacities. In our own reactor group we were driven to see this point because there simply were no engineers available who knew how to handle the project.

From the start, we followed a work-study program, even though we were understaffed. In relays, I sent my engineers away for advanced technical training in nuclear engineering. At the time this seemed the wrong thing to do, but there was no alternative. We had to develop many technically qualified people if we were to become an effective organization. Similar educational steps had to be taken by the industries that were working for us. Those of us who remained behind had to carry the burdens of the ones who went away to learn, but we became the stronger for it. The benefits from this technical training convinced me that it should be continued. As a result, everyone who has joined us since the very beginning has been sent away for additional training.

We deliberately avoided making distinctions between technical and administrative people. Everyone, from the senior people to the young engineer, is required to familiarize himself with, and do work in the technical aspects of the job. In a field as novel as nuclear power we cannot permit technical decisions to be made by men who are purely administrators.

We assign people to positions on the basis of their managerial and technical capabilities rather than their age or seniority. A man's rank, or whether he is an officer or a civilian, has no bearing on his assignment to a job. His brain and his ability are the only considerations by which he is judged and by which he survives.

It was also necessary, given the nature of our project, to establish an uncompromising standard of excellence. Attention to detail became the rule, because no matter how trivial an item appeared to be, if it might cause trouble it was by definition, not a detail.

The specter of Russia's giant scientific strides lent urgency to our work. We decided to save time by telescoping the procedures usually followed in new engineering projects. The sequence normally runs from basic research, to applied research, to the laboratory or "bread-board" model, finally to the full-scale working model. We skipped the stage when theory is tried out in laboratory or "bread-board" models, and designed our reactors to fit directly into ships and power stations. This was a gamble we could not have taken had we not been fortunate enough to receive the backing of our Congress. With their support we were able to cut construction time for the first atomic submarine by several years. The NAUTILUS was designed and built within the time usually required for the building of a conventional submarine.

Omitting the laboratory model stage did, however, increase our difficulties. To most laymen a laboratory model always seems to be equivalent to the finished, working product. But this is not so. There are many laboratory reactors; reactors that produce a little electricity under ideal laboratory conditions, and much is to

learned from them. There is a world of difference, however, between a research or experimental reactor and one that must actually produce useful power for a naval ship or a utility system. Whereas laboratory conditions favor the new project, reality is troublesome.

It is troublesome because as soon as you move from the laboratory to the practical world you deal with people outside your own group, people over whose qualifications you exercise no control. I use the utmost care in choosing the engineers -- naval and civilian -- for my own reactor group. I can, therefore, influence the quality of their design work. But for construction of our reactors and of the ships and power stations into which these are installed, we must depend on governmental and industrial organizations that do not specialize in atomic energy. Most of their work is with conventional types of ships and power plants. Their managers, as a rule, lack familiarity with the peculiarities of the atom. Therefore, they tend to go about building reactors and nuclear ships in the old and tried ways that were appropriate for conventional jobs. It has taken, and continues to take much time and effort to convince them that nuclear power is a more exacting kind of energy than steam or diesel power.

Old, established organizations develop undue veneration for routines and protocol, and it is extremely difficult for their managers to realize that what suffices for conventional work is quite inadequate when you undertake new engineering projects. We still have trouble getting the idea across that technological breakthroughs can never be brought about by routine methods and protocol. The essence of all progress is a shedding of preconceived ideas and accustomed ways of doing things, a venturing into the unknown where one is necessarily guided more by intuition and imagination than by established rules and regulations. How else can anything new be created?

Every attempt to develop something new is hampered not only by technical but also by administrative problems, and sometimes by lack of understanding on the part

of the general public. Advancement is hampered unless all who directly or indirectly exert influence on new projects learn to think on a higher intellectual plane. At the present stage of development only extremely competent, technically trained persons can design, build and operate reactors or devise appropriate safety regulations for their use.

The climb upward to higher technologies is always difficult and painful. The imaginative creativity of the theoretical scientist who deals with abstract concepts is always ahead of the technical and administrative competence of those who translate the abstract into the concrete. How fast we progress technologically depends largely on the time it takes to put new scientific ideas to practical use -- that is, on "lead time".

Much of our thinking is built on the erroneous belief that technology, which has so greatly eased man's physical labors, can similarly ease his mental labors -- a totally false conclusion; the very opposite is true.

When machines take over manual labor and routine mental chores, the complexity of life increases; efficient management of one's private and the nation's public affairs makes much higher demands on the human mind.

The consequence of technical progress is that man must use his mind more and his body less.

Let me summarize:

Progress -- like freedom -- is desired by nearly all men, but not all understand that both come at a cost. Whenever society advances -- be it in culture and education or science and technology -- there is, as I said, a rise in the requirements man must meet to function successfully. The price of progress is acceptance of these more exacting standards of performance and relinquishment of familiar habits and conventions rendered obsolete because they no longer meet the new standards. To move but one rung up the ladder of civilization, man must surpass himself. The simple life comes "naturally", the civilized life compels effort.

In any advancing society some elements will accept the advantages of life at a higher plateau, yet ignore its obligations. This is readily seen when backward people seek to modernize their society. Sociologists call it a "culture lag". Something akin to a culture lag exists even in highly developed countries. And, because all parts of a modern society are interdependent, failure to meet rising standards in any sector becomes a brake on general progress and harms society as a whole.

I have tried to give you an inkling of the advantages of nuclear power, especially for naval craft, and of the factors that hinder progress in reactor technology. I submit we must progress, and so we must pay the price of progress.

One final thought I would like to leave with you:

Today we are coming full circle. 2,500 years ago -- for a brief golden moment -- the citizens of Athens achieved a way of life in which all man's faculties -- mental, physical, esthetic -- were brought to a level never before or since achieved anywhere by so large a part of the whole citizenry. Greek civilization, at its apogee, rested on the meagerest energy base -- largely human labor -- labor of the citizens who, for the most part, were plain farmers, artisans, merchants, but who enjoyed some leisure because they had slaves -- men who were not part of the citizen body, but had lost their freedom in war or through other vicissitudes.

We now approach a time when, in the advanced countries of the world, science-based technology provides all citizens with innumerable efficient mechanical slaves, thus again giving the whole people leisure to develop their innate capacities.

I spoke of the unique aspect of modern civilization, of its total dependence upon non-renewable fossil fuels and of the urgent need to develop alternative energy sources before our present supply runs out. Let me stress once more that this calls for large numbers of intelligent, broadly educated and technically competent citizens to manage the complicated technologies which alone will insure us a civilized future. Oddly, just when more and more of man's rough physical labor and purely routine

are being taken over by machines, man himself, fully developed man, becomes
more and more the basis of civilized life upon which all must rest.

Thus, we return to the Greek ideal -- to Renaissance man -- the man of
excellence.