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Problems and Prospects in Atomic Energy

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PROBLEMS AND PROSPECTS IN ATOMIC ENERGY

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Admiral Smith and Gentlemen of the War College:—

I think that the best way to start a discussion on problems and prospects in atomic energy is to cover a few basic definitions of Nuclear Physics. First, nuclear fission, which is induced in the nuclei of several atoms at the heavy end of the atomic series. The nuclear fission which concerns us is fission of the Uranium 235 and Plutonium nuclei. In both of these nuclei the disturbance begins when a neutron enters the nucleus. Since a neutron, by definition, has no electrical charge, it is neither attracted nor repelled by the nucleus, so that most impacts are penetrative. Immediately, after the neutron has penetrated a Uranium 235 or Plutonium nucleus, a major disturbance takes place in this very dense sphere of "jelly". The balance between electrical repulsion and sub-atomic cohesive forces is so upset that the sphere turns into a dumbbell shape, then the terrific electrical repulsion of the two smaller "bells" accelerates them to very high velocities. As they break apart, each of them snaps back into spherical shape. This violent oscillation of the new nuclei results in ejection of one or more neutrons by each new nucleus. In about one percent of the cases, this ejection of a neutron is delayed for a time ranging up to a few seconds.

The essential properties of a nuclear fuel or explosive are two: first, that it must be fissionable by slow or fast neutrons in the sense that I have just described; second, that the result of its fission must not only be the release of energy, but also the release

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of a sufficient number of neutrons to cause further fission. It is a scientific fact that the nuclei of only three atoms fulfill the two requirements which make them nuclear fuels. These three atoms are the 239 Isotope of Plutonium and two isotopes of Uranium, namely, Uranium 233 and Uranium 235. Two of these three known nuclear fuels do not occur in nature, and, therefore, must be produced artificially by transmutation. Plutonium is produced by bombardment of Uranium 238 with neutrons, resulting in Plutonium 239. Uranium 233 is produced by neutron bombardment of Thorium 232 which results in Uranium 233. It is an odd and somewhat ironic fact that to produce the two man-made nuclear fuels in usable amounts, it is necessary to "burn" Uranium 235, the only natural fuel, in order to get the astronomical number of neutrons required in the process.

Up to now, I have casually referred to isotopes. I know from experience that many people are unfamiliar with the meaning of this Greek word. The term isotope is used to differentiate between atoms of the same element which have different weights. The chemical properties of an atom do not depend on the weight of the nucleus, but only on the number of electrical charges in the nucleus. By our present concept, this means the number of protons in the nucleus. Thus, there are three known isotopes of Hydrogen. Ordinary Hydrogen has a nucleus consisting of a single proton. Heavy Hydrogen, or Deuterium, has a proton and a neutron in the nuclous, whereas Tritium, or triple-weight Hydrogen, has a proton and two neutrons in its nucleus.

Having disposed of nuclear chemistry, we now come to the term "critical mass" of fissionable material. An exact definition of critical mass would require several pages of fine print, but an oversimplified one is all that we need here. There is no analogy to a critical mass in the case of chemical fuels or explosives. If there were, it would be impossible to make a sub-critical amount of TNT or coal ignite, but a super-critical amount would ignite spontaneously. For our purposes, a critical mass of fissionable material can be defined as the amount reached when the number of neutrons which escape from the surface is exactly balanced by the number of new neutrons created by fission within the mass. Obviously, an important factor in the critical size or mass is the number of neutrons released per fission. If this number were less than one and one-half for example, the critical mass would be tremendous and the volume might exceed the size of this room. In that case, further discussion of atomic energy would be quite academic.

Now, having defined a critical mass, the question of producing an explosion arises. My favorite way to discuss an atomic bomb in unclassified language is to picture two hams in a butcher shop. Each of the hams is sub-critical by itself. The flies in the butcher shop are the neutrons, and, as long as the hams are more than a diameter apart, a fly landing on either of them does not produce a chain reaction which builds up. However, if the hams are brought together in some fashion so that no fly lands on either of them until they have merged, there will be a real surprise when the next fly lands. In this case, we have surprised Nature by presenting her with a highly super-critical assembly. Nature then gets back at us by presenting us with a runaway chain reaction called an atomic explosion. In the case of an atomic bomb, there are two important time intervals. First, the assembly interval which involves mechanical movement, and, therefore, is relatively slow. The second interval is measured in fractions of a millionth of a second. It starts with the beginning of the runaway chain reaction and ends when the fissionable material has expanded to a point at which it is again below critical.

I would turn now to the effects of this atomic explosion. The first effect considered is blast. We are all familiar with the destructive effect of blast from bombs with chemical high explosives. In these pre-atomic bombs, the blast is intense in the immediate vicinity of the bomb but is of very short duration. It delivers a hammer blow or very sharp impulse to any unyielding material in the vicinity. In the case of an atomic bomb, material in the immediate vicinity, of course, would be incandescent. At distances of the order of one-half mile, the push of the shock wave and mass movement of the air lasts ten to one hundred times longer than the sharp push of an ordinary block-buster. Therefore, it is effective in knocking down buildings and other structures which are built to withstand only the side pressure of a hurricane or the shaking of a mild earthquake. It is important to remember that a building has a tremendous amount of potential energy which is released when it falls on itself. Then, if a falling building sets itself on fire, it proceeds to release a great deal of chemical energy. The point is, that an atomic bomb does not, by its own power, obliterate a city. It merely starts things and the city then obliterates itself.

In the case of Hiroshima, the only effect of the atomic blast was to raise a curtain of dust about 200 feet thick over the smashed city. Only one fire was visible one minute after the bomb detonated, and that was on a hillside. Perhaps some blacksmith shop had been knocked down.

As Los Alamos was being organized, we did a lot of talking about the explosion of an ammunition ship in Halifax Harbor in December 1917. That ship carried the equivalent of 2800 tons of TNT, and the explosion was reported to have had terrible effects on the city. We studied these reports carefully, but it was not until after the explosion of an ammunition ship at Port Chicago, in July 1944, that we became realistic in our estimate of blast damage. In the case of Port Chicago, which was an ammunition depot north of San Francisco, 1600 tons of high explosives detonated. I arrived at the scene less than two days later and made a personal check of the damage. The Naval magazine at Port Chicago had built-in protection against large explosions. With some luck, this protection was effective in preventing any secondary explosions or fires. In the light of the Port Chicago results, we reanalyzed the Halifax reports and concluded that a major factor in the Halifax disaster was a record blizzard which struck the city a few hours after the explosion.

The results of Halifax and Port Chicago have been confirmed on a larger scale by Hiroshima, Nagasaki and Bikini "ABLE". From these we can conclude that no spectacular blast damage will be done to tough structures like bridges, steel ships and heavy reinforced concrete buildings. Naturally, there would be a short range, say a few hundred yards, inside which practically any structure above ground would be rendered useless.

I have already covered damage from secondary fires. There is a further hazard from primary fires caused by the radiant heat of the bomb. I do not believe that this primary heat hazard is very serious except to exposed people. While wood and other inflammable material will char and smolder, any flash fires are apt to be blown out by the violent blast which arrives within a second or so.

A most important factor in the lethality of an air burst atomic bomb comes from the radioactivity. In this case, the overwhelming effect is from gamma radiation and all of this radiation dosage is received in the first few seconds after the bomb detonates. After this, the ball of fire has risen so far toward the stratosphere that it no longer irradiates the city. An air burst placed for maximum blast damage will not deposit any radioactive material on a city. People within a mile of an air burst bomb, who have been shielded in some fashion from the radiant heat but not shielded from the penetrating gamma radiation will show no effects for several hours. Then, if they have received heavy dosage they will become nauseated, and, in case of extreme exposure, will die within a few days. Marginal cases will show ordinary infections within a week. These arise from the fact that the radiation kills the unborn white corpuscles in the blood, and, therefore, the body is unable to fight off normal infections. Red blood corpuscles are also affected, but their cycle of replacement is longer, so this effect shows up after several weeks. Combatting infection by use of Penicillin and replacing blood by transfusion in marginal cases help recovery.

The semi-permanent radioactive contamination caused by the underwater atomic burst in the Bikini "BAKER" test has been given great prominence as the first sample of radioactive warfare. It is certainly true that the mist called the "base surge", which was formed by the falling column of water, initially contained the equivalent of one thousand tons of radium and deposited an appreciable amount of this poison in the water and on the target ships. Such a drenching would almost certainly have killed most of the crews of the ships which were completely enveloped. But, a most important point to remember is that the intensity of the gamma radiation from the fission fragments of an atomic burst decreases rapidly with time. Thus, at the end of sixty minutes, the radiation intensity is perhaps one percent of what it was at one minute. And, at the end of twenty-four hours, it has decreased to say one-thirtieth of what it was at one hour. It requires very delicate instruments to record the radiation intensity in the remaining Bikini target ships two years after the "BAKER" test. If the Bikini "BAKER" test is a sample of radioactive warfare, it can be said that our experience in handling the aftermath of an atomic attack indicates that the principal difficulties are logistic and administrative. By this I mean supply and replacement of clothing and keeping complete records of the exposure accumulated by all men who work in contaminated spaces.

Since there has been confusion on this point, I would like to emphasize that Uranium and Plutonium do not give off gamma radiation, and, therefore, do not require heavy shielding to protect people in the immediate vicinity. For example, you could sit on an unshielded atomic bomb indefinitely without damage to yourself or your descendants. It follows from this fact, that no radiation detection instrument so far conceived would have any chance of detecting even an unshielded atomic bomb at a distance exceeding a foot or two.

Up to now, I have discussed the uncontrolled chain reactions of atomic bombs. A controlled chain reaction in a pile or nuclear reactor involves us in many difficult problems which are skipped in the case of the bomb. The controlled chain reaction was used in the Hanford Uranium-Carbon piles to produce Plutonium. In this case, the neutrons were produced from the fission or burning of Uranium 235 atoms contained in the ratio of about 1 to 139 atoms of Uranium 238 in natural Uranium. The wartime goal of the Hanford Project was to transmute atoms of Uranium 238 into Plutonium, which is a different element. In this way, the newly created fissionable substances could be removed from the remaining metallic Uranium by chemical processes. Therefore, success in the Hanford Project was not dependent on creating a Plutonium atom for every Uranium 235 atom burned up in the process. Furthermore, the heat produced in the process was an unwanted by-product rather than something to be desired. Therefore, the fact that, in operation, the Hanford reactors produced a net decrease in total fissionable atoms, and also worked at such low temperatures that the heat produced was unusable, was accepted gratefully in exchange for usable amounts of Plutonium.

In modern atomic jargon, the Hanford reactor is a negative breeder. A positive breeder would be one in which advantage is taken of the fact that more than two neutrons are produced per fission and an attempt is made to capture these neutrons so effectively in Thorium or Uranium 238 nuclei that the total number of fissionable atoms actually increases as the chain reaction proceeeds. The arithmetic of the breeding process is fairly simple—for an investment of one neutron in a Uranium 235 nucleus you get out something more than two neutrons. Naturally, one of these neutrons must be reinvested to maintain the chain reaction, and one more must be captured in a Uranium 238 or Thorium nucleus to replace the Uranium 235 nucleus which has previously fissioned. The excess, beyond the two neutrons which came out of the fission, would, in theory, be available for additional capture, and, therefore, creation of more fissionable atoms. So far, positive breeding cycles exist only in theory: They are, of course, recognized as tremendously important if they can be achieved in practice.

The problem of designing nuclear reactors to operate at high temperatures is quite independent of breeding. In this case, the vital questions are chemical and metallurgical, and, certainly, for mobile power plants, the question of shielding against the intense gamma radiation and neutrons is of major importance.

It is well to remark that generation of industrial atomic power on a large scale, in the absence of positive breeding, is not justifiable on the basis of national security. It would be a very complicated and expensive method of disarming ourselves by burning up most of our stockpile of nuclear fuel. In the case of propulsion of military vehicles, such as aircraft and submarines, there is a legitimate competition with bombs for the available stock of nuclear fuel. Furthermore, since the development of prototypes can be prosecuted in each case without major expenditure of nuclear fuel, there is every reason to proceed with the development of mobile power plants for aircraft and submarines on an urgent basis. Then, when the developments bear fruit, the national economy of nuclear fuel, or the strategic situation with respect to employment of the fuel in power plants or bombs, may have changed.

The problem of propelling a submarine by nuclear power is roughly a factor of ten simpler than nuclear propulsion of a manned aircraft. There are two major factors in this comparison; the first having to do with thermodynamics, and the second having to do with shielding weight. Submarine designers are quite willing to accept propellers driven by steam turbines, whereas, such a solution would be unacceptable to aircraft designers in this age of jet propulsion. Therefore, the aircraft nuclear power-plant must operate at the high temperatures required by a turbo-jet system.

In regard to shielding, it so happens that, while very heavy shielding is required in the submarine reactor, this weight can still be carried by the submarine, whereas, the same shielding weight would make the airplane unable to fly.

Regardless of the technically dim prospect of achieving nuclear powered flight, barring some new discovery, the tremendous gain in military performance which nuclear power with its practically weightless fuel would give is ample justification for making a well controlled and carefully guided major effort to achieve this goal.

Another major problem in the atomic age relates to the amount of usable Uranium ore. In the present state of knowledge of mining and geology, high grade Uranium ore is extremely limited. Prospecting for high grade Uranium ore has gone on on a non-urgent basis for two generations simply because radium could only be found in Uranium deposits. The findings in this search have been that considerable deposits are located in the Great

Bear Lake region of Canada, in Czechoslovakia and in the Belgian Congo. Deposits of low grade ore, in which the Uranium is a by-product of processing for other minerals, are distributed fairly generally throughout the world. But the impact of the new demand for Uranium as a material of crucial importance has not yet produced major changes in the mining and processing industries. It is probable that during the coming generation the definition of economical and uneconomical in the mining of Uranium will be greatly changed. The changes will, of course, be affected by any new discoveries of freakishly rich deposits.

Thorium is of secondary importance, although more of it is available than Uranium. The reason, of course, is that it is not directly fissionable, and, unless positive breeding becomes a reality, Thorium would not be of really great significance.

Another problem in prospect in the atomic age relates to the philosophy of design and development of atomic weapons and vehicles for their delivery. At least, so far as the weapons are concerned, security restrictions prevent much beyond generalizations. This is unfortunate because sound rational thinking in the field of atomic weapons depends to a considerable extent on eliminating mystery and black magic and getting down to what I call the "nuts and bolts" approach. Nuclear fission, neutrons and atomic bomb assembly designs are just as much plain facts of life of the modern age as are electronics and its application in radar.

The philosophy of the wartime atomic bomb development assigned tremendous importance to the *reliability* of the bomb design and delivery system. At that time, and to a certain extent now, a mechanical or electrical failure of an atomic bomb which frustrated its delivery would be such poor overall economy that it should be avoided even at very large cost.

Conventional military vehicles and weapons have been developed by a process of trial and error. The unique feature in atomic bomb development has been, and still is, the fact that we are permitted a microscopic number of trials and we allow ourselves no errors. This thinking permeated our wartime philosophy and resulted in eighteen months of intense development activity in which full scale dummy bombs were dropped from B-29's under conditions representative of combat missions. As the development proceeded, the dummies more and more approached the real McCoy. For example, the final rehearsal of the Hiroshima flight was a flight from Tinian to Iwo Jima and return to the vicinity of Tinian where a non-nuclear duplicate of the Hiroshima bomb was dropped.

No amount of attention and effort spent on the bomb itself could overcome weakness in the delivery system caused, for example, by unreliability of the aircraft or its crew, opposition by the enemy, or unfavorable weather. Identifying and bombing the target by radar alone was not considered sufficiently reliable. It was part of our luck that, by the time enough fissionable material had been produced by Oak Ridge and Hanford, our non-nuclear components were developed and ready, and a practically perfect ready-made B-29 delivery organization was available and in full operation from the Mariannas to Japan. Under those practically ideal conditions of guaranteed efficiency of the delivery system, and absolute control of the air over the target, delivery became a demonstration.

In my opinion, much fallacious thinking has been generated by the striking success of the first two atomic deliveries. The effect has been to lead many articulate thinkers, including military planners, unconsciously to discount the effect of difficulties which would plague future deliveries in manned subsonic bombers.

In actual fact, the conventional long-range bomber passed its peak of effectiveness in 1944 with the first appearance of the German jet propelled fighter. The atomic delivery situation over Japan would have been entirely different if we had faced strong forces of German jet fighters over the Empire. I am sure that our approach to the delivery would have been entirely different and would probably have included heavy escort.

Naturally, the speed of the delivery vehicle when it equals or exceeds that of our present jet fighters, confers an increasing amount of protection. Present thinking would concede practical invulnerability to a delivery vehicle which travels at more than twice the velocity of sound.

The major limiting factors in the case of guided missiles are in propulsion and guidance at ranges of significance to atomic bomb delivery. As I have indicated earlier, the effective radius of destruction of an atomic bomb is not so great that we can tolerate errors of a mile or more in placing it on the target. This fact requires achievement of a high degree of discrimination and reliability in the navigation brains of an unmanned missile before it can be entrusted with an atomic warhead. The final choice between manned and unmanned delivery will always depend on the characteristics of the target, the defense, and the relative location of the launching base.

Now to change from purely material and operational considerations to an examination of *attitudes*. I was impressed throughout the atomic weapon development period of World War II, say from 1943 to the actual deliveries from the Mariannas, with the absolute, hard-boiled, realistic, and pragmatic approach of the scientists. They refused to credit even their own best radar systems developed at M. I. T. with being able to identify a target city under difficult conditions. Even in the case of Hiroshima, which was a river delta with practically no similarity to any other seaport within hundreds of miles, the scientists and military planners demanded visual delivery. The thoroughness of our preparations was shown by the fact that up to within two hours of strike time we had weather planes circling over our several targets.

At the end of World War II, the attitude of our vocal scientists was abruptly changed from hardboiled realism and pessimism to a sort of mystic, uncritical acceptance of wild claims which they had been the first to dismiss during the war. If you have seen the movie *"One World or None"*, which was put out in an effort to promote world government, you may remember the statement in the ringing voice of Raymond Gram Swing: "The B-29's which delivered the atomic bombs to Hiroshima and Nagasaki had a range of 1500 miles. Within six months after the war's end, the range of atomic bomb carrying airplanes had increased to 6000 miles!" That statement was approved for the script by some of the same scientists who would have refused to credit the B-29 with a range of 1800 miles during World War II.

This change of attitude perhaps resulted from shock. I would illustrate further effects of this shock by quoting from an article by W. A. Higginbotham, in the *New York Times,* Magazine Section, November 3, 1946: "......no scientist sees any possibility of defense, for two main reasons:

"1. Because atomic energy is the basic energy of the universe and its crushing force is all-powerful.

"2. Because man will always make mistakes in the operation of any defense system."

"Neither of these factors will change. There can be no defense against the atomic bomb". This quotation is a typical example of the sincerely motivated campaign of the atomic scientists, conducted throughout 1946 and the early part of 1947.

Now I will read a comment on the effect of such a campaign, written by an expert in psychological warfare, who was in charge of the Psychological Branch of the Dutch War Ministry and a member of the Inter-Allied Psychological Study Group in England during the late war. This was in a letter to the *New York Times*, in June 1947. I will read extracts from it:

"The general idea in this atomic war of nerves appears to be that fear of another war and fear of the bomb's tremendous destruction will force mankind nearer to a constructive plan for peace. This idea, however, must be contested since, down through the ages, fear has been a notoriously bad leader of mankind. Too great a fear ends in one of two reactions, neither of which is constructive.

"In the first place, such a fear can paralyze the human mind —hypnotize it, as it were, make it passive, ready to accept dangers of war rather than bear the nervous tension of peace. In Psychology we call it passive surrender to the thing feared.

"On the other hand, such a fear, which still works on the human mind as primitive fear did in the ancient world, can provoke mankind to frantic explosions of aggression . When fear affects men in this manner they try to deal the first blow—to cast the first bomb.

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"The confused state of mind, resulting from this combination of post-war guilt feelings and the fears engendered by the atomic war of nerves, resembles ancient periods when people waited passively for the world's doom because of an undefined magic spell and mysterious fear passed on from general anxiety with which the world of those days were infected. In the middle ages this kind of mood spread along with the pandemics of the epoch (the Black Death, Plague, etc.).

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"During the hectic days when the Germans were successfully executing their war of nerves I thought that I had seen some deadly psychological warfare, but none of those attacks, I now feel, could out-do the atomic war of nerves to which we are being subjected."

In my opinion, this mystic attitude toward the atomic bomb has become dangerously widespread in the United States and has affected the thinking of many intelligent people, including military planners. The general idea seems to be that the potency of the atomic bomb somehow lends a considerable degree of invulnerability to its carrying vehicle, that the "absolute" weapon will be delivered "inevitably" to the intended target, and that the results will be cataclysmic to the target.

It is of crucial importance to our national defense that all of these shaky, unprovable assumptions be subjected to the most searching and skeptical analysis and test. It should also be remembered that whatever we know, or do not know, about the ability of our possible enemies to produce and deliver atomic bombs, they most certainly are aware of our capabilities in this respect. Therefore, if we are provoked into a war, even a Hitler will have anticipated and made reasonable allowances for our known ability to strike his key cities with atomic bombs.

I worry when I see in the *Saturday Evening Post* of September 11, 1948, an article by Joseph and Stewart Alsop, from which I will read an extract:

"What is novel in the new concept is the additional provision of a small, specialized offensive force, such as was not available to the democracies in 1914 or 1939. Only a minor percentage of total resources will be invested in this special force, which will be composed primarily of long-range bombers. But the bombers will carry the absolute weapons, and will have the mission of destroying the enemy's vitals in immediate retaliation for the first aggressive act. By this destruction of the enemy's vitals, it is hoped that the general counter-offensive will become possible not after four years but after as many months. It is hoped, in short, that even if the deterrent fails, even if war comes despite all our labors to avoid it, the war may yet be short and the world we know may yet be saved.

"In illustration of what one must pray will never occur, let us suppose that the worst has happened. War has begun after the new strategic concept has been implemented. Of the uncounted divisions of the Soviet empire, as many as can be rapidly transported—probably over 100—will be instantly launched across Europe toward the English Channel. The nations of the Western European Union will dispose their forty-five divisions on their selected defensive line—most probably the Rhine, which is so distant from Russia that logistical factors will limit the first impact of the Red Army's attack. Fleets of transports will be gathered to strengthen the divisions of Europe with divisions from the United States.

"As the battle is joined on land, the struggle for control of the seas will break out with fury, for the Red Fleet now possesses a formidable submarine force. Sabotage also will begin, of such character and on such a scale as will seriously impede the first effort of the West.

"Meanwhile, however, on the first notice of attack, orders will go out to the special offensive force. From the United States, long trains of aircraft will fly, by day and night, to their prepared bases across the Atlantic. There, at points beyond the immediate reach of the strong Russian Ground Arm, will be all the facilities, all the supplies for immediate air warfare, from runways to hospitals, from gasoline to ammunition. While the vast Soviet Army is still grinding across Europe, the air missions will strike out—1800 miles, 2000 miles, 2200 miles—toward the targets of Russia. From Baku north to Leningrad, from Smolensk west to Novosibirsk, the vitals of the Soviet State will be scorched and destroyed with the terrible fire of the atomic bomb.

"Soon, at the distant front, the disaster at the center will be felt. The Giant's arm will still be brawny, but he will be sorely stricken at the heart. As the arm falters from the heart's injury, so must the Red Army falter if cut off from all support except from the sullen satellites. And then the forces of the West, which once seemed almost too weak for defense, will of a sudden become strong enough for the attack. The change in relative strengths will permit a general counter-offensive by the Western Armies in which all will join. And the great war machine will be hurled back across Europe, along the road by which it came."

Meditating on this extract, I think back to an article in *Esquire Magazine* for January 1942, which was already on the newstands on December 7, 1941. In it an American expert on Japan included these as the clinching and last paragraphs of his article:

"Japanese fighting men have proved their courage in successives victories; their courage under a preliminary defeat is yet to be shown. They have demonstrated their fighting prowess against poorer trained and slower thinking people; they have yet to meet a nation that can out-think them, as can every other nation today ranking as a first-class power. Those who know the Japanese do not believe they could stand up in any vital test of the kind, except in defense of their homeland, when they could fight on their own terms on a terrain they know thoroughly and for the land they love.

"As a menace to any country of any fighting consequence, Japan does not exist.

"As a first-class power, Japan is a myth.

"The sooner this fact is recognized, the sooner will all talk of war with Japan die away, to the betterment of the world and to the betterment of Japan."

The warnings I have given are certainly not intended to belittle the atomic bomb in any respect. They are primarily directed toward a return of our thinking to the hardboiled, realistic kind which produced the bomb in the first place. We have need of such thinking in these parlous times.