UNITED STATES
ATOMIC ENERGY COMMISSION
Washington 25, D. C.

INFORMATION FOR THE PRESS
Telephone ST 8000, Ext. 307

FOR RELEASE A.M. PAPERS
Saturday, July 23, 1949

REMARKS BY LAWRENCE R. HAFSTAD,
DIRECTOR OF REACTOR DEVELOPMENT
UNITED STATES ATOMIC ENERGY COMMISSION,
BEFORE THE INSTITUTE OF AERONAUTICAL SCIENCES
LOS ANGELES, CALIFORNIA, JULY 22, 1949
(Ambassador Hotel--7:30 P.M. PDT)

ATOMIC POWER AND ITS IMPLICATIONS FOR AIRCRAFT PROPULSION

It is indeed a privilege to meet with this particular group tonight to present my impressions of the problems involved in the development of nuclear reactors, first in the general sense, and second, for the specific purpose of use in aircraft.

This group is especially qualified to appreciate the nature of the problems involved, both from a technical and from a policy point of view. Reactor projects have much in common with aircraft development projects. Both are expensive and risky. In both fields, one must obey the precept "Be bold, be bold and ever more be bold, but be not too bold". Following that advice takes more than technical knowledge. It requires wisdom.

This report tonight is timely, too, for since I have been with the Commission just long enough to learn the ropes, I should be able to give you the impressions of an outsider who has had the privilege of getting a good, hard inside look at the Commission's Reactor Program.

Of course, this assumes that I will be skillful enough to handle the security questions involved. Fortunately, I do not think this will be too difficult. What our competitor wants to know is, "What solutions or promising approaches have we found to specific technical problems?" What you gentlemen are probably most interested in is: "Is the objective we have set for ourselves worth attaining and are we going about it the right way?" These are questions peculiar to our own situation and our own frame of reference. The answers we get are certainly not those which are applicable to our competitor. In this area, therefore, we can afford to be frank without giving aid and comfort to the competitor.

Let us see if we can get squarely in mind just what are we trying to do in the overall atomic energy effort? Not with respect to specific technical projects, but what are the things we have to do in a broad sense? These are, I would say:

First: To maintain undisputed leadership in technical knowledge and facilities for the United States in all areas of the atomic energy field, either for war or peace.

Second: To establish a trained corps of personnel familiar with all areas of atomic research and in particular with nuclear radiation and its hazards. This corps is our standing army of the modern age, and would have to be maintained to serve in time of war, even if not organized to contribute in time of peace.

Third: We want organized task forces sufficiently competent to explore, and sufficiently alert to exploit any technical advance, which has promise for either peace or war.

Fourth: We want the wisdom to see that the effort expended in the above activities is somehow kept proportional to the probable returns.

As part of the above, some kind of a reactor program is an essential part of the overall effort. Reactors are the machines for giving us the controlled release of nuclear energy, and as such, certainly have promise both for peace and for war. Though the spectacular aspects of nuclear energy has been oversold in the popular press, the stubborn fact remains that one pound of Uranium can be persuaded to release an amount of energy equivalent to 2,000,000 pounds of coal. When all is said and done, atomic energy is certainly not the magic perpetual motion machine which has been publicized, but it has the inherent possibilities of providing an incredibly compact storage battery.

Let's look at this analogy a little closer. Our ordinary automobile battery delivers 6 volts and has a capacity of about 100 ampere hours, or a total power storage therefore of very roughly, one horsepower hour. A weight of Uranium equal to that of an automobile battery would be capable of delivering about 300,000,000 horsepower hours. Edison was a great inventor, but the famous Edison cell, produced after years of effort brought forth an improvement of only 30 percent over the conventional lead cell compared to a conceivable 300,000,000 percent for the Uranium energy source. I will return to the many difficulties later, but this analogy shows the challenge of the problem, the conceivable rewards, the "pie in the sky." It would seem that the possibility of nuclear reactors for power production must at least be explored. The '49ers had much less incentive.

What else can reactors be used for? In addition to energy, reactors produce neutrons. These in turn can be used to produce radioactive isotopes, or to produce more, or other, fissionable material. So long as concentrated energy sources are desirable, fissionable material will be an "economic good." A stockpile of fissionable material would certainly be more useful than the gold at Fort Knox. In war, it could be used for bombs and might be used for propulsive power. In peace, it would be available for civilian power insofar as the supply, and the economics of the situation would permit. It would appear, therefore, that a stockpile of fissionable material is indeed desirable. Accepting this, then considerable effort would appear to be justified on a special type of reactor called a "breeder," which shows promise of helping to maintain, if not even augmenting, our supply of fissionable material.

To describe a breeder we must digress for just a moment to a technical detail. As most of you know, the element Uranium, as it occurs in nature, is composed of two kinds, one variety slightly heavier than the other. The fissionable variety from which we can get energy has a mass of 235 units. The other, unfissionable, has a mass of 238 units. The U-238 form is 139 times as prevalent as the U-235 form. The trick in a "breeder" type of reactor is this: With a proper choice and arrangement of materials, the neutrons which are produced in the initial natural U-235 fission processes can be captured--<u>after</u> they have released their energy--by the atoms of unfissionable U-238 and as a <u>by-product</u> used to convert the U-238 into a fissionable form of material. Thus it is conceivable, not only that energy can be extracted from U-235, but that as a by-product we acquire a potential stockpile of fissionable material 139 times as great as we had when we started! With such a stockpile we might have a chance for diversions to power for civilian uses. Again we have a challenging goal and unless we have lost our zest for adventure, it is a goal from which we will be deterred only by a convincing demonstration of its scientific impossibility.

If reactors are so desirable, why don't we go ahead and build some? Now we come to the difficulties! Here are a few of them:

1) That for any reasonable thermodynamic efficiency in utilizing the great energies available, it is necessary to operate at temperatures well above the conventional engineering range.

2) The compactness of reactors which is an important inherent advantage proves troublesome in regard to the heat transfer problems which involve heat transfer rates far transcending previous experience.

3) The materials chosen for the reactor must withstand not only high temperatures but also high nuclear radiation densities, with unpredictable changes in the physical properties of the materials concerned. The seriousness of this problem can perhaps be visualized by this kind of a comparison. How would you like, for example, to design airplanes or engines if, in use, the properties of the aluminum and steel would gradually change to those of cast iron or lead?

4) If we finally find a structural material for reactors which appears suitable so far as physical properties are concerned, we must now add still another requirement. The nuclear properties must be such that the structural material will not capture neutrons and thus deplete the supply and reduce the power. This requirement drives us to consider strange new elements, and raises a whole array of procurement problems.

5) Even after we have our reactor working we find that the fission products produced as an essential part of the reaction "poison" the reaction itself. The ashes smother the fire. Now you gentlemen are well aware of the enormous maintenance problems for aircraft engines. Every 800 hours they must be disassembled, inspected, have defective parts replaced, and then reassembled and tested. The work is staggering. However, how would you like it, if instead of merely disassembling, the entire engine would have to be dissolved in nitric acid, and the rebuilding of the engine started with getting a solution of certified chemically pure iron? This is the fuel reprocessing problem!

6) Finally, assuming we have solved the structural problems listed above, we have a whole new category of problems in connection with the working fluid or heat transfer medium used to convert the heat into power. The nature of these problems can be suggested by the fact that from rough comparisons of the volumes of

reactors and the present highly perfected aircraft engines, the rates of heat transfer must be more than an order of magnitude greater for nuclear reactors than for conventional engines. Orthodox advances will not be sufficient. The problems involve the use of liquid metals with all the associated corrosion, erosion, purification and pumping troubles which we can readily imagine as being associated with those elements which appear to have suitably low melting points.

When one considers the host of difficulties and troubles which lie in the road ahead in the development of atomic power the problem does look formidable. I am reminded of a statement made a little over a hundred years ago by the great chemist, Wöhler, in regard to the status of organic chemistry at that time. Wöhler wrote to Berzelius as follows:

> "Organic chemistry just now is enough to drive one mad. It gives me the impression of a primeval tropical forest, full of the most remarkable things, a monstrous and boundless thicket, with no way of escape, into which one may well dread to enter."

That's an excellent description of the atomic energy field right now, in 1949! In the meantime, however, what has happened to organic chemistry? Well, newspaper headlines give the answer. Miracle drugs are practically tailor-made these days. DDT and 2-4-D are taken for granted by the farmer. Synthetic rubber threatens to displace the natural product. A hundred years from now what will be the status of atomic energy? Who now has the wisdom to predict either failure or success?

We can all hope for the era of free power and effortless living usually associated with the Atomic Age. This implies the successful development of large, land based, electric power producing reactors. We have also heard discussed the military advantages which might be gained by nuclear propulsion of ships and aircraft. I will discuss these in more detail later but the point I want to make now is that whereas the technical problems would be least in the land based power reactor, and progressively more difficult in the ship and aircraft reactors, the present urgencies or priorities are just the other way around. Perhaps fortunately, however, the same ground must be covered in the initial stages whether the ultimate purpose is for civilian or military use. We might take as an analogy, a transcontinental journey, starting from Washington in the frontier days. Whether the ultimate goal was Oregon or California, the route was the same through Cumberland Gap and on to St. Louis. To complete our comparison we might put civilian power in California and military power in Oregon. These are the things we dream about. At the moment we are really only approaching Hagerstown, and our worries and our plans are all concerned with surviving the hazards of the journey to St. Louis.

I don't need to stress before this group the importance of the incentive given to technical developments by military needs. This group is well aware, I might even say, painfully aware, of the vicissitudes of the development of the airplane to the highly perfected state in which we have it today. Similarly in the atomic power field it appears that military needs will have to provide the incentive to carry through difficulties, for progress even though ultimate dividends may be expected in the civilian economy.

Going further back into history, we can cite the difficulties of converting ships from wood to steel. Again, the incentive was military, but note this quotation:

> "Early experiences with iron as the material for hull construction were far from reassuring. In England where several iron warships had been completed by 1846, firing trials conducted in 1845 and in 1850 indicated that 32-pounder and 68-pounder shot striking iron plating were likely to break up and form more splinters from the shot themselves and the iron of the target than were caused by the impact of the same shot upon wooden targets. Accordingly, the British Navy pronounced iron to be an unfit material for hull construction."

Only if both the opportunities and the difficulties in the field of atomic energy are fully appreciated can the history of the atomic developments over the last several years be understood. This is a field in which the experts disagree. The more distinguished they are the more violently do they disagree. /At this point, I want to disqualify myself as an expert. Scientists live and work in laboratories, not in marble buildings in Washington! I am an ex-scientist now. My job is to be a good listener and an accurate interpreter./ When experts disagree, a middle of the road course of action is indicated and this indeed is what we have in the Commission's Reactor Development Program.

As has been announced, and as presented in Budget hearings before Congress, so there are no security questions involved, the Commission program consists of two main parts. The first is a strong applied research program seeking to establish the basic facts, the handbook data if you like, which will ultimately be needed in solving the reactor design problems. For the reactor program the center of this type of authority is at the great Argonne Laboratory at Chicago.

Due to the foresight of the Manhattan District and its advisors, and to the continuing generous support by the Commission and Congress, the nation has an exceptionally well supported predominantly non-military applied research program in the atomic energy field. In the large national laboratories we have thousands of people working on and becoming acquainted with atomic energy problems. In our atomic energy production plants we have thousands more. These people are our standing army, mentioned above as requirement Number 2, and our preparation for any eventuality of the so-called Atomic Age.

But it will take more than the accumulation of a library full of knowledge to get power-producing reactors. We have 40,000,000 automobiles on the roads of the United States but we still do not "understand" the mechanism of combustion. It is for this reason that the second part of the Commission's program is the engineering development and construction of a series of definitely experimental prototype reactors. These represent assignments to specific task forces as mentioned in requirement Number 3.

Of course, the nation has had reactors of various kinds, from almost the beginning of its atomic energy program. The famous chain reacting pile at Chicago was the first of such reactors. A series of reactors was built during the war culminating in the huge single purpose production reactors at Hanford. Other reactors have since been built but these are by and large, research type of reactors, small in size, and none of them capable of producing useful power in appreciable amounts. The next phase in the historic development of reactors calls for designing and constructing of reactors which are larger, more complicated, and more difficult to build than any we have produced thus far. As in any new technical development, there are many uncertainties and many risks involved. It is here that the experts disagree on details of designs of reactors which will do the jobs that need to be done. Largely, for this reason, in the four years since the end of the war, no really new or greatly improved versions of reactors have been built in this country. The reactor of most advanced design and performance is in Canada.

The proposed reactor development program of the Commission crystallized out of the four years of discussion and argument as well as from new knowledge gained from the applied research program since the end of the war. Reactors can conceivably be used for a wide variety of purposes. Special reactors of many types have been proposed by responsible people for purposes varying from small compact units for propelling guided missiles, to huge stationary power plants for providing cheap electric power for supplying our great cities and distilling ocean water for irrigating our deserts. To the people most fully informed, it is clear that the difficulties of building any reactor are so great that only a very few projects can be adequately supported with money and particularly with competent technical manpower at the present time. It is for this reason that it is essential from the multitude of possible reactors, only a few carefully selected projects should be chosen and very strong technical support should be focused on these few.

Getting back to the fundamentals, a reactor can be made to produce two things: First, a large number of neutrons, and second, a large amount of heat or power. At Hanford, in the production reactors, the neutron supply is utilized for the conversion of the non-fissionable uranium-238 into fissionable plutonium for use in atom bombs. In the existing Oak Ridge reactor, again the neutrons are used for the production of isotopes for peacetime research purposes. In both cases, the heat generated is wasted--it is lost in water coolant at Hanford, in air coolant at Oak Ridge. At the present time, there are no reactors in existence so designed that the heat produced can be made to serve useful purposes.

An obvious forward step would be the design of a reactor in which the neutrons produce fissionable materials as in the existing production reactors, but in addition, the heat generated is put to work. Unfortunately, scientists and engineers at present do not have enough basic knowledge to design such obviously desirable reactors. Their first step would appear to be to produce a reactor specifically for the single purpose of generating large amounts of heat at temperature which will permit conversion to power. So extensive is our ignorance, however, that even such a simplified design is forcing us into pioneering activities beyond the present boundaries of human knowledge. Before any reactor can be built with a performance appreciably better than those we now have, a large amount of applied research in very specialized fields is necessary. This is the activity with which our laboratories have been preoccupied for the last four years.

We are now at the stage where if we intend to progress further, it will be necessary to find the courage to build a few reactors, to test what we think we know. The reactors in the Commission's program are essentially experimental prototypes.

None of them can be described as an "end-item" which will drive an airplane or a ship, or power and light a city. Further generations of reactors will be required before such desirable goals can be attained. It is this fact which sets a time scale of ten to twenty years before useful and economical civilian applications of atomic power can be expected. However, if the ultimate goal is ever to be attained, the first steps must sooner or later be taken, and it is these first steps with which we are concerned in the present reactor program.

As described by Dr. Robert F. Bacher, former Commissioner, and a moving force in reactor development work, the current program consists of four reactors:

a. The first of these has been designated as a materials testing reactor. We call it "MTR." While it is itself an experimental reactor, as its name implies, it is intended also to give information on the behavior of materials in reactors so that larger and more powerful special purpose reactors may ultimately be built. This reactor is of particular interest to the Air Force since it represents the boldest step into the unknown which we now dare to take, moving in the direction of compact, high radiation density reactors which must ultimately be developed if the Air Force needs are to be satisfied.

b. The second reactor is a land based prototype of a reactor for use in propelling naval vessels. It would be a simple, single purpose reactor designed specifically and solely for the purpose of producing large amounts of heat, under conditions which will permit conversion to propulsive power.

c. The third reactor is a single purpose experimental reactor designed specifically to give us information about the breeding process. This reactor at the present time is the most likely to demonstrate the actual breeding of new fissionable material. It is, however, neither a high power reactor nor designed for the purpose of demonstrating appreciable amounts of useful power though an incidental amount of power may be produced by a by-product.

d. The fourth reactor is the more ambitious project--the Knolls Atomic Power Laboratory Reactor. This reactor is intended to produce a really significant amount of electric power. At the same time, it is hoped that this reactor will be able to demonstrate at least partial success in breeding. This reactor is, therefore, a very complex device since its design represents a compromise between the demands for power production and for breeding. If successful, however, this reactor would represent a major step forward in the direction of the production of useful power without depleting, and perhaps even increasing our national supply of fissionable material for any purpose.

Whether by accident or by design, this program is a reasonable middle of the road program. It represents a balance between reactors contributing to the solution of military and civilian problems, a balance between reactors which use up fissionable material and reactors which promise to replenish or increase our national supply of fissionable material, a balance between a bold attempt to solve immediate problems by the engineering approach as in the Navy reactor and the intermediate breeder, and the more long-term research approach of gaining more information about the behavior of materials under novel, but controllable conditions as in the materials testing reactor, and the experimental fast neutron breeder.

I would like now to comment on the fourth requirement which I mentioned above and which was concerned with getting value received for money invested. How does one put a money value on any new developments particularly on one of a military nature? What, for example, would have been the value of the "Merrimac" to the South had not the "Monitor" come along" What was the value of the "Monitor" to the North in 1862 dollars? If we want to be modern, what was the value of the "Spitfire" in the Battle of Britain, or what is the current value of an atomic bomb?

We have heard much discussion recently of the cost of producing atom bombs but what are they really worth to us--in dollars? It would be helpful to have at least a rough estimate of the present value of an A-bomb, either in dollars or in equivalent divisions or battleships or air-groups. While this may sound difficult, order of magnitude engineering estimates to keep our thinking straight, are not too hard to make.

We know, for example, that at the end of the war, our daily war expenses were approaching $300 million per day. If the A-bombs shortened the war by even 10 days, the entire $2,500,000,000, cost of the Manhattan effort can be written off, and recorded, as a spectacular success, and a value, as contrasted to cost, of at least $1,500,000,000 each to set on the Hiroshima and Nagasaki bombs.

Since warfare seems to be mainly a competitive destruction, we can get another estimate in an entirely different way. Taking the radius of destruction for a bomb as from one to two miles, the area destroyed would be approximately six square miles. In an average city the property value runs perhaps $50,000,000 per square mile. The destruction per bomb, therefore, represents about $300,000,000 and gives a figure of the "advantage" to us, and therefore of the value to us, in this insane competition in destructiveness.

We can approach the problem in another way to get another independent estimate. I have heard that a man by the name of Churchill, who seems to have a reputation in these matters, has stated that, but for the A-bomb, World War III would have been underway. Now for those who know how many bombs we have, it should not be too difficult to pro-rate the annual estimated cost of this war among the bombs on hand.

Finally, let us approach the problem in still another way, using an infantile form of operations research. We have been told that one A-bomb is equivalent in effect to 20,000 tons of TNT. Since big, single bursts "over-kill" at the center, let us cut this by some suitable factor, say 10, for example. Now one of our large bombers can carry a pay load of about ten tons, therefore, to carry 2,000 tons would require 200 planes. This is unassailably accurate arithmetic! Large bombers cost half-a-million dollars to build, but with logistic support, more like $2,000,000 in combat. One A-bomb makes one bomber the equivalent of two hundred. Ergo, one bomb is "worth" $400,000,000.

There is another conclusion which can be drawn from this quick operations research calculation. We should think twice or maybe even three times before permitting too casual diversions of material from the stockpile, even for other conceivable military uses. It follows also that civilian power will remain "pie in the sky" unless by a "break" in the breeder program or some other solution to the raw material problem, a more ample supply of fissionable material can be provided. Finally, it follows that this is indeed a game in which if we are to play at all, we play with "blue chips."

In the reactor field what would the nuclear-powered air equivalent of the "Merrimac" be worth in a future contest against a fleet of chemically-fueled airplanes? What would a nuclear-powered naval vessel be worth in a future engagement if it were--as the "Merrimac" and "Monitor" were--one whole generation ahead of the conventional fleets of the day? What would be the value nation if, as has been suggested, atomic energy could used to evaporate sea water to make the deserts bloom? These are the really fundamental questions, and I am glad that it is Congress' responsibility and not mine to make decisions on them. It is, however, my responsibility to see that we get value received out of each dollar which is appropriated for the reactor program, and this will require more than anything else that effort be kept commensurate with both priority and promise.

I would like, therefore, in view of its special interest to this group, to return to the aircraft propulsion reactor to consider it more in detail. To this group, fully aware of the serious limitations of chemical fuels, I feel sure that the desirability of an ideal nuclear power plant for aircraft is obvious. I can, however, quote a Congressional report on the subject. In the Brewster report we find the following statement:

> "In the event of war or in any international situation likely to lead to war, nuclear energy for the propulsion of aircraft would be comparable in significance to the atomic bomb itself. Presently known limitations inherent in all chemical fuels make difficult the delivery by air of atomic bombs against a distant enemy. Therefore, if the United States had nuclear energy propulsion in addition to atomic bombs, it would be the dominant factor in maintaining world peace. Until these ends are attained, the United States must depend on military weapons and techniques currently available."

With the desirability of an ideal solution to this problem there is general agreement. There is agreement too in regard to the contention that developing any kind of an aircraft reactor will be extremely difficult. The NEPA Project, carried out by the Fairchild Company, under an Air Force Contract, has been engaged in a vigorous attack on this problem since 1945. The North American Aviation Company and the Rand Project have also made important contributions. These studies all seem to indicate that, granting the difficulties of the reactor problem itself, the power conversion problem represents a challenge of almost equal magnitude.

As seems to be characteristic of this field of activity, anything which is obviously desirable and important seems to be almost incredibly difficult. To help resolve the impasse, the Commission last year made a contract with the Massachusetts Institute of Technology to make a study of the problem and to come up with recommendations. The result of this study was the Lexington Report, the details of which are at present quite properly highly classified.

The immediate course of action indicated in the Lexington Report is essentially that the aircraft propulsion project should be continued in an intensive study phase, both theoretical and experimental, for the next two or three years, by which time it might be hoped that data might become available to permit a reevaluation and a more decisive conclusion. It is recognized that this study phase should be made national in scope to include the NACA and AEC as well as the National Military Establishment.

These are eminently sound guideposts and they are being followed. An Ad Hoc Committee, consisting of representatives of the Air Force, Bureau of Aeronautics, NACA, and AEC, has been meeting since last January to coordinate the work of the various government agencies involved and to insure an industry wide approach to the technical problems. In such a joint attack on a problem clearly there will be some duplication which must be eliminated and some shifts of emphasis which somehow must be consummated. Committee procedures grind slowly but this work is well under way. Many of the companies represented here tonight have recently contributed technical talent to the National effort now being organized.

In the meantime, in accordance with the Lexington Project recommendations the NME has been asked to evaluate the military worth of the proposed weapon if and when it is produced. This is a really tough assignment. It is indeed controversial, but not in the sense of an inter-service feud. This is definitely not an Air Force vs. Navy issue. Both the Air Force and the Bureau of Aeronautics want nuclear-powered airplanes if at all possible, and so long as the Atomic Energy Act is in existence neither can hope to build a private empire in this field even if it so desired. The issue, and the controversy is really a fundamental one. It rests on the typical, perplexing, circular, hen and the egg, nature of all the decisions involving new weapons which the military are continuously asked to make. How valuable nuclear-powered aircraft might be depends heavily upon when it will be available, what the maintenance problems are, what the cost will be in diversion of fissionable material, not only for the aircraft reactors installed, but also for the inventory required by the complex reprocessing procedures required for nuclear fuels. Unfortunately, the answers to these questions depend on the priority which is attached to the development program. How soon nuclear-powered aircraft can be available depends on how much effort we put into the program. Similarly, how soon we can give information as to probable performance and costs will depend on how rapidly the work progresses. The dilemma is very real and very serious. It was to aid in solving just such problems that the Weapons Systems Evaluation Group, under General Hull, was set up in the National Military Establishment.

The best summary of the situation which I can give is that the pessimists, who in general are those best informed, have thought through the immediate reactor and power-transfer problems and are staggered by the maintenance and operations problems which would be involved if the actual aircraft propulsion devices for combat use were to be based on our present knowledge and practices. The optimists on the other hand either are not yet aware of the very real immediate difficulties, or they are betting heavily on new ideas and new developments arising during the course of the work which avoid some of the currently foreseeable troubles. In this connection, I seem to recall, however, that not many years ago all the technical facts, and all the arguments of the experts, indicated an upper limit of 100,000 pounds as an absolute ceiling for the size of heavier-than-aircraft. This is an area in which it will no doubt be wise for us to be open-minded but skeptical. The best we can hope for in a program such as this is one in which the best available advice is sought and used.

In my introduction I raised the question as to whether our objective was worth while and whether we had a sound approach. Let me now try to summarize the situation as it looks at the present time.

We want to maintain technical leadership in the atomic energy field. This is our objective and our assignment by Act of Congress. As part of this effort we want a vigorous reactor program. This program must earn its keep for either peace or war purposes. The initial part of this program is the same whether the ultimate use of the reactors developed is civilian or military. We have a generously supported applied research program in the large national laboratories, to give us basic information for new developments and for providing a trained cadre of specialists in the atomic energy field. We have engineering task forces attacking some of the most promising possibilities available to us at the present time. Most urgent are the two premium fuel uses of interest to the military, namely, power for ships and power for aircraft. The first of these while difficult, can conceivably be attained by direct frontal attack. The second is being attacked indirectly with the Materials Testing Reactor, representing an important, exploratory advance as well as providing an almost essential research tool. The MTR will be to reactor development what wind tunnels are to aircraft developments.

Another strong task force is engaged in a difficult but promising assignment on a reactor which can either be considered as giving power with fissionable material as a by-product or fissionable material with power as a by-product. In either case success would represent a major step in advance toward economical power for either military or civilian use.

The fourth task force is engaged in a frontal attack on the problems presented by the chronically short supply of fissionable material. Ideal success would increase by a factor of 139 the potential stockpile of fissionable material and might bring atomic energy for civilian use within sight. Even very partial success might go far toward helping us increase the efficiency of present production processes.

Success in all of these task force efforts is probably too much to hope for, but the possible return in each appears high enough so that success in one will pay for the rest. The risks are great but the stakes seem greater.

Details of the program are controversial and on these it is undoubtedly discreet for me to maintain a studied silence. I might be permitted, however, to end with a quotation from one of the wisest of scientists, Benjamin Franklin, which dates from the year 1780:

> "The rapid progress true science now makes, occasions my regretting sometimes that I was born so soon. It is impossible to imagine the height to which may be carried, in a thousand years, the power of man over matter... Oh that moral science were in as fair a way of improvement."